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Social Cognitive Development and Mental Health in Adolescence

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Signed declaration

I, Jovita Tung Leung, 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.

My contribution to the experimental chapters is indicated below.

- **Chapter 2:** I was involved in the later stage of experimental design as the study was part of a large research project. I was responsible for the majority of the data collection, analysis and the write-up of the manuscript.
- **Chapter 3:** I was involved in the later stage of experimental design as the study was part of a large research project. I was responsible for the majority of the data collection, analysis and the write-up of the manuscript.
- **Chapter 4:** I contributed to the experimental design, data collection, analysis and write-up of the manuscript for this study.

I can confirm that joint publications for each chapter have not been published at other universities or as part of other PhD theses.

Signed: *[signed by Jovita Leung]* **Date**: 10th March 2023

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ABSTRACT

Adolescence, defined from the age of 10-24, is a key developmental period which is associated with protracted biological, psychological, and social changes. While these neurocognitive changes play an important role in the individual's social, affective, and cognitive development, adolescence has also been described as a time of "storm and stress", representing a time of increased vulnerability to mental health problems. This thesis described a series of experimental studies investigating the effects of cognitive training on adolescents' social cognitive development and mental health.

The first experimental chapter (Chapter 2) described a cross-sectional study investigating the effect of age and puberty on susceptibility to prosocial and antisocial influence in 520 adolescents aged 11-18 years. The next two experimental chapters examined the effect of social cognitive training programmes on adolescents' social cognitive development and mental health. **Chapter 3** explored the changes in susceptibility to prosocial and antisocial influence following two 8-week social emotional training programmes in 465 adolescents aged 11-16 years. **Chapter 4** described an experimental study examining the effectiveness of an affective control training paradigm (compared to a control training paradigm) in 242 adolescents aged 11-19 years. The study examined the training effect across two training groups, the extent to which training effect varied as a function of age, and how training effect associated with self-reported mental health problems, emotion regulation difficulties, and self-control ability.

Finally, **Chapter 5** summarised the findings of the empirical studies and discussed how these findings inform the social cognitive development and mental health during adolescence.

IMPACT STATEMENT

Adolescence is a period of protracted biological, psychological, and social development. It also represents a time of increased vulnerability to mental health problems. This thesis examined the developmental changes of social cognitive processes in adolescents, and how social cognitive training can impact adolescents' mental health.

The results presented in this thesis suggest that adolescence is a period characterised by a heightened propensity to prosocial and antisocial influence and highlight the potential of social emotional training in reducing susceptibility to antisocial influence. The thesis also demonstrated that it is possible to improve affective control and that training benefits are related to a reduction in mental health difficulties in adolescence.

The work presented has potential impact both within and outside academia. In terms of dissemination, this thesis has contributed to the publication of two peer-reviewed papers to date, with a further paper submitted to a peer-review journal. The results have been presented at international and national conferences.

Outside of academia, findings from this thesis have potential implications for public health and mental health policy. A novel app-based affective training programme has been developed to better understand the potential of computerised interventions in adolescent development. Evidence from this thesis suggests that improvements in affective control are associated with a reduction in mental health difficulties and affective control training therefore constitutes a promising avenue for prevention and early intervention. An increased focus on developing interventions for adolescents, a developmental period characterised by both elevated risk but also a potentially enhanced ability to benefit from interventions, has the potential to impact health, productivity and social outcomes in society.

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ABBREVIATIONS

ACC	anterior cingulate cortex
AffeCT	affective control training
aSART	affective sustained attention to response task
ATC	anterior temporal cortex
DERS	difficulties in emotion regulation scale
dmPFC	dorsomedial prefrontal cortex
MiSP	Mindfulness in Schools Project
MT	mindfulness training
PDS	pubertal development scale
pSTS	posterior superior temporal sulcus
PTSD	post-traumatic stress disorder
SDQ	strengths and difficulties questionnaire
SES	socioeconomic status
SST	student skills training
TPJ	temporal parietal junction
vmPFC	ventromedial prefrontal cortex

CHAPTER 1: INTRODUCTION

1.1 Defining adolescence

Adolescence (meaning 'to grow up' from the Latin word 'adolescere') describes the period of life beginning with puberty and ending when the individual has achieved adult independence in the society (Patton et al., 2016; Spear, 2000). The chronological definition of adolescence has long posed a conundrum, with the World Health Organisation defining it as the second decade of life, between 10 to 19 years (World Health Organization, 2014), and a more recent proposal to define it from the age of 10 to around 24 years (Sawyer et al., 2018). In this thesis, I will use the latter definition of 10-24 years. Adolescence is a key developmental period, which is associated with protracted biological, psychological, and social changes. With the advancement in neuroimaging techniques and an increasing body of research focusing on this age group, brain imaging studies over the past two decades have demonstrated continued structural and functional development in the adolescent brain (Mills et al., 2014; Tamnes et al., 2013, 2017). It has been proposed that these neurocognitive changes play an important role in the individual's social, affective and cognitive development (Blakemore & Mills, 2014).

Adolescence has been described as a time of "storm and stress" (Hall, 1904). While it is a period of substantial brain development, it also represents a time of increased vulnerability to mental health problems (Paus, Keshavan & Giedd, 2008). 75% of lifetime cases of mental health disorder have their onset before the age of 24 (Kessler et al., 2005). In addition, adolescence is a period of social reorientation in which individuals become more sensitive to socially and emotionally salient stimuli in the environment (Blakemore, 2008; Casey et al., 2010). Adolescents are also hypersensitive to social evaluation and social rejection

(Sebastian, Viding, Williams & Blakemore, 2011). Together with changes in pubertal hormones, these multifaceted changes could contribute to the vulnerability observed during adolescence (Silvers et al., 2012; Steinberg, 2005). Studying how different components of social, affective and cognitive processing develop during adolescence may increase our understanding of how they are associated with mental health problems, and whether improving these processes would have a beneficial impact on adolescents' mental health.

1.2. Adolescent brain development

Until about 25 years ago, it was assumed that the human brain reaches maturity at some point in childhood. Until fairly recently, the majority of developmental neuroscience studies were based on post-mortem human brain studies or animal studies. However, with the advancement in neuroimaging technology over the past two decades, it has become possible to examine structural and functional brain development across the human lifespan (e.g. Casey, Tottenham, Liston & Durston, 2005; Crone & Elzinga, 2015).

1.2.1 White matter and grey matter

Brain development during adolescence is characterised by a decline in cortical grey matter volume (largely composed of neuronal cell bodies and synapses, as well as other neural matter such as glial) and an increase in cerebral white matter volume (which consists of myelinated axonal tracts, Mills et al., 2016). Longitudinal studies in four cohorts of participants across three countries demonstrated that cortical grey matter volume, which is the product of cortical thickness and cortical surface area, is at its highest during late childhood and steadily decreases throughout adolescence (Tamnes et al., 2017). At the same time, cerebral white matter volume, which is mainly composed of myelinated axons, increases linearly during adolescence (Mills et al. 2016; see Figure 1.1).

Not all regions of the brain develop at uniform rates (Tamnes et al., 2017) found that posterior regions of the cortex mature before more anterior regions. During late childhood, cortical volume reduces more prominently in the occipital and parietal lobes. During late adolescence, pronounced volume changes are evident in the frontal lobe and the temporal and parietal regions whereas the occipital cortex does not undergo substantial change (Tamnes et al., 2013, 2017; see Figure 1.2). Among the late-maturing cortical brain regions, the frontal lobe has been of particular interest to developmental research as its development is tightly linked to improvements in executive functions and self-control (Blakemore & Robbins, 2012; Crone & Steinbeis, 2017).

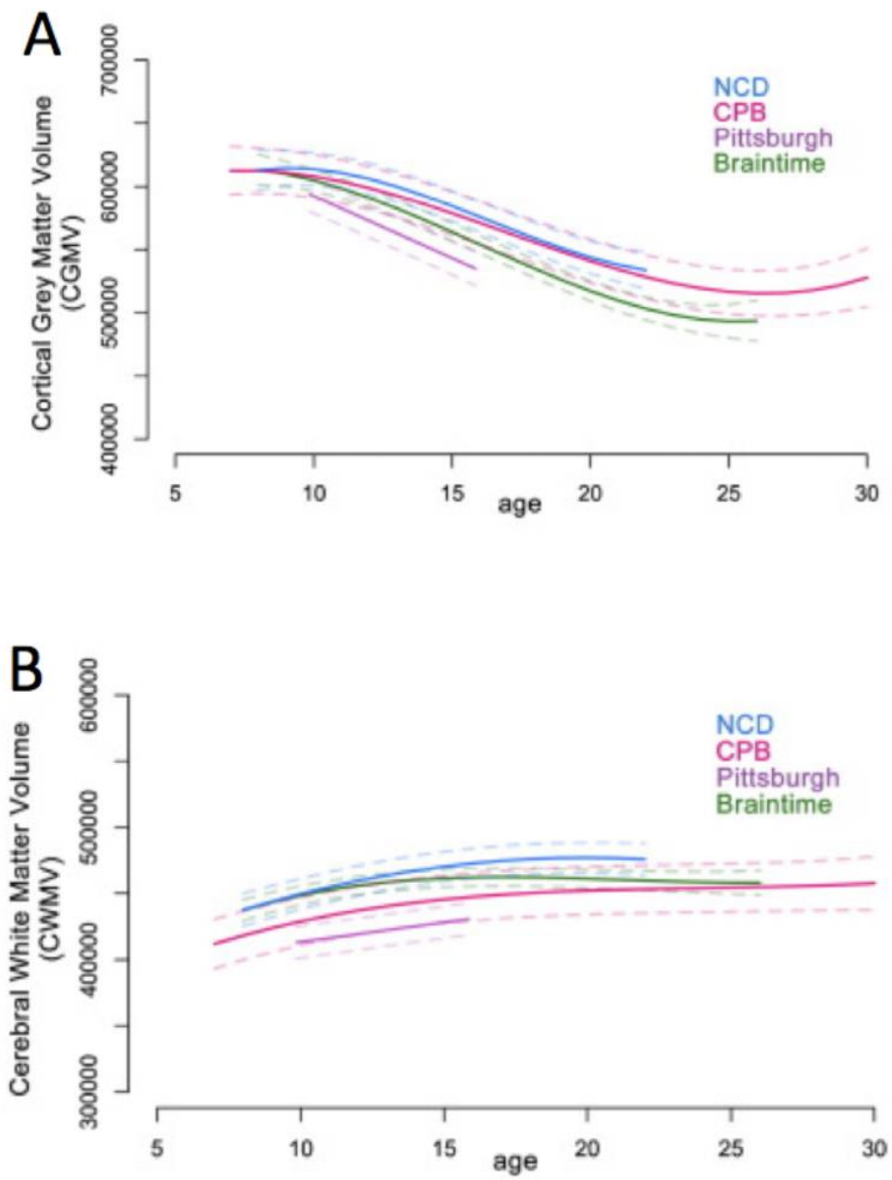

Figure 1.1 Developmental trajectories for cortical grey matter volume (panel A) and cerebral white matter volume (panel B). The lines represent changes over time and colours correspond to each of the four cohorts studied. Reprinted from Mills et al. (2016).

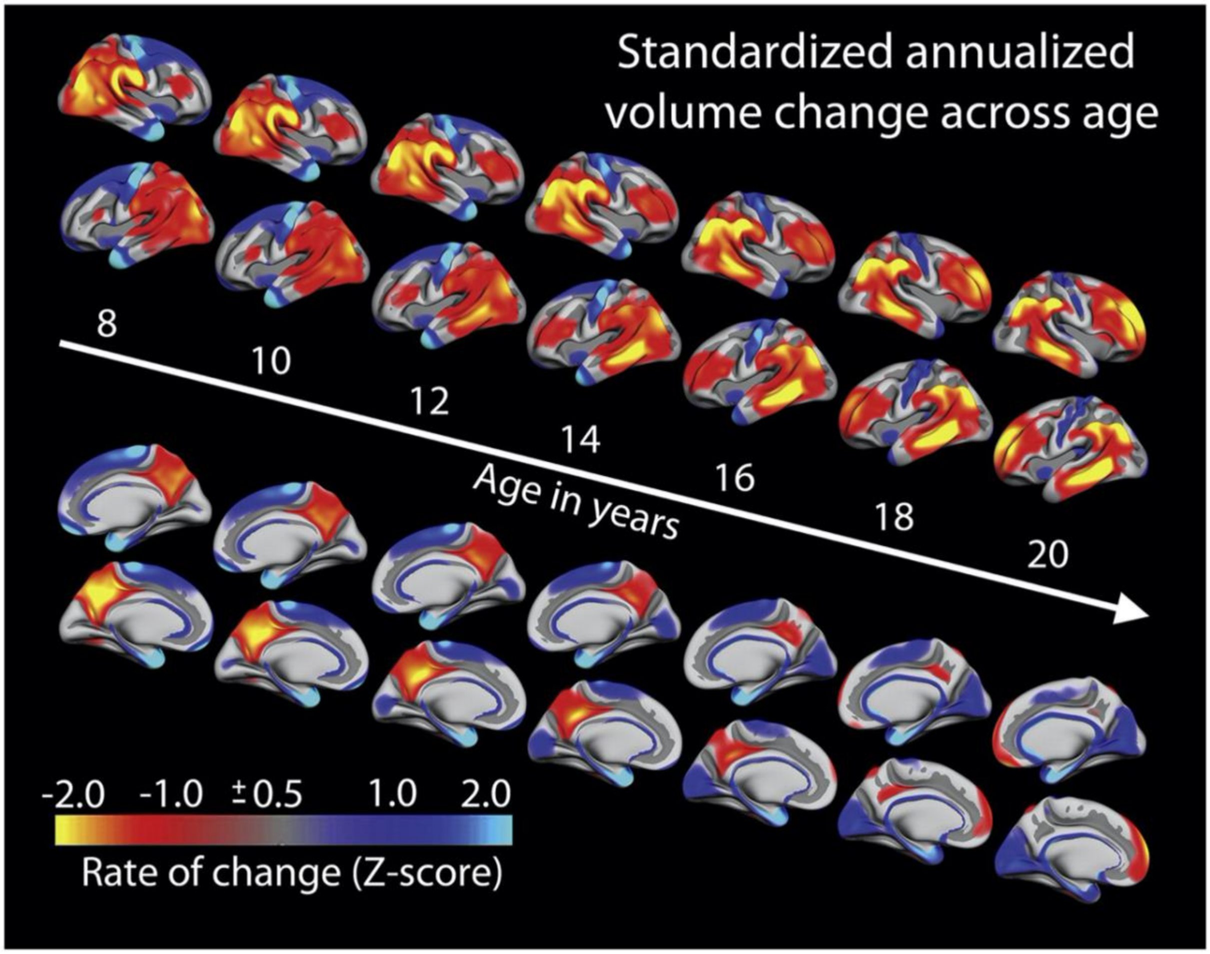

Figure 1.2. Developmental changes in cortical volume. Red-yellow regions indicate the greatest rates of reduction in cortical volume, while blue-cyan regions indicate smaller relative reduction in volume. At the age of 8, larger than average volume reductions are seen mainly in the parietal lobes and in the lateral occipital cortices. At age 20, relatively larger reductions are observed laterally in the frontal lobes and the inferior parietal and temporal cortices, as well as the anterior medial frontal areas. Reprinted from Tamnes et al. (2013).

1.2.2 Social brain development

Some of the latest maturing brain regions are found within the 'social brain', which is the network of regions in the brain that are involved in the recognition, understanding and interpretation of cues from other people. The social brain network involves the dorsomedial prefrontal cortex (dmPFC), the anterior cingulate cortex (ACC), the posterior superior temporal sulcus (pSTS), the inferior frontal gyrus, the amygdala, and the anterior insula (Blakemore, 2008).

Mentalising, or theory of mind, is the ability to make attributions about other people's mental states (including their beliefs, thoughts, intentions and feelings) and allows us to interpret and predict others' behaviours based on our understanding of their mental states (Frith & Frith, 2003). Neuroimaging studies have consistently found associations with activity within dmPFC, pSTS, temporal parietal junction (TPJ), and anterior temporal cortex (ATC), highlighting that these regions are of particular importance in the process of mental state attribution (Kilford et al, 2016).

1.3. Adolescent social development

1.3.1 Mentalising and perspective taking

Historically, studies on the development of mentalising have focused on childhood, pointing to changes in the ability to attribute mental health of others during the first five years of life (Frith & Frith, 2007). Neuroimaging studies over the past 20 years suggest that the brain regions involved in mentalising and taking other people's perspectives are still maturing during adolescence. Longitudinal neuroimaging studies have shown that regions in the social brain undergo protracted development and substantial changes between late childhood to adolescence. For instance, grey matter volume and cortical thickness in the TPJ and pSTS decrease from childhood into the early twenties, whereas grey matter volume in the anterior temporal cortex increases until adolescence and the cortical thickness in this region increases until early adulthood (Mills et al., 2014). All three regions are involved in mentalising (Blakemore, 2008). This suggests that the brain regions that are involved in social cognitive processes such as mentalising continue to mature structurally throughout adolescence and into early adulthood.

Functional neuroimaging studies have found age differences in the activation of the dmPFC and TPJ during mentalising tasks (Blakemore & Mills, 2014), with other developmental neuroimaging studies reporting reductions in dmPFC recruitment between adolescence and adulthood (reviewed in Blakemore, 2008). For example, studies have observed higher activity in the TPJ in adults than in adolescents (12-18 years) when responding to scenarios relating to their own mental states as compared to physical events (Blakemore et al., 2007). Previous research in adults found that the TPJ is highly activated in tasks that require reasoning about other people's intentions and beliefs (cognitive theory of mind; Schlaffke et al., 2015), whereas the mPFC is highly activated by inferences about emotions and preferences (affective theory of mind; Leopold et al., 2012; Sebastian et al., 2012). These studies suggest that the pattern of recruitment of these brain regions during mentalising changes across adolescence.

Adolescents also show developmental changes in sensitivity to others' perspectives. Perspective taking, which is the ability to take into account other people's point of view, is an important determinant of successful social functioning in everyday life (Fett et al., 2011). While fundamental aspects of perspective taking develop during childhood (Barresi & Moore, 1996; Leslie, 1987; Perner & Davies, 1991), the development of more complex perspective taking skills continue to develop throughout adolescence. Studies investigating the development of perspective taking have often employed the Director task, in which participants are instructed by a 'director' to move objectives around a set of shelves that contain a number of objects, some of which are occluded from the director's point of view. Participants have to correctly interpret the director's instructions and take into account the director's perspective to move only objects that the director can see.

Studies have found that performance on the director task continues to improve between childhood and adulthood. For example, a sample of 7 to 27 years old were asked to complete a computerised adaptation of the Director task (Dumontheil et al., 2010). A 'no-director' non-social control condition was included to differentiate between the general cognitive control demands of the task and the social components of the task (see Figure 1.3). In the non-social control condition, the task was identical to the director condition except that, instead of having to take into account the director's perspective, participants had to ignore the objects with a grey background. While performance in both conditions improved from 7 to 17 years, performance in the director condition continued to improve beyond 17 years and into adulthood. These findings were replicated in another study (Symeonidou et al., 2015), suggesting the ability to take into account other people's perspective to guide decisions continues to mature in late adolescence, over and above developmental improvements observed in more general cognitive control processes that are required in both conditions. A neuroimaging study using the same paradigm found that, while both adults and adolescents recruited the dmPFC when the social cues were needed to accurately perform the task, adolescents also recruited the dmPFC when social cues were not needed (Dumontheil et al., 2012).

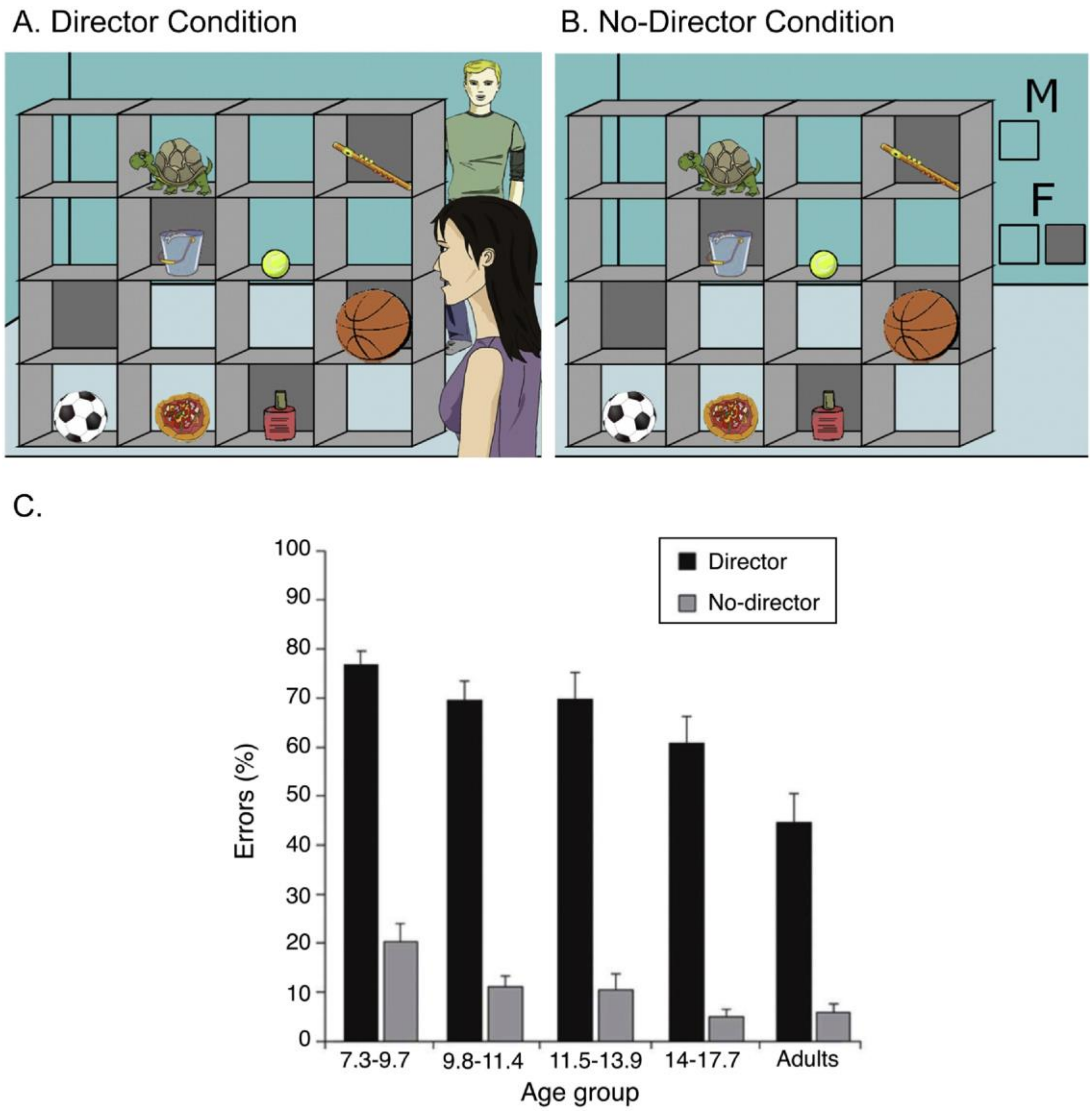

Figure 1.3. The Director Task. Example of a trial from the Director task, showing a social (**A**: Director) and non-social control (**B**: No director) condition. Adolescents aged 14-17 years made more errors than did adults in the Director condition, whereas in the No director condition, no difference was found between the 14-17 years and adult age groups **I.** Reprinted from Dumontheil et al. (2010, 2012)

1.3.2 Peer influence in adolescence

Adolescence is a period of pronounced social reorientation when adolescents start to spend more time with their friends, and peer relationships become increasingly important (Blakemore & Mills, 2014). A large body of research has demonstrated that adolescents are particularly susceptible to peer influence, especially in the context of risk-taking behaviour, such as dangerous driving, smoking and drinking (Eaton et al., 2012; Tomova & Pessoa, 2018). For example, lab-based studies have shown that the presence of peers increases the likelihood of risky driving behaviour in adolescence, including one by Gardner and Steinberg (2005). Here, adolescents (13-16 years), young adults (18-22 years) and adults (24 years and above) took part in a driving simulation game in two conditions – alone and in the presence of two friends. While all age groups took a similar level of driving risks when alone, 13-16 years old took almost three times the number of risks, and 18-22 years twice the number, when playing the game in the presence of peers. In contrast, the presence of peers had no impact on risk-taking in adults over the age of 24.

Another study investigated the susceptibility to social influence on risk perception in a sample of 563 participants aged between 8 to 59 years (Knoll et al., 2015). Participants were presented with everyday risky scenarios and were asked to rate how risky they perceived the scenario to be. They were then informed about the risk ratings purportedly given by other adults or teenagers and were asked to rate the same scenario again. Whilst all age groups were influenced by the ratings of others, young adolescents (12-14 years old) were the only group that was more strongly influenced by other teenagers' ratings than by adults' ratings (Knoll et al., 2015). Together, these findings suggest that adolescents go through a social transition in which the presence and opinions of their peers are of particular importance.

An explanation for this heightened susceptibility to social Influence during adolescence is the fear of social rejection. It has been proposed that adolescents adapt their behaviour in order to avoid social rejection (Allen & Badcock, 2003). A widely used social exclusion paradigm called Cyberball, in which participants play a ball-tossing game with two other players, has demonstrated that adolescents are more sensitive than adults to social exclusion and report lower levels of mood and self-esteem, as well as higher levels of anxiety, after social exclusion (Pharo, Gross, Richardson & Hayne, 2011; Sebastian et al., 2010).

1.3.3 Peer influence on prosocial and antisocial behaviours

The majority of research on social influence has focused on risk-taking behaviour, so questions remain as to whether adolescents are similarly susceptible to social influence in different contexts. Research has demonstrated that social influence can also encourage prosocial behaviours in adolescence (Choukas-Bradley et al., 2015; van Hoorn et al., 2016). For example, adolescents aged 12-16 years old gave a more generous allocation of coins to their group after they saw their peers approve such behaviour (van Hoorn et al., 2016), and

12-15 years old were more likely to volunteer to help others in the community if they believed their peers were doing so (Choukas-Bradley et al., 2015).

Foulkes et al. (2018) investigated differences in susceptibility to prosocial influence between childhood and adulthood (Figure 1.4). Participants were asked to rate how likely they would be to engage in a prosocial behaviour. They were then told the average (fictitious) rating from other adolescents or adults and were asked to rate the same behaviour again. The study found that children (8–11 years), young adolescents (12–14 years) and mid-adolescents (15–18 years) all significantly changed their ratings in line with the rating from others, while young adults (19–25 years) and adults (26–59 years) did not.

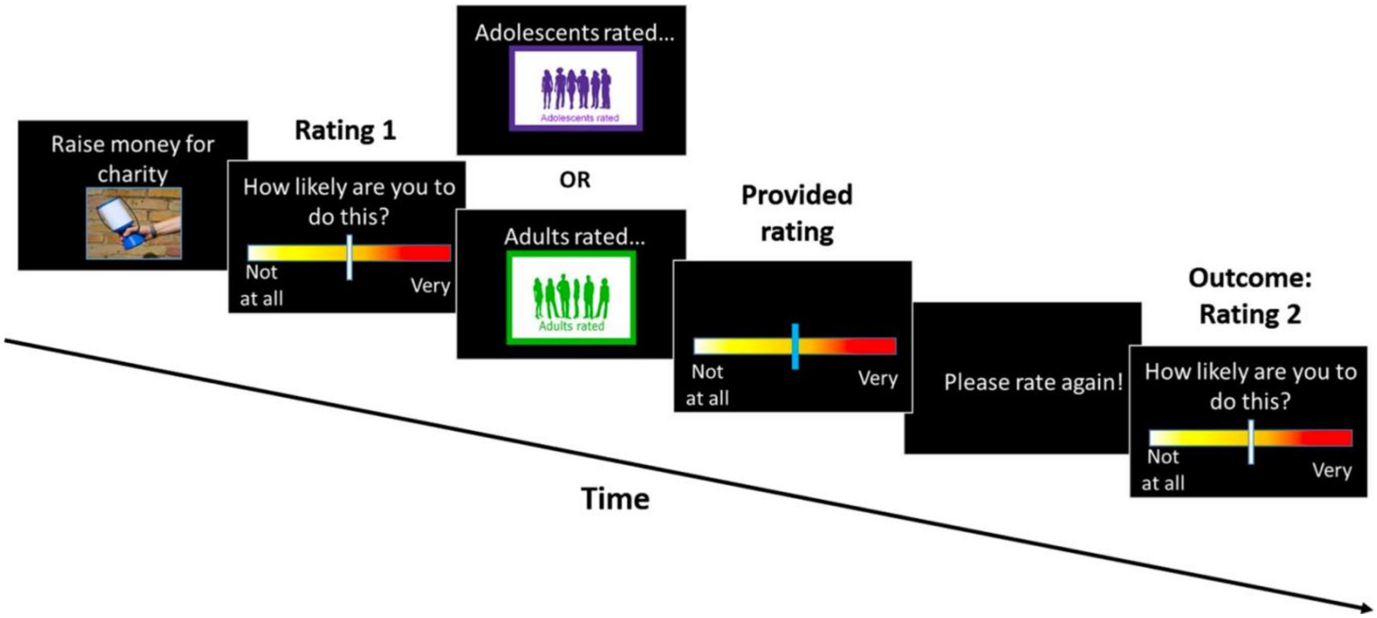

***Figure 1.4. The prosocial influence task*.** Example of the prosocial influence task. Participants were first asked to rate how likely they would be to engage in a prosocial behaviour, such as 'Raise money for charity'. They were then shown the average rating provided by a (fictitious) group of either adults or adolescents and were then asked to re-rate the same scenario for themselves. Reprinted from Foulkes et al. (2018).

Individuals can also influence each other to behave more antisocially, i.e. in ways that are potentially harmful to other people. Antisocial influence is common at all ages (Monahan, Steinberg, & Cauffman, 2009; Slattery & Meyers, 2014), but tends to peak during adolescence, with several studies demonstrating that peer influence is an important contributor to many types of antisocial behaviour in adolescence. These include minor delinquency, serious offending, reckless driving and bullying (Doehne, von Grundherr, &

Schäfer, 2018; Espelage, Holt, & Henkel, 2003; Shope, Raghunathan, & Patil, 2003; Simons-Morton, Lerner, & Singer, 2005).

Antisocial influence also occurs for indirect forms of antisocial behaviour, such as gossiping about and ostracising others. This type of antisocial behaviour has been associated with achieving a high social status; adolescents are more likely to be influenced by peers who engage in this type of behaviour when those peers are popular (Card, Stucky, Sawalani, & Little, 2008; Garandeau & Cillessen, 2006; Heilbron & Prinstein, 2008). For example, 11-year-olds were asked to nominate which of their classmates they thought were bullies and which classmates they thought were "cool" (Juvonen & Ho, 2008). Children who perceived bullies as also being cool were likely to show increases in their own bullying behaviour a year later (Juvonen & Ho, 2008). Furthermore, using longitudinal social network analysis with a sample of children (aged 9–10) and young adolescents (aged 11–14), Sijtsema, Rambaran, Caravita, and Gini (2014) found that young adolescents, but not children, selected peers as friends who were similar in levels of bullying perpetration (ostracising others), and became more similar to friends in this behaviour one year later. The findings suggest that young adolescents are more susceptible than children to being influenced by indirect antisocial behaviour of peers.

In the current section I have described peer influence on behaviour and decision making in adolescence. In the next section, I will turn to cognitive development in adolescence, with a particular focus on the development of social-affective cognitive processes.

1.4. Adolescent cognitive development

1.4.1 Emotion regulation

Emotion regulation is defined as the modification of emotional states through a three-stage process: 1) *identification*, where emotions are perceived as sufficiently negative or positive that require regulation; 2) *selection*, where a range of emotion regulation strategies are presented and evaluated; and 3) *implementation*, where contextual factors are evaluated to determine the best approach to implement the selected emotion regulation strategy (Gross, 2015; Schweizer, Gotlib & Blakemore, 2020). While emotion regulation capacity improves from early life through adulthood (Cole, Martin & Dennis, 2004), the developmental trajectories of these three stages are not uniformly linear. For instance, emotion differentiation, which is a crucial part of the identification stage, reduces from childhood to adolescence, and then improves again throughout adolescence until adulthood (Nook et al., 2018). Increased habitual use and implementation of emotion regulation strategies, such as cognitive appraisal, are suggested to improve more linearly from late childhood to adulthood (McRae et al., 2012; Zimmermann & Iwanski, 2014).

Neuroimaging research has suggested that age-related improvements in emotion regulation capacity depend on strengthened reactivity between prefrontal regions implicated in cognitive control, and emotion- and reward-processing regions, such as the amygdala and striatum (Aldao et al., 2016). For example, 13-18 years old adolescents exhibited greater amygdala and striatal reactivity to distracting emotion stimuli than either children or adults did (Hare et al., 2008; Somerville et al., 2011). Adolescents aged 11-17 years also showed decreased responses to emotional stimuli in the ventromedial prefrontal cortex (vmPFC) relative to adults (Barbalat, Bazargani, & Blakemore, 2013; Etkin et al., 2006; Hare et al., 2008). The vmPFC plays a role in affect regulation and in the formation and pursuit of socio-affective goals (Davey, Yücel, & Allen, 2008), and its functional connectivity with the amygdala is associated with the habituation of emotional stimuli (Barbalat et al., 2013; Etkin et al., 2006; Hare et al., 2008). In another study, children and adolescents exhibited increased PFC activation to distracting negative emotional stimuli, relative to neutral stimuli, and this modulation was correlated with age (Perlman, Hein, & Stepp, 2014). This study also found that prefrontal activation was correlated with emotional regulation, whereby adolescents with lower emotional reactivity showed greater activation in an Emotional Oddball Task in which participants had to press a button at the target stimuli while ignoring emotional distractors. This suggests that prefrontal modulation of affective responses is associated with both normative developmental changes and individual differences in emotional reactivity (Perlman et al., 2014).

The brain regions implicated in cognitive control, emotion and reward processing play a crucial role in emotion regulation. The habitual use of more complex strategies, as well as an increased ability to switch between strategies in response to changing situational demands across development are postulated to emerge as a function of improved cognitive control capacity (Aldao, Sheppes, & Gross, 2015). Schweizer et al. (2020) proposed that changes in emotion regulation are, in particular, related to developing affective control.

1.4.2 Affective control

Affective control refers to the application of cognitive control (the capacity to attend and respond to goal-relevant information) to affective contexts, , whilst inhibiting attention and responses toward distracting affective information (Braver, 2012; Schweizer et al., 2020). Affective control constitutes all three proposed facets of cognitive control as applied to affective contexts: inhibition (the ability to override or suppress goal-irrelevant stimuli or responses), updating (the ability to monitor information in working memory and replace irrelevant information with updated content) and shifting (the ability to switch flexibly between multiple tasks and mental sets; Miyake & Friedman, 2012). Developmental research has employed “hot” (affective) and “cool” (non-affective or neutral) cognitive control tasks to investigate age-related performance differences (e.g. the Iowa gambling task and the classic Stroop task for hot and cool cognitive control, respectively), and evidence suggests that the developmental trajectory of the three facets in affective control varies.

The Iowa gambling task has been used to examine ‘hot’ cognitive control (Bechara et al., 1994). In this task, participants are presented with four decks of cards, with each card either yielding a reward or an occasional loss. Participants have to repeatedly choose cards to optimize their long-term outcomes. Each deck of cards has a different probability of yielding rewards and losses, and two decks contain risky cards that have high immediate rewards but negative long-term outcomes, whereas the other two decks contain safe cards that have smaller immediate rewards but positive long-term outcomes. To perform well on this task, participants have to refrain from choosing high immediate rewards and choose the safe options over the risky options.

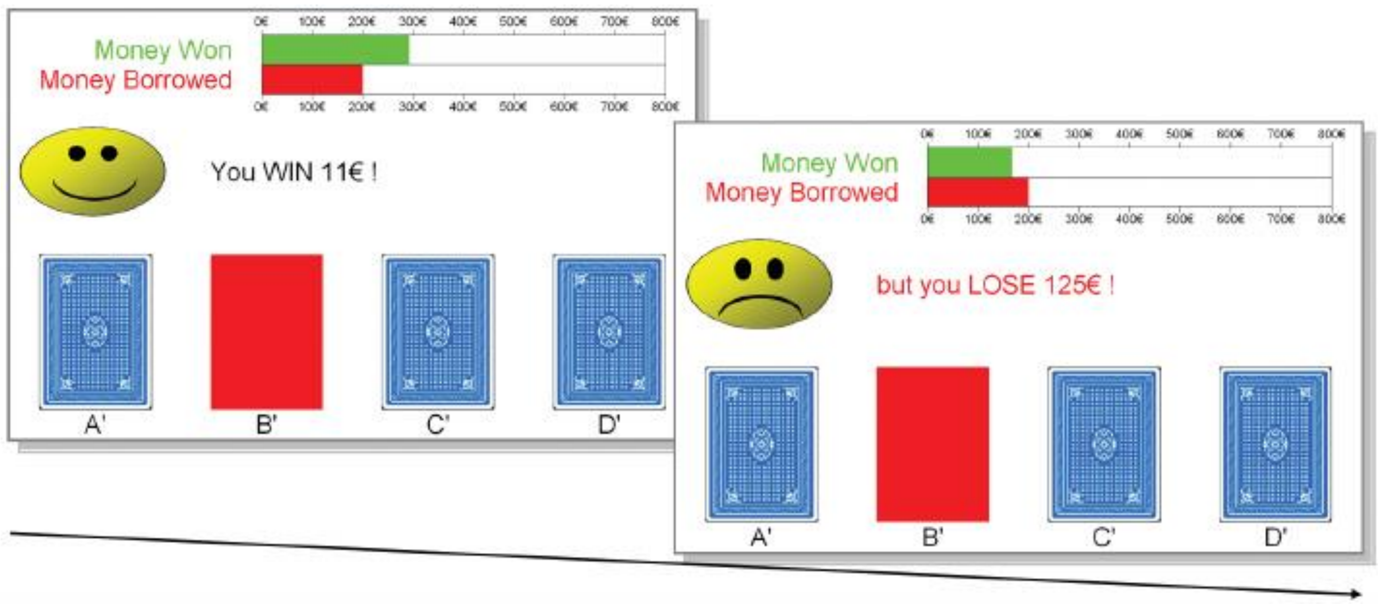

Figure 1.5. Example trial of the Iowa Gambling Task, in which the participant picked a card from Deck B. The participant received a reward of $11 (left), followed by a punishment of $125 (right). Reprinted from Cassotti, Houdé, & Moutier (2011).

To measure 'cool' cognitive control, researchers often use the classic Stroop task (Stroop, 1935). Participants are presented with colour words in different font colours. Participants have to selectively attend to (and name) the ink colour. Cognitive control (inhibition) is measured by the reaction time to name the colour of the ink in congruent trials (i.e., where the colour of the word and font colour are the same) and incongruent trials (i.e., where the colour of the word and font colour are different). Successful performance of the task requires the ability to overcome automatic tendencies to read the word and to respond in accordance with current goals. This task results in slower reaction times when participants have to name the colour of the ink (e.g. red) of a different colour word (e.g. blue).

Affective inhibition

The development of inhibition in affective contexts has been studied largely using affective go/no-go tasks or an emotional Stroop task. During these tasks, participants are often required to withhold response or avoid interference of goal-irrelevant stimuli. These studies have revealed a linear age-related decrease in interference from affective stimuli (Cohen et al., 2016; Lagattuta, Sayfan, & Monsour, 2011), which mirrors the developmental trajectory observed in the inhibition of neutral stimuli (Tottenham et al., 2011). This means that as children get older, their ability to override goal-irrelevant affective stimuli improves.

However, other studies have shown a quadratic, rather than linear, trajectory for affective inhibition (Somerville, Hare & Casey, 2011). For example, using a go/no-go task, adolescents aged 13-17 years showed reduced inhibition to happy faces, compared with neutral faces, relative to both children and adults.Meanwhile, inhibition to neutral faces indicated a linear improvement with age. Cohen et al. (2016) replicated this finding of greater interference from positive faces in a go/no-go task in 13-17-year-olds, whilst showing a linear improvement in inhibition to negative and neutral faces. This means that inhibition of negative faces was poorest amongst young adolescents, followed by the older adolescent group, with adults performing the best. Similarly, older adolescents did not differ from either young adolescents or adults in terms of their reaction time to neutral faces. However, young adolescents showed a slower response time to neutral faces as compared to adults. This suggests that adolescents, compared to adults, experienced greater interference of both positive and negative emotions (Figure 1.6).

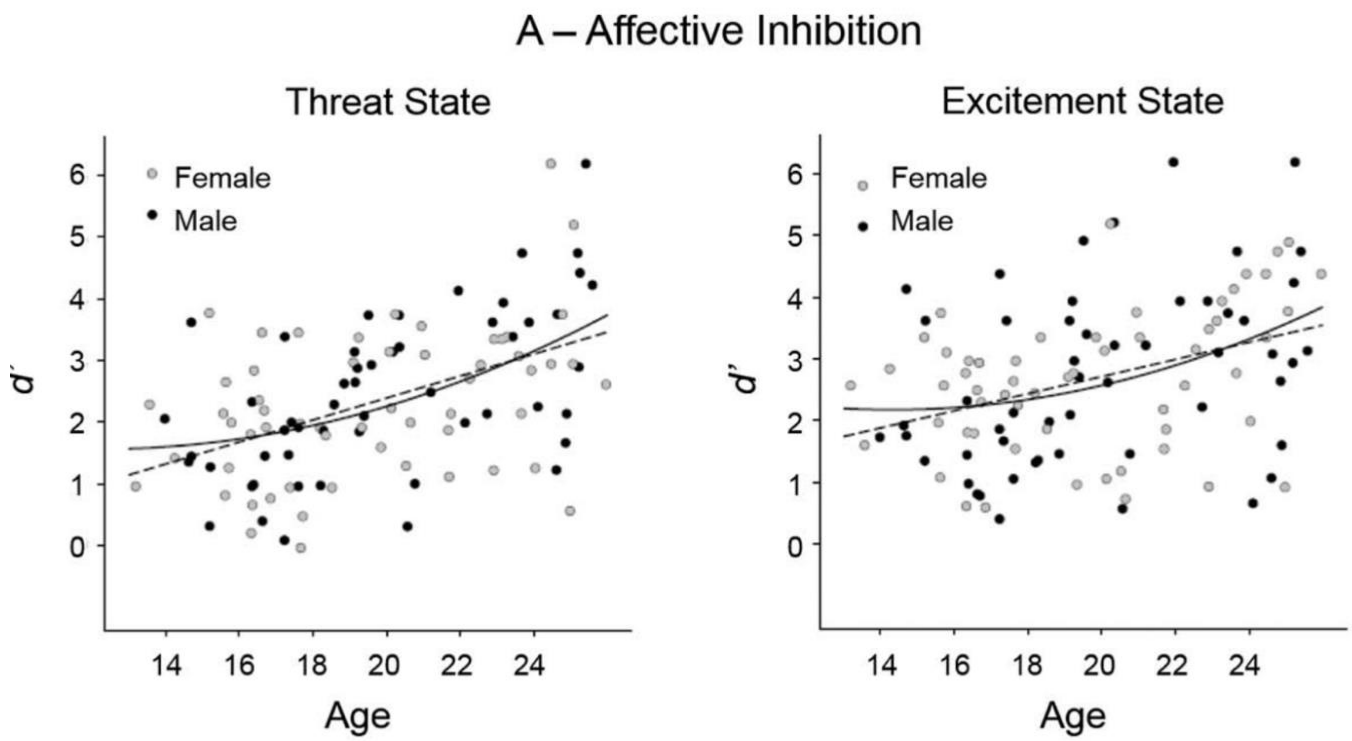

Figure 1.6. Age-related development of affective inhibition. Age-related improvements from adolescence to adulthood in affective inhibition. Y-axis represented performance on a go/no-go task inducing affective states of threat (anticipation of noxious noise) and excitement (anticipation of monetary reward) compared to a neutral state. The left and right panels show a quadratic association between task performance and age when

experiencing threat and excitement (i.e., affective control), respectively. Reprinted from Schweizer, Gotlib & Blakemore (2020).

Updating and Shifting

There is less evidence to indicate the developmental trajectory for affective updating and shifting. For affective updating, a study compared performance between young adolescents (12-14 years old) and adults (18-29 years old) using an affective n-back task. This required participants to update the gender of a face in 'gender' trials, and updating the emotional expression of a face in 'valence' trials (Cromheeke & Mueller, 2016; Figure 1.7). Whilst adolescents' updating capacity was comparable to that of adults in the valence condition, adolescents' performance during the gender condition was compromised. In the valence task, affective control is required to update affective material, whereas in the gender task participants are required to inhibit affective task-irrelevant features in order to attend to their non-affective stimuli. In the gender task, adolescents showed increased reaction time in affective updating of task-irrelevant happy cues, compared to neutral and angry cues (see left panel of Figure 1.8). However, adults' reaction times to affective stimuli were not affected by the valence of the cue in the gender task. In contrast, there were no age-related differences on affective updating in the valence task. In other words, for both young adolescents and adults, updating was quickest for happy cues during the valence task (see dotted line in Figure 1.8)

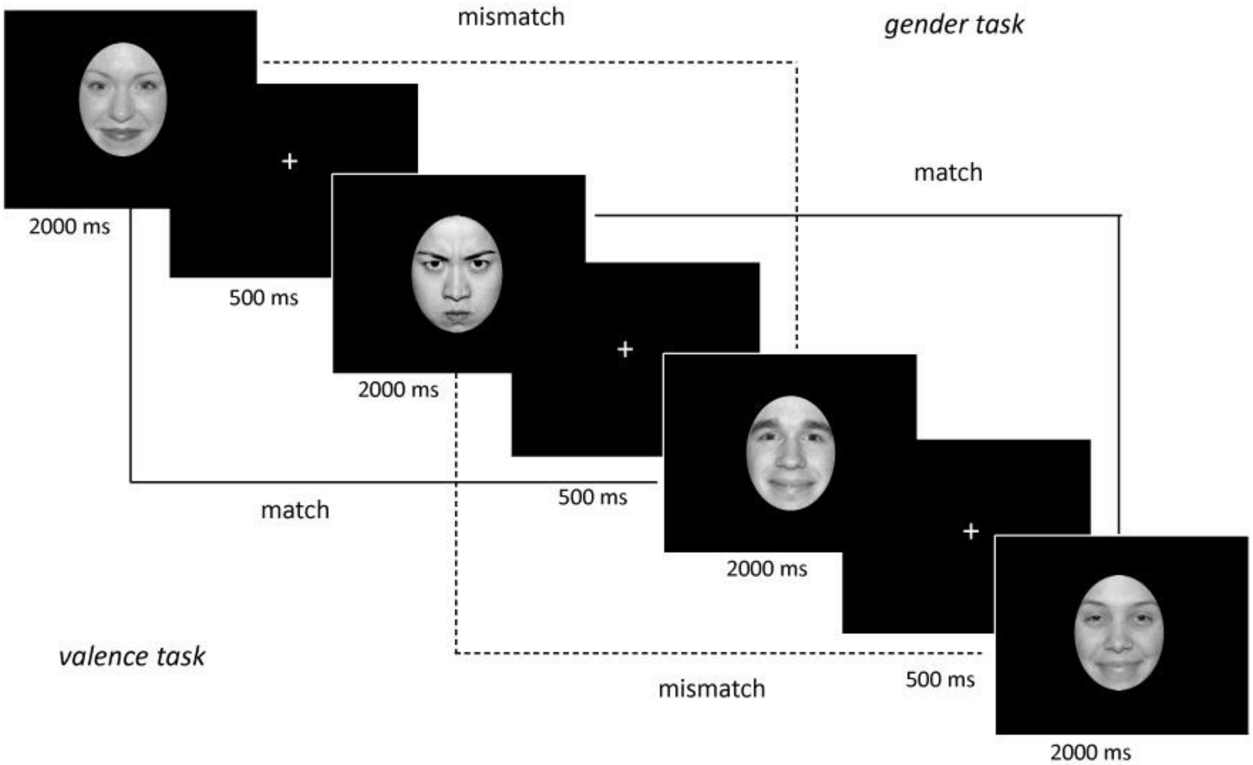

Figure 1.7. Experimental design of the affective n-back task. Example trial for the gender and valence conditions in the 2-back task. In the valence condition (left corner), match trials were trials where the emotional expression of the current face matched the one that appeared two trials earlier. In the gender condition (right corner), match trials were trials where the gender of the current face matched the gender of the face two trials back. Reprinted from Cromheeke & Mueller (2016).

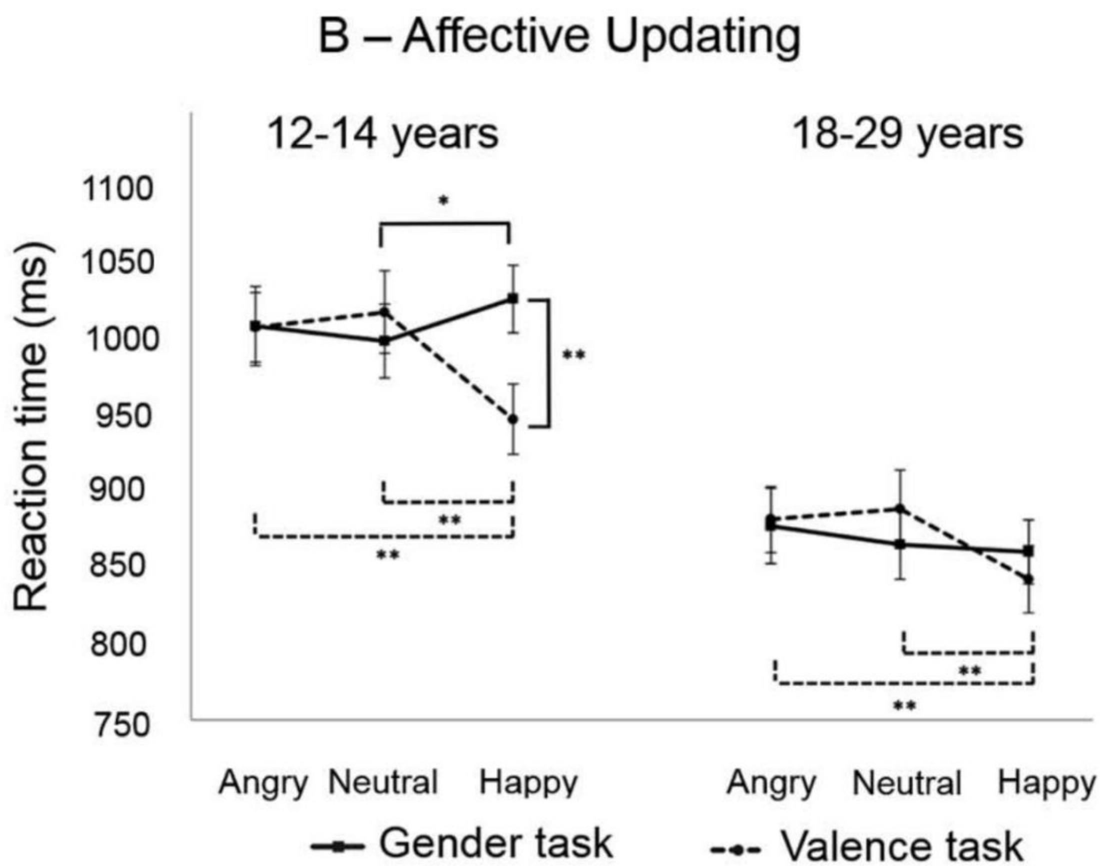

Figure 1.8. Age-related differences in affective updating. Reaction time (ms) for young adolescents and adults in an affective n-back task. The solid line represents reaction time for gender task, whereas the dotted line represents reaction time for valence task (see Figure 1.7 for experimental design). Reprinted from Schweizer, Gotlib & Blakemore (2020).

The findings described above on affective updating contrasted with affective shifting, where evidence showed that young adolescents (11–14 years) had overall lower shifting errors (i.e., better affective control) than older age groups (15-30 years) in an affective compared to a neutral task context (Schweizer, Parker, et al., 2019). The study used an affective Madrid Card Sorting Task, in which participants were shown a card on each trial, and were required to sort cards according to continuously changing rules: background colour, numbers of items and shape (for the neutral condition) or background colour, numbers of items and emotional facial expression (for the affective condition; Figure 1.9). Findings indicated that young adolescents performed significantly better in the task compared to the older age groups, suggesting that younger adolescents have better affective control than mid-adolescents and adults (Figure 1.10). Taken together, the abovementioned findings suggested that the three constructs of affective control (i.e., inhibition, updating and set-shifting) do not develop in unison.

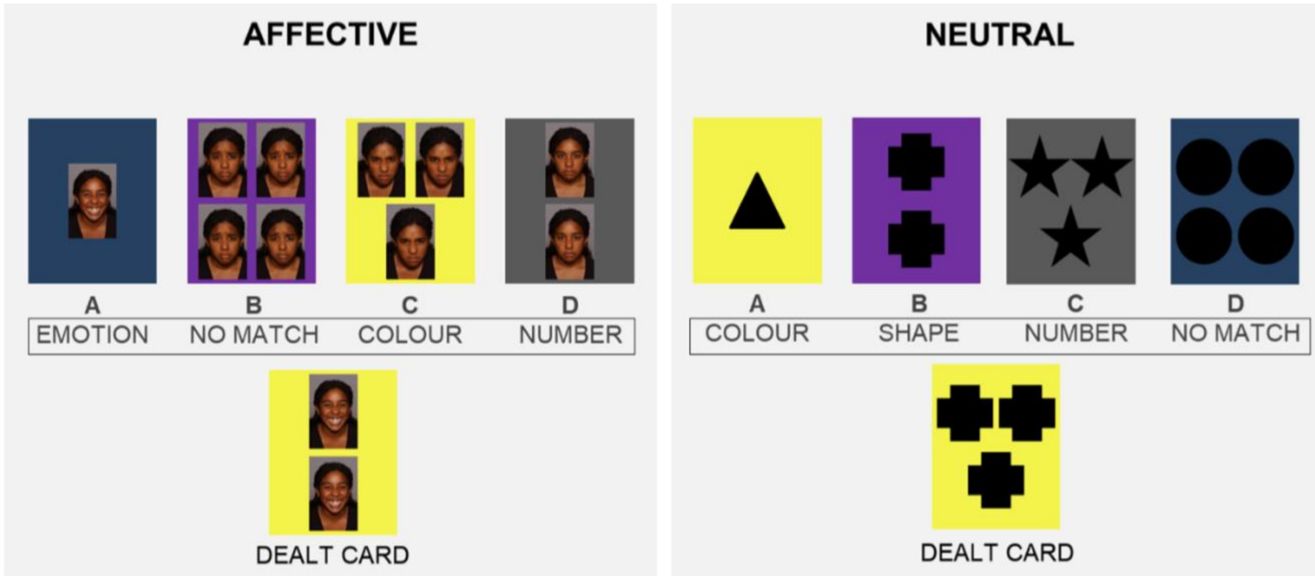

Figure 1.9. Example trial of the Affective Madrid Card Sorting Task. During each trial, participants were dealt a card, which they had to assign to one of the four decks according to three possible rules: background colour, numbers of items and shape (for the neutral condition, right panel) or background colour, numbers of items and emotional facial expression (for the affective condition, left panel). Black box indicated the sorting rule for each four of the decks. Reprinted from Schweizer, Parker, et al., 2019).

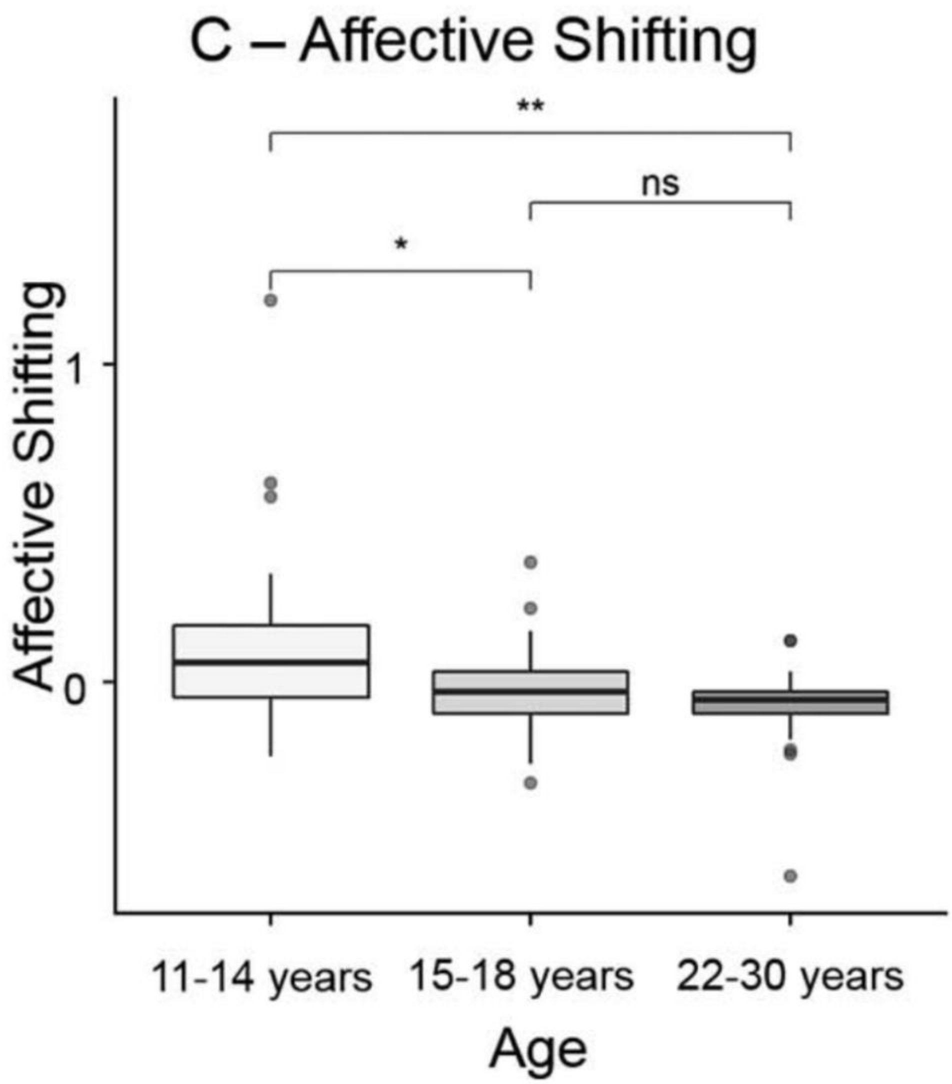

Figure 1.10. Age-related difference in affective shifting. Affective shifting, measured as the proportional difference in errors for the affective relative to neutral condition in an affective Madrid Card Sorting Task. Higher scores indicated better affective shifting. Reprinted from Schweizer, Gotlib & Blakemore (2020).

1.4.3 The role of affective control in adolescent mental health

Studies have consistently found that lower affective control is associated with the presence of mental health difficulties in adolescents across all three facets of affective control (Kilford et al., 2015; Ladouceur et al., 2013; Mirabolfathi, Schweizer, Moradi, & Jobson, 2020). For example, adolescents aged 10-18 years with depression made more commission errors (false positives) for negative than for positive targets, compared with those without depression, in an affective go/no-go task (Kilford et al., 2015). The findings suggested a mood-congruent effect of existing depressive symptoms on the processing of affective stimuli. A more recent study looked at the influence of trauma exposure and the impact of post-traumatic stress disorder (PTSD) symptoms on affective control in adolescents aged 13-19 years. Performance on affective control task was significantly worse in adolescents with high levels of PTSD symptoms who had been exposed to trauma compared to those who had not been exposed to trauma (Mirabolfathi et al., 2020).

Together, these results suggest that poor affective control in those with mental health difficulties may contribute to their affective difficulties. However, little is known about developmental changes in the relationship between affective control and mental health difficulties (Schweizer et al., 2020). One study that examined these reported age-related differences with younger adolescents (11-14 years), whose affective shifting performance was superior than that of mid-adolescents (15-18 years). However, poorer affective control, especially in the younger adolescent group, was associated with greater mental health difficulties relative to their older peers and adults (22-30 years; Schweizer et al., 2019). It is also worth highlighting that the causal effect of affective control on mental health is still unclear due to limited longitudinal evidence. Therefore, further research investigating the developmental changes in the association between affective control and mental health difficulties could constitute a promising pathway for mental health intervention.

In the current section, I have described cognitive development in adolescence, with a particular focus on the development of social-affective cognitive processes. In the next section, I will turn to cognitive and emotional training, with a specific focus on mindfulness and affective control training. In addition, I will describe the role of cognitive and emotional training in adolescent mental health.

1.5. Cognitive and emotional training

1.5.1 Mindfulness training and adolescents' mental health

Mindfulness was originally derived from the Buddhist concept of 'sati', which means 'to be aware'. It was then defined as the regulation of attention to focus on an individual's present moment experiences with a curious and open attitude, and it often involves the switching and redirecting of one's attention (Bishop et al., 2004). Higher levels of mindfulness have been associated with better functioning for a range of psychological and academic outcomes in children and adolescents, such as improved mental health and wellbeing, mood, self-esteem, self-regulation, positive social behaviours and academic learning (Miners, 2008; Weare, 2013).

Recently, mindfulness-based training has become increasingly popular in improving cognitive, behavioural and mental health outcomes in children and adolescents. This is mainly due to evidence suggesting that mindfulness training could be an effective way to improve cognitive and social skills that lead to benefits in individuals' social functioning and mental health (Weare, 2003, 2012).

For example, a meta-analysis examined 33 mindfulness training studies in children and adolescents and found that participants who underwent mindfulness training showed greater improvement in mindfulness skills and executive functions compared to those in control groups (Dunning et al., 2019). Additionally, the same study suggested mindfulness training to have positive effects on measures of depression, anxiety, stress and negative behaviours in adolescents. This is in line with the hypothesis that improvement in cognitive skills (e.g., executive functions) from mindfulness training might transfer to mental health and wellbeing outcomes (Kuyken et al., 2016; Weare, 2012).

However, it is worth noting that, while benefits acquired from mindfulness training were associated with better mental health outcomes, the effect size was small (Cohen's d = .19; Dunning et al., 2019). One possible explanation for the small effect size could be due to the lack of methodological rigour, such as the lack of randomisation for intervention and lack of active control groups in some of the included studies. As a result, the authors further refined the included studies and analysed 17 (of the 33) randomised controlled trials that compared mindfulness training with an active control group to better understand the effect of mindfulness training on children and adolescents' cognitive processes and mental health

(Dunning et al., 2019). The findings showed that mindfulness training in children and adolescents led to greater improvements in mindfulness skills, depression, anxiety and stress compared to active control training. Specifically, mindfulness training led to moderate improvements in mindfulness skills and depression symptoms, and small improvements in anxiety symptoms. These findings were in line with studies involving adults, in which mindfulness training has shown to be effective in improving mindfulness skills, stress, depression and anxiety (Khoury et al., 2013, 2015)

Mindfulness training has also shown promising effects in promoting positive behaviour (e.g. helping behaviour) and reducing antisocial tendencies in adolescents (Bögels et al., 2008; Donald et al., 2019; Franco et al., 2016). A recent systematic review of 16 studies found that mindfulness-based training led to an increase in prosocial behaviours in children and adolescents (Cheang et al., 2019). Mindfulness training can also be efficacious in reducing antisocial behaviours in adolescents (Bögels et al., 2008; Dunning et al., 2018; Franco et al., 2016), with one study finding that a 10-week mindfulness programme reduced self-reported aggression in 12-19-year-olds relative to a wait list control group (Franco et al., 2016). However, a meta-analysis showed that mindfulness did not have a significant impact on negative behaviour (e.g. aggression and hostility) relative to active control training (Dunning et al., 2018).

While some of these studies provide evidence that mindfulness training might encourage prosocial behaviours and reduce antisocial behaviours, less is known about how training affects susceptibility to prosocial and antisocial *influence*. Mindfulness training could modify an individual's susceptibility to prosocial and antisocial influence through its effect on executive control. Specifically, it has been suggested that the benefits of mindfulness might be partly attributable to improved self-control, which is the ability to inhibit prepotent responses to effectively respond to goal-relevant information (Elkins-Brown et al., 2017; Masicampo & Baumeister, 2007). One study showed that adolescents aged 13-18 years with low levels of self-control were more susceptible to antisocial influence and more likely to become involved with deviant peers (Marshall, Molina & Pelham, 2003). Another large-scale study found that young adolescents aged 12-15 with higher levels of self-control were less susceptible to peer influence (Meldrum, Miller & Flexon, 2013).

Moderate correlations between self-control and self-reported mindfulness have been reported in adolescents aged 12-14 years (Riggs, Black & Ritt-Olson, 2015). In a study of children aged 9-11 years, higher scores on the mindfulness attention awareness measure were associated with greater accuracy on an inhibitory control task (Oberle et al., 2012). Taken together, these studies suggest that self-control skills taught during mindfulness training could help to reduce susceptibility to social influence.

It has been hypothesised that the benefits of mindfulness training on mental health outcomes were mediated by improvements in affective control (Hölzel et al., 2011; Lutz et al., 2008). However, while previous studies have investigated the effect of mindfulness training on cognitive control, they predominantly focussed on 'cool' cognitive control measures rather than 'hot' cognitive control. Results from these studies were also inconclusive, with some reporting improvements in cognitive control measures and others reporting null effects post-training (Dunning et al., 2019). A recent randomised control trial examined the effect of mindfulness training on affective control in adolescents aged 11-16 years (Dunning et al., 2022). Participants were randomly allocated to either an 8-week mindfulness training programme or an 8-week social emotional training programme. Affective control was measured using three experimental tasks:

1. An affective working memory task, in which participants were required to remember lists of neutral works while simultaneously counting the number of distracting shapes that appear on either neutral or emotionally negative background images (Figure 1.11).
2. An affective Stroop task, in which participants were presented with happy or sad words that were superimposed over a series of faces with happy, sad, or neutral facial expressions. Participants had to respond whether the word is ‘happy’ or ‘sad’ as quickly and accurately as possible (Figure 1.12).
3. An affective sustained attention to response task (aSART), in which participants were presented with a series of single digits and asked to press a button for every digit except for ‘3’ (the target). The stimuli were presented with neutral (e.g., farmyard animals) or negative (e.g., baby crying) sounds in the background (Figure 1.13).

The findings indicated that mindfulness training did not have a significant impact on any of the three affective control measures when compared with the control training (Dunning et al., 2022). The study also examined whether the effect of mindfulness training, as compared to the control training, would mitigate self-reported mental health difficulties related to the COVID-19 pandemic. The findings suggested that, while self-reported mental health outcomes were worse at follow-up (during the pandemic) than at baseline and post-training, there were no differences between the mindfulness and control training group. This was part of a larger study, which I will discuss in more detail in chapter 3.

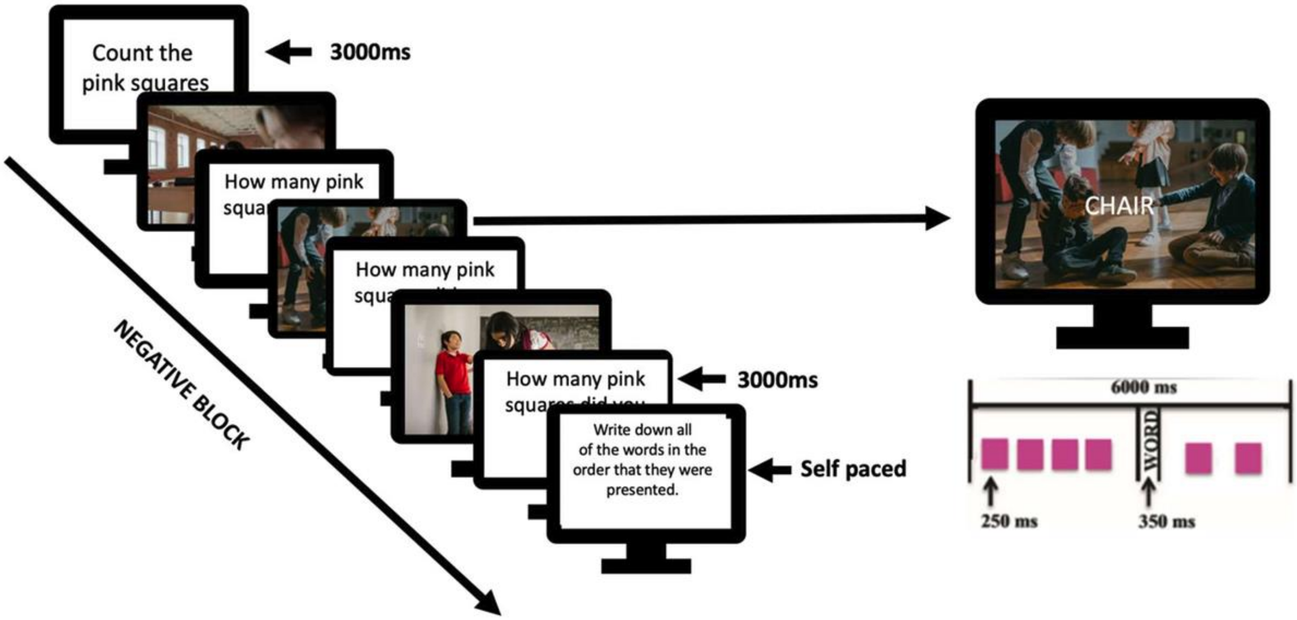

Figure 1.11. Affective working memory task. A sample 3-trial block for the affective working memory task during the negative condition. The task consisted of two cognitively demanding tasks. The first one was a target (storage) task, where participants had to learn and recall a set of words presented one word per trial in a block of 2-5 trials. The second task was an operation (distractor) task, which was interpolated with the target task, and participants had to count and report the number of shapes (pink square) within a given trial. Reprinted from Dunning et al., (2022).

Figure 1.12. Affective Stroop task. Example of congruent (left), neutral (middle), and incongruent (right) stimuli from the affective Stroop task. Participants were presented with happy or sad words that were superimposed over a series of faces with happy, sad, or neutral facial expressions. Participants had to respond whether the word was 'happy' or 'sad' as quickly and accurately as possible. Reprinted from Dunning et al., (2022).

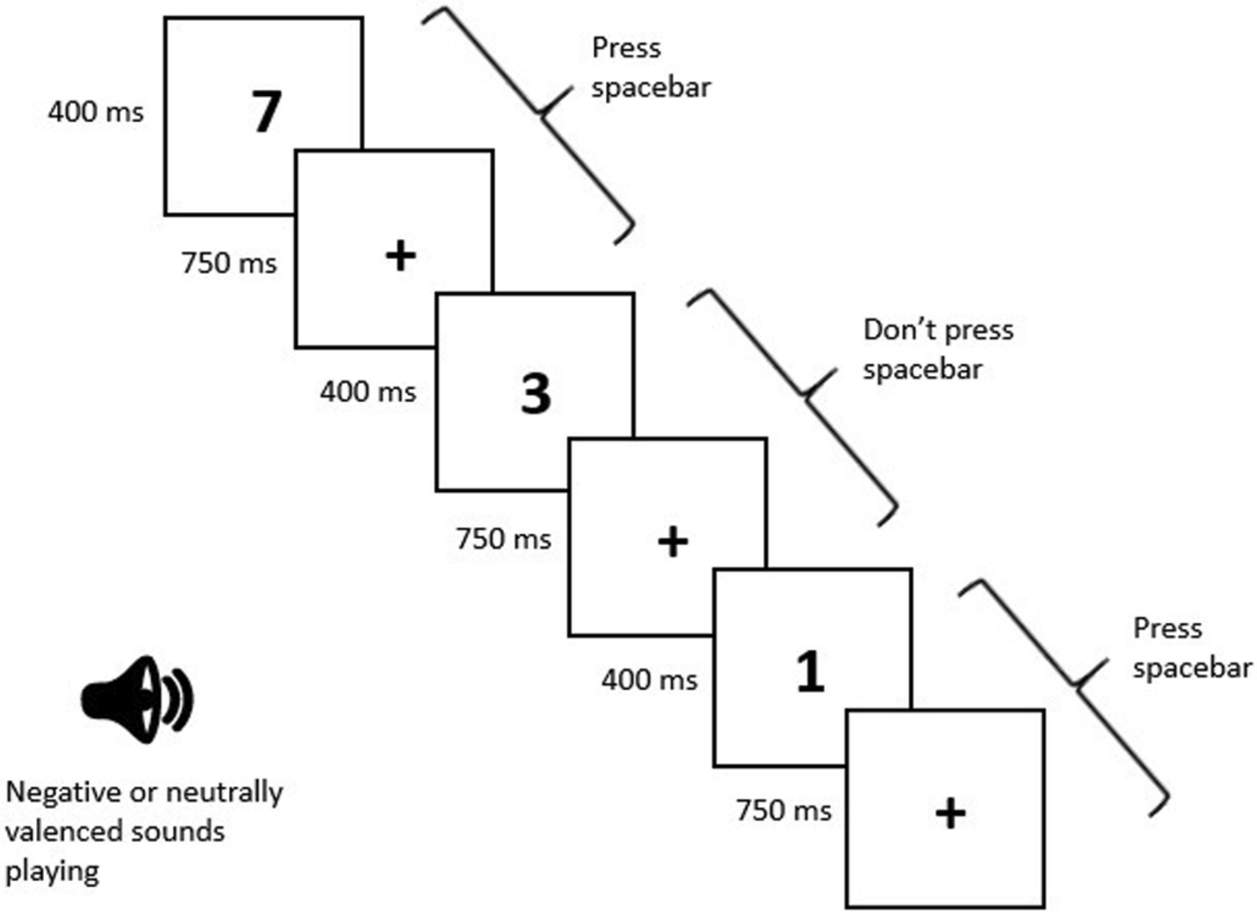

Figure 1.13. Affective sustained attention to response task. An example of the affective sustained attention to response task trial sequence. Participants were presented with a series of single digits and were asked to press a button for every digit except for '3' (the target). The stimuli were presented with neutral (e.g., farmyard animals) or negative (e.g., baby crying) sounds in the background. Reprinted from Dunning et al., (2022).

1.5.2 Affective control training in adolescence

Training studies with adolescents and young adults have shown both that affective control can be improved and that the gains in affective control are associated with improved emotion regulation and reduced mental health symptoms (e.g., Schweizer et al., 2017). For instance, one study examined the effect of affective control training, neutral cognitive control training, and no training on self-reported test anxiety in young adults aged 19-22 (Minihan et al., 2021). Participants in the affective control training group had to complete 20 sessions of training on an affective dual n-back task that lasted between 30-45 minutes. The task involved simultaneously presenting an image of a negatively valenced face (e.g., angry, sad, fearful) on a 4 x 4 grid and a word (e.g., exam, test) said aloud over headphones. Participants were required to press a button to indicate if either or both stimuli matched with the stimuli presented n-trials before (Figure 1.14). The findings suggested that both the affective control training group and the neutral cognitive control training group showed improvements in measures of affective control and cognitive control following training, as compared with the no training group. The affective control training group also showed greater reduction in anxiety symptoms compared to the neutral cognitive control training group (Figure 1.15).

Similarly, another study investigated the effect of a 20-day affective control training compared to control training in a group of adolescents (14-18 years) with PTSD (Schweizer et al., 2017). Participants in the affective control training group had to train on an affective dual n-back task for 30-45 minutes every day, whereas participants in the control training group had to train on a neutral cognitive control task for the same duration. Those in the affective control training group demonstrated greater pre- to post-training increases in cognitive control than those in the control training group. Additionally, participants in the affective control training group also showed greater improvements in post-traumatic stress disorder symptoms, as well as increased use of adaptive emotion regulation strategies than participants in the control training group (Schweizer et al. 2017).

In summary, these studies suggest that affective control is amenable to cognitive training, and such training can lead to improvements in emotion regulation and mental health outcomes (du Toit et al., 2020; Pan et al., 2020; Veloso & Ty, 2021). Improving affective control, particularly during adolescence, may therefore constitute a promising intervention target to improve mental health outcomes.

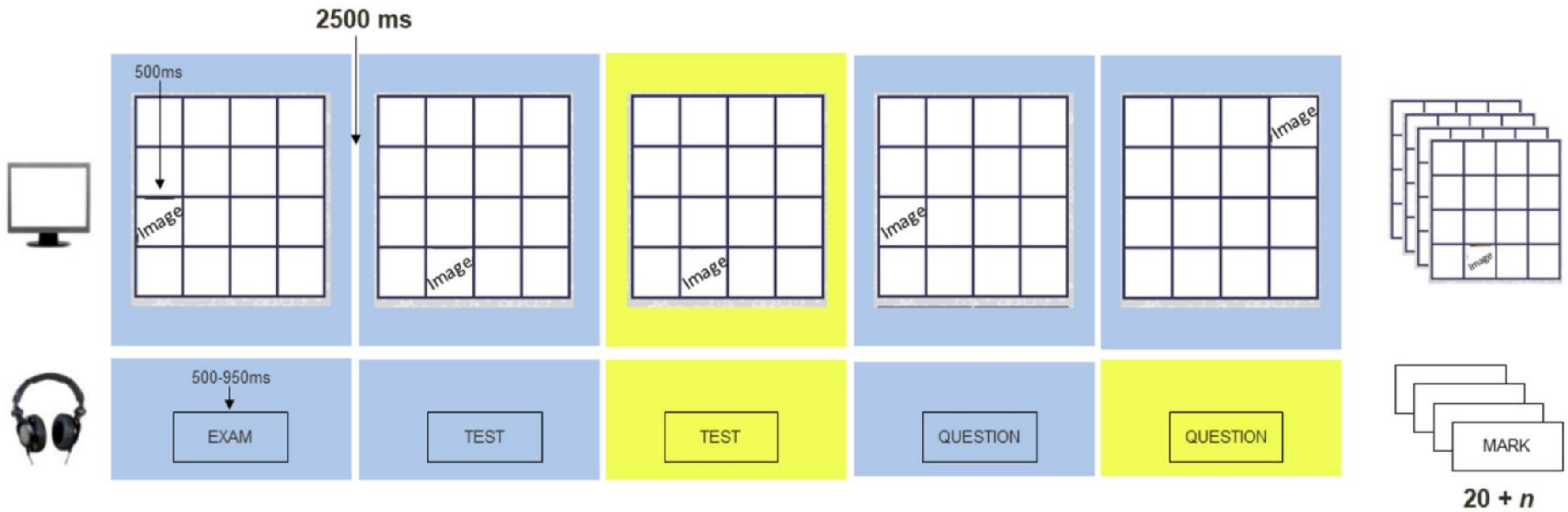

Figure 1.14. Affective dual n-back task. Example block of the affective dual n-back task where n=1. The trial with the yellow background represented the target stimuli. Participants were required to indicate, using a button, whether either or both the visual and auditory stimuli match the stimuli n-trials back. Reprinted from Minihan et al. (2021).

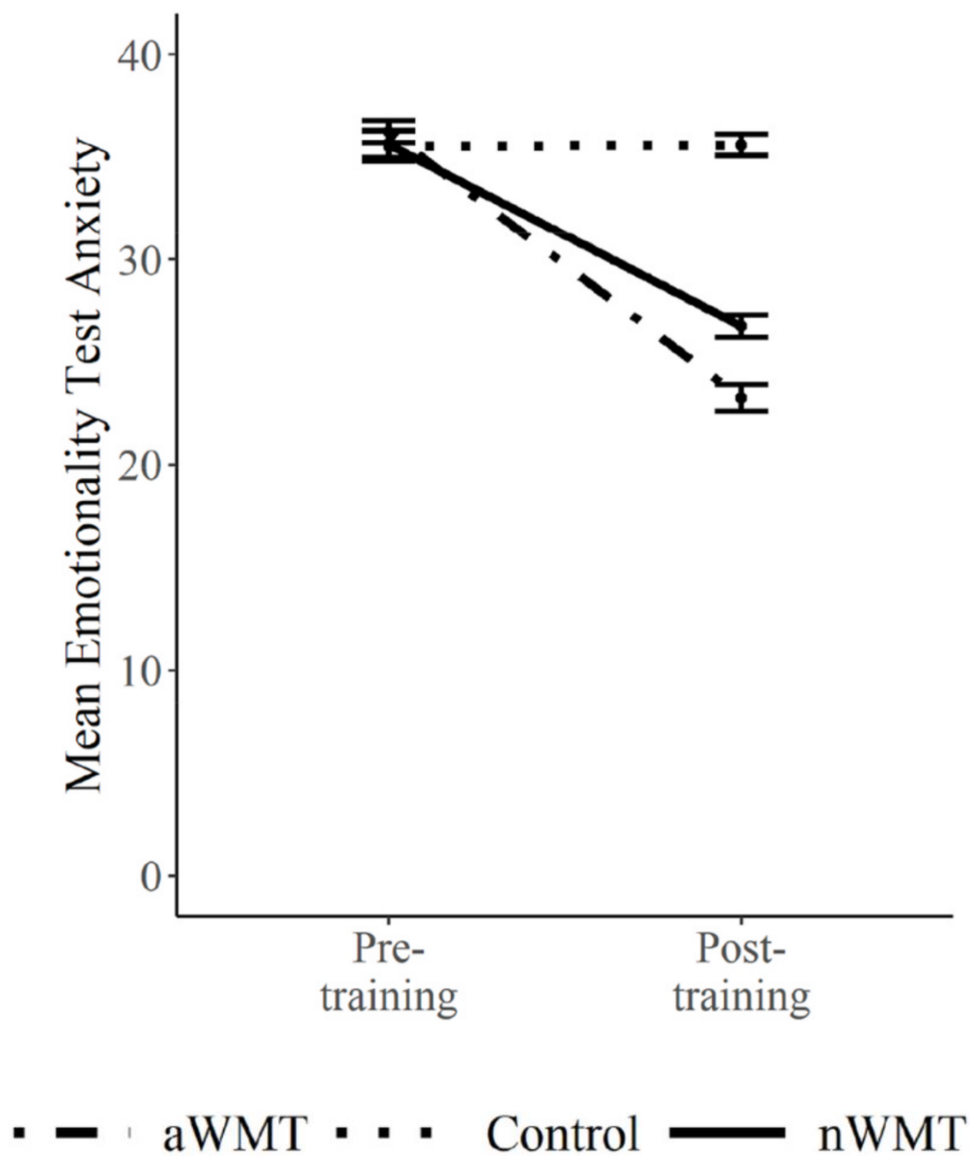

Figure 1.15. Pre- and post-training changes in self-reported anxiety measure across training groups. aWMT = affective control training group; nWMT = neutral cognitive training group; control = no training control group. Reprinted from Minihan et al. (2021).

1.6. Thesis overview

Following this introduction, I report the findings from a series of studies that examine the developmental changes of social cognitive processes in adolescents, and how social cognitive training can impact adolescents' mental health. In **Chapter 2**, I describe a cross-sectional study investigating the effect of age and puberty on susceptibility to prosocial and antisocial influence in 520 adolescents aged 11-18 years. As described in Section 1.3.2 and 1.3.3, whilst there is evidence that adolescents are particularly susceptible to social influence as compared with adults, and that peers play an important role in prosocial and antisocial influence during this period of life, these processes have not been investigated within participants in a single experimental task, and, to date, the effect of puberty has not been assessed. This chapter aimed to further explore the relationship between developmental changes during adolescence and susceptibility to prosocial and antisocial influence.

The next two experimental chapters examine the effect of social cognitive training programmes on adolescents' social cognitive development and mental health. **Chapter 3** explores the changes in susceptibility to prosocial and antisocial influence following two 8-week social emotional training programmes in 465 adolescents aged 11-16 years. The study builds on evidence described in Section 1.5.1, which suggested that mindfulness training can promote positive behaviour (e.g. helping behaviour) and reduce antisocial tendencies in adolescents. However, there is limited evidence on the effect of mindfulness training on susceptibility to prosocial and antisocial influence.

Chapter 4 describes an experimental study examining the effectiveness of an affective control training paradigm (compared to a control training paradigm) in 242 adolescents aged 11-19 years. Evidence presented in Section 1.4 and Section 1.5.2 demonstrated the developmental changes of affective control and the role of affective control in adolescent mental health. This study examines the training effect across two training groups, the extent to which training effect varies as a function of age, and how training effect associated with self-reported mental health problems, emotion regulation difficulties and self-control ability.

Finally, **Chapter 5** summarises the findings of the empirical studies and discusses how these findings might inform social cognitive development and mental health during adolescence.

CHAPTER 2: SUSCEPTIBILITY TO PROSOCIAL AND ANTISOCIAL INFLUENCE IN ADOLESCENCE

The study presented in this chapter has been published as: Ahmed, S.*, Foulkes, L.*, **Leung, J. T.*,** Griffin, C., Sakhardande, A., Bennett, M., ... & Blakemore, S. J. (2020). Susceptibility to prosocial and antisocial influence in adolescence. *Journal of Adolescence*, 84, 56-68. *Joint first author

2.1 Introduction

Individuals tend to adopt the opinions, judgements, and behaviour of other people in order to fit in with them (Turner, 1991; Zaki, Schirmer & Mitchell, 2011). The degree of conformity is age-dependent, with studies showing that susceptibility to social influence is highest during late childhood and adolescence, then steadily declining into adulthood (Foulkes et al., 2018; Knoll et al., 2015, 2017; Steinberg & Monahan, 2007; Sumter et al., 2009).

Adolescence is defined as the period between the onset of puberty and the achievement of a stable adult role in society, approximately between 10-24 years old (Sawyer et al., 2018). Significant social re-orientation takes place during adolescence as more time is spent with peers than with family (Lam, McHale & Crouter, 2014; Larson & Richards, 1991; Nelson et al., 2005; van den Bos, 2013), and peers become an additional important source of social influence (De Goede et al., 2009). Several studies have shown that adolescents are particularly sensitive to peer rejection (Peake et al., 2013; Sebastian et al., 2011; Somerville, 2013) and social approval (Foulkes & Blakemore, 2016). The heightened susceptibility to social influence in adolescents, combined with the increased fear of social rejection, increases the likelihood that adolescents will conform to their peers in order to gain social acceptance (Blakemore & Mills, 2014).

Social influence in adolescence

Social influence is often a prosocial process; individuals of all ages can be influenced by others to behave in a way that benefits other people or society, such as through cooperation, donation, and volunteering (Barry & Wentzel, 2006; Padilla-Walker & Carlo, 2014; van Hoorn, van Dijk et al., 2016). Several studies have investigated such prosocial influence across the lifespan. In adults, learning about other people's prosocial actions has been associated with donating more generously to charity (Frey & Meier, 2004; Nook et al., 2016; Shang & Croson, 2009), acting more fairly in economic games (Fowler & Christakis, 2010; Peysakhovich & Rand, 2015), and protecting the environment (Goldstein, Cialdini, & Griskevicius, 2008). A similar pattern has been seen in adolescence, with adolescents distributing coins more generously to their group after they observed peers approve such behaviour (van Hoorn et al., 2016) and being more likely to volunteer to help others in their community if they believed other students in their school, particularly high-status students, were already volunteering (Choukas-Bradley et al., 2015).

Foulkes et al. (2018) investigated differences in susceptibility to prosocial influence between childhood and adulthood. Unlike the studies described above, social influence effects here pertained to changes in hypothetical actions and not actual behaviours. Participants were first asked to rate how likely they would be to engage in a prosocial behaviour, such as 'Give up your seat on the bus'. They were then shown the average rating provided by (fictitious) previous participants, and were finally asked to re-rate the same scenario for themselves. The study found that children (8–11 years), young adolescents (12–14 years) and mid-adolescents (15–18 years) all significantly changed their ratings in line with the feedback, whilst young adults (19–25 years) and adults (26–59 years) did not.

Individuals can also influence each other to behave more antisocially, i.e. in ways that are potentially harmful to other people. Antisocial influence is common at all ages (Monahan, Steinberg & Cauffman, 2009; Slattery & Meyers, 2014), but tends to peak during adolescence, with several studies demonstrating that peer influence is an important contributor to many types of antisocial and risky behaviours in adolescence. This includes minor delinquency, serious offending, reckless driving, and bullying (Doehne, von Grundherr & Schäfer, 2018; Espelage, Holt & Henkel, 2003; Shope, Raghunathan, & Patil, 2003; Simons-Morton, Lerner, & Singer, 2005). In experimental studies, the number of risks taken by adolescents during a simulated driving game increased almost threefold when they were being watched by friends compared to when alone, whereas this was not the case for adults (Chein et al., 2011; Gardner & Steinberg, 2005).

Antisocial influence also occurs for indirect forms of antisocial behaviour, such as gossiping and ostracising others. This type of antisocial behaviour has been associated with achieving a high social status; adolescents are more likely to be influenced by peers who engage in this type of behaviour because those peers are often popular (Card et al., 2008; Garandeau & Cillessen, 2006; Heilbron & Prinstein, 2008). For example, in a study by Juvonen and Ho (2008), 11-year-olds were asked to nominate which of their classmates were bullies and which of their classmates they thought were “cool”. Children who perceived bullies as also being cool were likely to show increases in their own bullying behaviour a year later . Furthermore, using longitudinal social network analysis on a sample of children (aged 9-10) and young adolescents (aged 11-14), Sijtsema et al. (2014) found that young adolescents, but not children, selected peers as friends who were similar in levels of bullying perpetration (ostracizing others), and became more similar to friends in this behaviour one year later. The findings suggest that young adolescents are more susceptible to being influenced by indirect antisocial behaviour than are children.

Puberty and social influence

The majority of studies to date have investigated the development of susceptibility to social influence across chronological age. However, research has shown that puberty also plays an important role in adolescent social outcomes (Waylen & Wolke, 2004) and social-affective development (Crone & Dahl, 2012). Puberty is the period during which adolescents reach sexual maturity and become capable of reproduction, which typically begins between 9 and 12 years of age (usually 1–2 years earlier in girls than in boys; Kail & Cavanaugh, 2010). Hormonal changes occurring during puberty have a direct effect on the adolescent brain, which in turn influences the individual's mental state and behaviour (Cameron, 2004; Dahl, 2004; Sisk & Foster, 2004). Given that there is normal variation of around five years in the timing of pubertal onset (Parent et al., 2003), pubertal development is partially dissociable from chronological age. Several studies have shown that pubertal status—independent of chronological age—influences the structure and function of brain regions implicated in social cognition (Bramen et al., 2012; Forbes et al., 2010; Goddings et al., 2012; Wierenga et al., 2018). Therefore, when examining the development of social influence, as with any other social cognitive process, it may be informative to examine the effects of puberty as well as chronological age.

To date, no studies have directly assessed the impact of puberty on prosocial or antisocial influence, but several studies on related phenomena suggest that puberty may be relevant. In one such study, adolescents aged 11-14 with more advanced pubertal development report higher levels of sensation-seeking and greater drug use, independent of age (Martin et al., 2002), which has been related to increased peer influence (Wang et al., 2016). In another study of adolescents, instead aged 12-17, an increase in negative self-evaluation was uniquely associated with pubertal maturation and not age (Ke et al., 2018). Since low self-esteem and fear of ostracism play a role in social influence (Carter-Sowell, Chen & Williams, 2008; Uslu, 2013), these findings suggest that puberty may also therefore independently affect susceptibility to social influence.

It is possible that there are gender (or sex) differences in the experience of puberty and susceptibility to social influence (Negriff, Ji & Trickett, 2011). Studies have shown that advanced pubertal status is associated with increased reactivity to social rejection in brain regions implicated in social and affective processing, independent of age (Silk et al., 2014). However, other evidence has shown that this increasing rejection sensitivity is observed among girls but not boys across development (Stroud et al., 2017). Moreover, advanced pubertal status at age 11 years was associated with higher levels of social anxiety, only in girls (Deardorff et al., 2007). Both sensitivity to social rejection and social anxiety may be relevant for understanding susceptibility to social influence. Given that puberty influences social behaviour, the present study investigated how susceptibility to social influence varies with pubertal status in addition to chronological age in boys and girls separately.

The current study

The current study used a similar paradigm to Foulkes et al. (2018) in order to assess the effect of four variables: participant age, type of social information (*prosocial* or *antisocial*), direction of influence (whether other people report being more or less likely than you to engage in a behaviour; Knoll et al. 2017) and pubertal status, on susceptibility to social influence in a large group of participants aged 11 to 18 years. This age range was chosen as it is the period when social influence appears to undergo the most change (Chein et al., 2011; Foulkes et al., 2018; Gardner & Steinberg, 2005; Knoll et al., 2017; 2015), perhaps due to adolescents being hypersensitive to peer rejection (Peake et al., 2013; Sebastian et al., 2011; Somerville, 2013) and social approval (Foulkes & Blakemore, 2016). Although it has been well documented that peers play an important role in prosocial and antisocial influence during adolescence, these processes have not been investigated within participants in a single experimental task, and to date the effect of puberty has not been assessed.

Susceptibility to social influence was measured here as *the extent to which participants change reports of their own prosocial/antisocial behaviour after seeing how much others endorse the same prosocial/antisocial behaviour*. Participants first rated how likely they would be to engage in a prosocial/antisocial behaviour, such as carrying someone's bag for them or stealing someone's bag (Rating 1). Participants were then presented with the 'average rating' that other participants gave for the same behaviour ('provided rating'; participants were informed that the rating is from other adolescents, but in fact provided ratings were randomly generated). Finally, participants re-rated how likely they would be to engage in the same behaviour (Rating 2). There were four hypotheses:

1) *Age differences in susceptibility to social influence:* The extent to which participants change their ratings from Rating 1 to Rating 2 for both prosocial and antisocial behaviour will decrease with age. This is based on previous evidence that the magnitude of susceptibility to social influence (for risky or antisocial behaviour and prosocial behaviour) decreases over age (Foulkes et al., 2018; Knoll et al., 2015; Steinberg & Monahan, 2007; Sumter et al., 2009).
2) *Effect of social condition:* The extent of social influence will be affected by the type of social condition (*prosocial* or *antisocial* actions). Given the lack of previous research comparing antisocial and prosocial influence in the same study, this hypothesis was non-directional.
3) *Direction of influence:* the extent of social influence will be affected by whether the provided rating is higher or lower than participant's Rating 1 and this would be different depending on the social condition.
4) *Puberty-related differences in susceptibility to social influence:* The extent to which participants change their ratings will be affected by pubertal status (controlling for age), but we had no strong directional hypotheses here.

2.2 Method

2.2.1 Participants

Participants were recruited through their school as part of a study investigating the mechanisms of change in adolescent mindfulness training. Researchers reached out to schools directly and advertised the study through social media. Data from 552 participants (before mindfulness training commenced) from 12 schools in Greater London and Cambridgeshire were collected alongside a range of other cognitive tasks and questionnaires. IQ was measured using Cattell's Culture Fair Intelligence test (Institute for Personality and Ability, 1973). Data from 32 participants were excluded from the analysis, either because the participant did not complete the social influence task (n=21), they were not attending to the task (n=4), they had an SEN requirement (n=1) or they were missing IQ data (n=6). In total, data from 520 participants aged 11.2-18.5 (M=14.33, SD=1.74; 355 female, IQ ranged from 62-160; M=111.4; SD=17.14) were analysed for Hypotheses 1, 2 and 3. Of the 520 participants, only 369 participants had puberty data and were therefore included in the analysis for Hypothesis 4 (see *Puberty measure* below for more detail).

The study was approved by the UCL Research Ethics Committee. Informed consent from parents and assent from all participants was obtained. Participants were compensated £15 in vouchers for taking part in a 3-hour testing session, which was held at the participants' school. The majority of testing took place in groups (comprising between 2 and 15 participants); one participant was tested by themselves as they missed the testing session.

Due to school scheduling constraints, testing sessions were split over two days for four groups of participants (N=46). All other testing sessions were completed in one day.

2.2.2 Puberty measure

Pubertal status was measured using the Pubertal Development Scale (PDS; Petersen et al., 1988), a self-report scale that assesses five general indicators of development (growth in height, skin changes, growth of body for both boys and girls; facial hair growth and voice change for boys only; and breast development and menarche for girls only). Responses are coded on 4-point scales (1=no development and 4=completed development). For girls, a question about onset of menarche was rated on a 3-point scale (1=no and 3=yes definitely). Respondents on the PDS can be grouped into puberty categories using several methods. Pubertal development is traditionally classified into five Tanner stages – prepubertal, early pubertal, mid-pubertal, late pubertal, and post-pubertal (Carskadon & Acebo, 1993). However, given the unbalanced number of participants across the five groups, particularly the lack of prepubertal and a small number of early pubertal participants (N=49), we divided participants into two groups: early/mid (stages 2 & 3) and late/post puberty (stages 4 & 5) (Chan et al., 2015; Deardorff et al., 2007; see Table 2.1). Girls in the early/mid group were pre-menarche and girls in the late/post group were post-menarche (e.g. Burnett et al., 2011). Boys in the early/mid group had low individual ratings on growth of body hair, voice change, and growth of facial hair growth compared to boys in the late/post group (see Norris & Richter, 2008, for scoring details).

Pubertal status	Males	Mean age (range)	Females	Mean age (range)
Early/mid	99	13.31 (12-16)	64	12.80 (12-18)
Late/post	31	15.48 (13-18)	175	14.93 (11-18)
Total	**130**		**239**	

Table 2.1. Participants separated by pubertal status

2.2.3 Stimuli

Eighty-two scenarios (41 prosocial and 41 antisocial, see Supplementary Material for full list) were created for this task, each describing a social behaviour (e.g. prosocial: "Give money to charity"; antisocial: "Make fun of a classmate"). An image depicting the scenario was included to make the task more engaging (see Figure 2.1). The list of prosocial behaviours was adapted from a previous task assessing prosocial influence (Foulkes et al., 2018), with adaptations made to ensure the behaviours were relevant to the current adolescent age group. Prosocial scenarios covered helping and sharing behaviours towards strangers, family, and friends; giving to charity; and prosocial risk behaviours such as defending classmates. The list of antisocial scenarios was devised for this study and covered a range of behaviours relevant to adolescents, including violation of privacy, indirect aggression (e.g. gossiping), direct aggression (verbal, physical), theft and vandalism. Following Foulkes et al. (2018), moderately prosocial and antisocial behaviours that could reasonably elicit a variety of response ratings were chosen, to ensure that the randomly generated provided rating (supposedly the average rating from other participants) would be believable across the full range of the scale. All scenarios were rated on clarity and age-appropriateness by five independent raters with expertise in adolescent social cognition. Scenarios that were kept had consensus on clarity and age appropriateness.

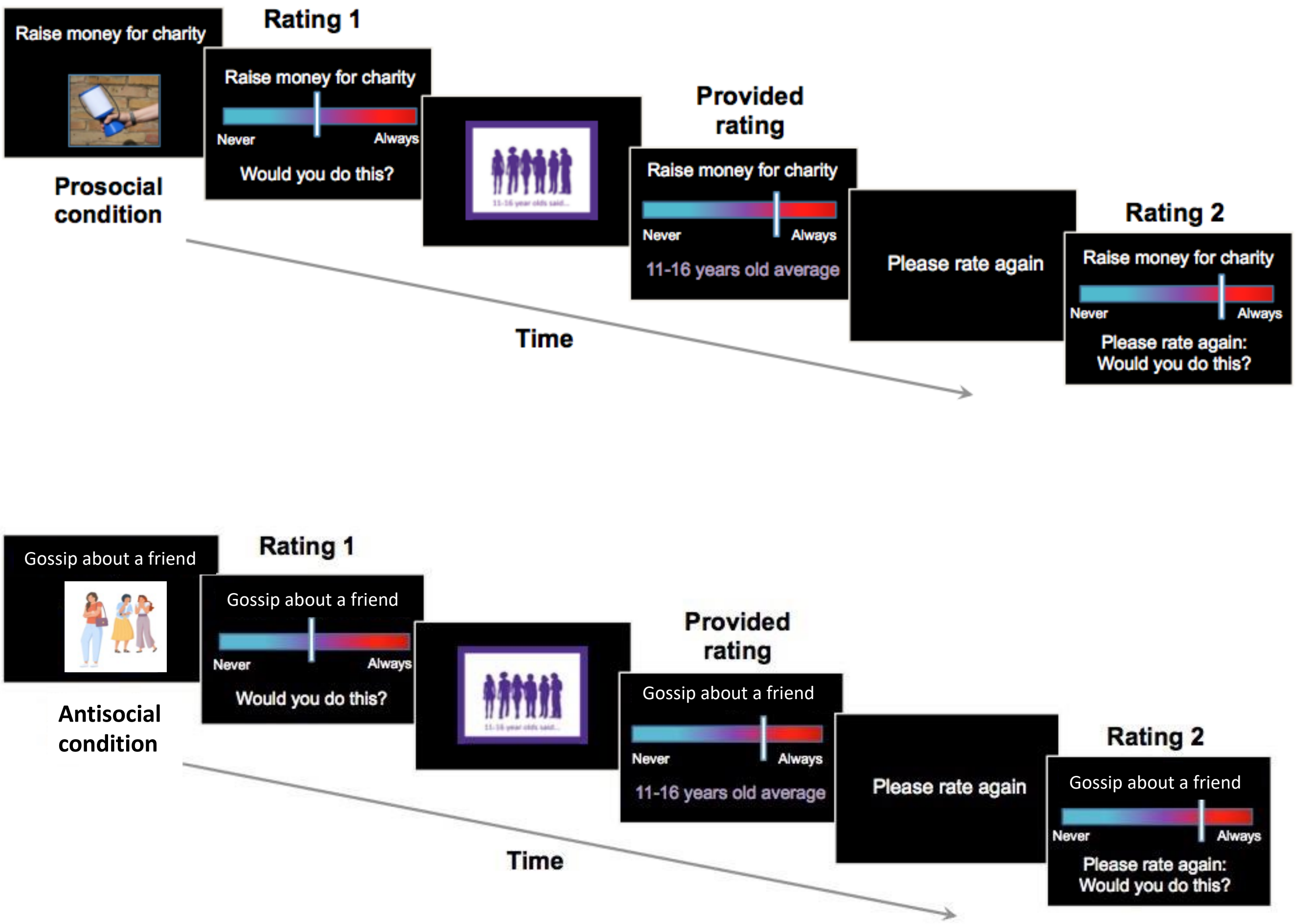

Figure 2.1. Trial sequence for the social influence task (top: prosocial trial, bottom: antisocial trial). Participants were asked to rate how likely they would be to engage in the behaviour (Rating 1). They were then shown the average rating of other adolescents (provided rating) and asked to rate the scenario again (Rating 2).

2.2.4 Procedure & trial sequence

Participants completed the task in groups at their school, guided by a team of three or four researchers. The laptops were sufficiently spread out so that participants could not see each other's screens or talk to anyone else while taking part. Before the task, participants read instructions on the screen and were shown an example trial. They then completed a practice trial and had the opportunity to ask any questions. Each participant completed 16 trials (eight for each social condition; prosocial and antisocial) randomly selected out of the possible 82 scenarios. The order in which participants saw prosocial or antisocial trials was randomised.

During each trial, participants were first shown (for 3 s) a sentence and image that depicted either a prosocial or antisocial behaviour (see Figure 2.1). They then rated how likely they would be to engage in that behaviour, using a computer mouse to move their slider on a visual analogue scale (Rating 1; no time restriction). The rating scale was anchored with the words "Never" at its leftmost point and "Always" at its rightmost point. When participants were required to make a rating, the slider first appeared at a random position on the scale in order to avoid any consistent anchoring bias. The position chosen by the participant was recorded to two decimal places (Never = 0.00; Always = 10.00). Next, participants were shown (for 2 s) a screen saying "11-16-year-olds said", and were then shown a rating of the same scenario, purportedly the average answer provided by a group of 11-16 years olds (this was the age group initially tested as part of the MYRIAD study; data from 17-18 year olds were later collected to widen the age range). This provided rating (2 s) was in fact a random number generated between 2 and 8; this range was used instead of 1-10 to ensure the figure was plausible as an average rating. Finally, participants were shown a screen saying, “Please rate again” (2 s), and then were asked to rate again how likely they would be to engage in that behaviour (Rating 2; no time restriction). The whole task took approximately 13 mins (see Figure 2.1 for trial sequence) and was programmed using Cogent 2000 (Cogent 2000 Team, 2015) and run in MATLAB version R2015a (The Mathworks, 2015) on 13-inch laptops.

Following the end of the study, participants were debriefed and informed that the ratings from other participants were in fact randomly generated.

2.2.5 Statistical analysis

Linear mixed-effects models were used for all analyses. All statistical analyses were conducted in R (R Core Team, 2013) using lme4 (Bates, Mächler, Bolker, & Walker, 2014) and were based on the models used by Foulkes et al. (2018). The categorical variables were coded as: social condition (1=prosocial, 2=antisocial), pubertal status (1=early-mid, 2=late-post), gender (0=female, 1=male) and direction of influence (1=lower, 2=higher).

Hypothesis 1 and 2: Age differences in susceptibility to social influence and the effect of social condition on susceptibility to social influence

This analysis investigated the degree to which participants changed their ratings after seeing the provided rating, and whether the extent of this change depended on age and/or the social condition. Because the provided rating was a randomly generated number between 2.00 and 8.00, it was not related in any systematic way to Rating 1.

The dependent variable in the model was the absolute difference between the participant's Rating 1 and Rating 2 (*change in rating*). Predictor variables in the model were the absolute difference between the provided rating and Rating 1 (*Δrating*); the main effects of age and social condition; two-way interactions between Δrating and age and Δrating and social condition (*prosocial, antisocial*); and a three-way interaction between Δrating, age and social condition were conducted. The variable Δrating was included in the model as a means of assessing whether the difference in magnitude between the participant's Rating 1 and the provided rating influenced the extent to which they changed their ratings. The model used to test Hypotheses 1 and 2 is summarised as follows:

Change in rating = Δrating + age + social condition + IQ + gender +
(Δrating X age) + (Δrating X social condition) +
(Δrating X social condition X age)

Subject-specific and scenario-specific intercepts were included as random effects and IQ and gender were included as covariates. Social condition was Helmert-coded to follow an orthogonal coding scheme.

Use of absolute values in main models

Note that, as in previous studies that used similar analyses (e.g. Foulkes et al. 2018; Knoll et al. 2015), absolute values of *change in rating* and *Δrating* were used in the model, rather than positive and negative values. This was because positive and negative values of *change in rating* both represent social influence, depending on the trial. It was not the case that a positive value would represent *more* social influence than a negative one. In other words, it was meaningful that a participant had changed their rating by e.g. five absolute points between their first and second rating, but not meaningful (in this paper) whether this was because the participant had been influenced to increase or decrease their first answer. One paper specifically addresses whether the direction of influence is relevant in social influence (Knoll et al., 2017), but in this paper we were interested simply in the magnitude of social influence.

However, a potential issue with using absolute values arises when considering Δrating. This is that a trial in which a participant sees the provided rating and then changes their answer in the *opposing* direction to the provided rating will be treated in the model in the same way as a trial in which the participant changes their answer to be *closer* to the provided rating. For example, a participant who first rates 5, sees a provided rating of 8, and then increases their answer to 7 will receive the same absolute Δrating (i.e. 2) as a participant who first rates 5, sees provided rating of 8, and then drops their answer to 3. This is a potential problem because only the former scenario should be considered social influence, but both are treated as social influence in the model. One possible solution was to include rating 1 in the model in order to provide an ‘anchor’ for Δrating, but this led to multicollinearity as rating 1 was in the model as a predictor twice (once on its own and once as part of Δrating). However, there were only a minority (6.33%) of trials in which participants rated substantially in the opposing direction (greater than 2 points). Therefore, the original model with absolute values was kept, and all trials were retained in the analysis.

Hypothesis 3: Direction of influence

This analysis investigated the degree to which participants changed their ratings *in the direction* of the provided rating and how it varied with age and social condition. Two separate models were run, one for prosocial scenarios and one for antisocial scenarios. As with the analysis for Hypothesis 1 and 2, the dependent variable in the models was the absolute difference between the participant's Rating 1 and Rating 2 (*change in rating*). Predictor variables in the models were *direction of influence* (trials when the provided rating was either *higher* or *lower* than the participant's Rating 1; see Knoll et al., 2017); the main effect of age; and a two-way interaction between direction of influence and age. The models used to test Hypothesis 3 are summarised as follows:

Change in rating (prosocial scenarios only) = direction of influence + age + gender + IQ + (direction X age)

Change in rating (antisocial scenarios only) = direction of influence + age + gender + IQ + (direction X age)

As with the Hypothesis 1 and 2 analysis, subject-specific and scenario-specific intercepts were included as random effects, with IQ and gender included as covariates.

Hypothesis 4: Puberty-related differences in susceptibility to social influence

For the subset of participants who completed both the puberty questionnaire and the social influence task (n=369), a secondary analysis was conducted that included pubertal status (early/mid, late/post) as a covariate of interest whilst controlling for age. Given the unbalanced gender split and different timings for the onset of puberty, boys and girls were analysed separately. The model used to test Hypothesis 4 is summarised as follows:

Change in rating = Δrating + pubertal status + social condition + IQ + age +

(Δrating X pubertal status) + (Δrating X social condition) +

(Δrating X social condition X pubertal status)

We also ran quadratic and cubic models for model comparisons; the linear model had the smallest Akaike Information Criterion (AIC=24879) compared to the quadratic model (AIC=24882; p=.427) and the cubic model (AIC=24886; p=.576) and was therefore the best fit.

All analyses are reported with IQ as a covariate (repeated analyses without IQ as a covariate are reported in the Supplementary Material). Planned comparisons were performed to inspect changes in social influence between puberty groups and social condition using the *lsmeans* package (Lenth, 2016).

2.3 Results

2.3.1 Social influence analysis

We ran a linear mixed-effects model to examine the extent to which participants changed their rating from Rating 1 to Rating 2, after seeing the provided rating purportedly from other people. We also examined whether this was influenced by participant age (*Hypothesis 1*) and/or social condition (prosocial or antisocial; *Hypothesis 2*).

There was a significant main effect of Δrating (difference between the provided rating and Rating 1; p=.001, see Table 2.2), indicating that participants demonstrated greater changes from Rating 1 to Rating 2 when the disparity between their Rating 1 and the provided rating was greater. There were also significant main effects of age (p=.002) and social condition (p=.028), suggesting that the difference between Rating 1 and Rating 2 became smaller as age increased, and also smaller for prosocial relative to antisocial scenarios. However, note that we were primarily interested in the *interaction* between Δrating and the other variables. Δrating takes into account the provided rating, and therefore indicates the extent to which social influence has occurred. Assessing interactions between Δrating and the other variables allows us to assess whether the extent of social influence was dependent on age, social condition, or both.

There was a significant interaction between age and Δrating (p=.008, see Table 2.2) on change in ratings, indicating that social influence decreases linearly with age and thus supporting Hypothesis 1 (see Figure 2.2). However, there was no interaction between

Δrating and social condition on change in ratings (*p*=.350) nor a three-way interaction between Δrating, social condition and age (*p*=.359) either (*Hypothesis 2*).

	χ^2	**Estimates**	**SE**
Intercept	103.827	1.935***	0.190
Delta rating	10.664	0.203**	0.062
Age	9.348	-0.034**	0.011
Social condition	4.835	0.042*	0.019
Gender	0.033	0.003	0.016
IQ	64.405	-0.007***	0.001
Delta rating x Age	6.988	-0.011**	0.004
Delta rating x Social condition	0.887	-0.026	0.027
Delta rating x Age x Social condition	0.840	0.002	0.002

Table 2.2 Chi square and parameter estimates (and standard errors) of the main model predicting *change in rating* (absolute difference between Rating 1 and Rating 2) as a function of the main effects (Δrating, age, social condition) and the interactions between the main effects when controlling for IQ and gender. Note: *** p<.001; ** p<.01; * p<.05

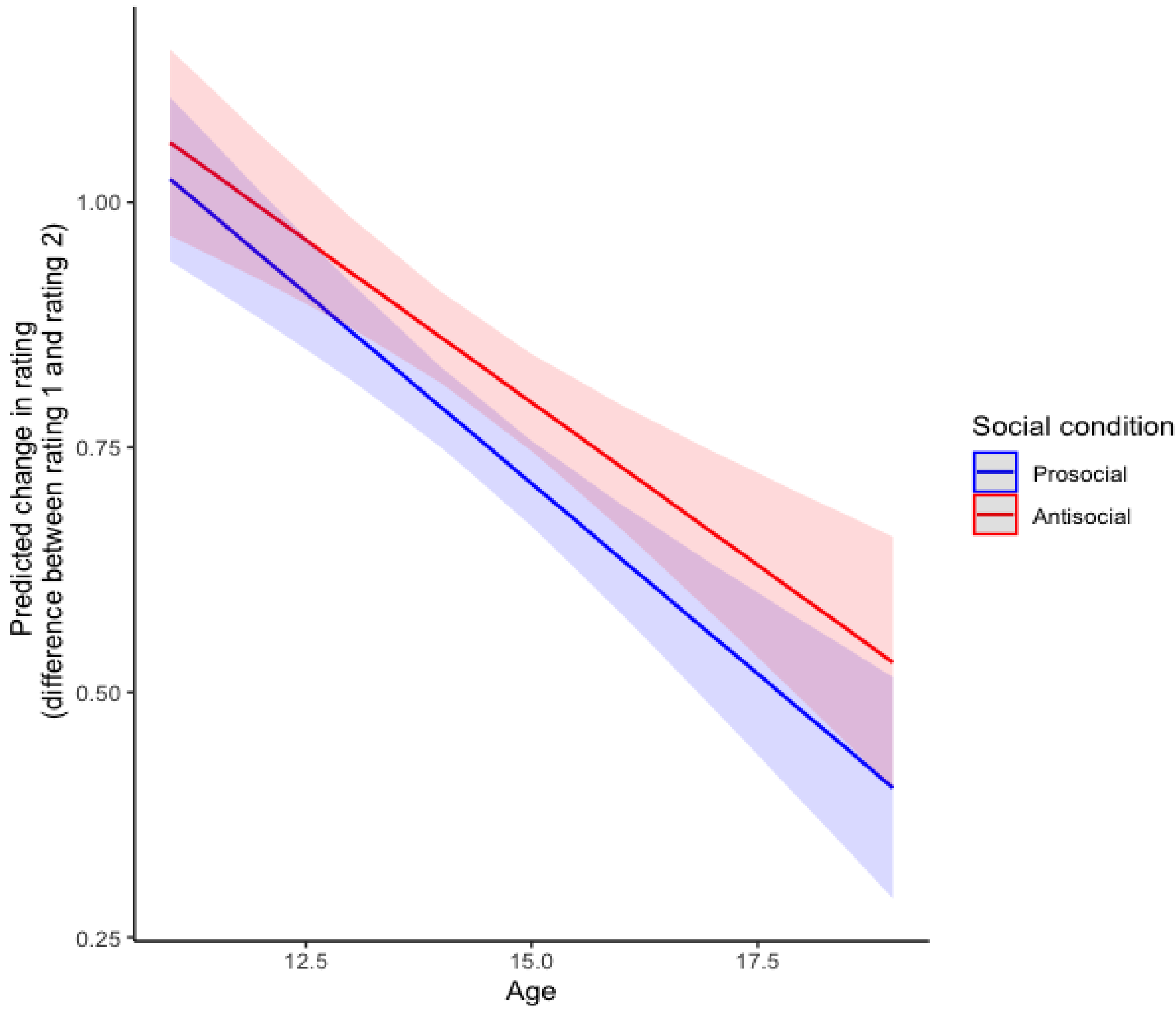

Figure 2.2. Predicted values for the average change in prosocial and antisocial rating predicted by the difference between the provided rating and the first rating (Δrating), shown across age. The slopes were calculated using estimates of the linear mixed-effect models.

Analyses without controlling for IQ (Hypothesis 1 & 2)

We conducted the same analyses for hypothesis 1 (Age differences in susceptibility to social influence) and hypothesis 2 (Effect of social condition) but without controlling for IQ. The model was otherwise the same as the main social influence analysis, and can be represented as follows:

Change in rating = Δrating + age + social condition + gender +
(Δrating X age) + (Δrating X social condition) +
(Δrating X social condition X age) + (1|subject/scenario)

There was a significant main effect of Δrating, indicating that participants demonstrated greater changes from Rating 1 to Rating 2 when the disparity between their Rating 1 and the provided rating was greater (see Table 2.3).

There was a significant interaction between age and Δrating on change in ratings, indicating that social influence decreases linearly with age, therefore supporting hypothesis 1. However, there was no interaction between Δrating and social condition on change in ratings or a three-way interaction between Δrating, age and social condition (hypothesis 2), in line with the analysis controlling for IQ.

	χ^2	**Estimates**	**SE**
Intercept	48.866	1.120***	0.160
Delta rating	8.842	0.193**	0.065
Age	8.622	-0.033**	0.011
Social condition	5.487	0.044*	0.019
Gender	0.274	0.009	0.016
Delta rating x Age	5.516	-0.011*	0.004
Delta rating x Social condition	0.848	-0.025	0.027
Delta rating x Age x Social condition	0.689	0.002	0.002

Table 2.3. Chi square and parameter estimates (and standard errors) of the main model predicting *change in rating* (absolute difference between Rating 1 and Rating 2) as a function of the main effects (Δrating, age, social condition) and the interactions between the main effects when controlling for gender. *** p<.001; ** p<.01; * p<.05

2.3.2 Direction of influence analysis

We also ran two linear mixed-effects models (prosocial and antisocial separately) to examine the effect of direction of influence (*Hypothesis 3*) and whether this was influenced by participant age.

For prosocial scenarios, there was a significant main effect of direction (p<.001) and a significant interaction between direction and age on change in rating (p=.001, see Table

2.3, Figure 2.3a). This indicated that, when the provided rating was higher than their Rating 1, participants were more likely to change their Rating 2 in line with the provided rating (i.e. change their rating to be more prosocial) than when the provided rating was lower than their Rating 1. This difference in the direction of influence decreased with age.

For antisocial scenarios, there was also a significant main effect of direction (p<.001) and a significant interaction between direction and age on change in rating (p<.001, see Table 3, Figure 2.3b). This indicated that when the provided rating was lower than their Rating 1, participants were more likely to change their Rating 2 in line with the provided rating (i.e. change their rating to be less antisocial) than when the provided rating was higher than their Rating 1. This difference in the direction of influence decreased with age.

	Prosocial			**Antisocial**		
	χ^2	**Estimate**	**SE**	**χ^2**	**Estimate**	**SE**
Intercept	132.182	3.296***	0.287	57.454	2.191***	0.289
Direction of influence	17.380	-1.166***	0.280	20.140	1.505***	0.335
Age	44.335	-0.116***	0.017	6.742	-0.043**	0.016
Gender	0.899	-0.021	0.022	1.837	0.037	0.027
IQ	30.667	-0.007***	0.001	27.929	-0.008***	0.001
Direction of influence x Age	10.769	0.064**	0.019	12.279	-0.081***	0.023

Table 2.4. Chi square and parameter estimates (and standard errors) of the models (prosocial and antisocial condition separately) predicting *change in rating* (absolute difference between Rating 1 and Rating 2) as a function of the main effects (direction of influence, age) and the interactions between the main effects when controlling for IQ and gender. Note: *** p<.001; ** p<.01; * p<.05

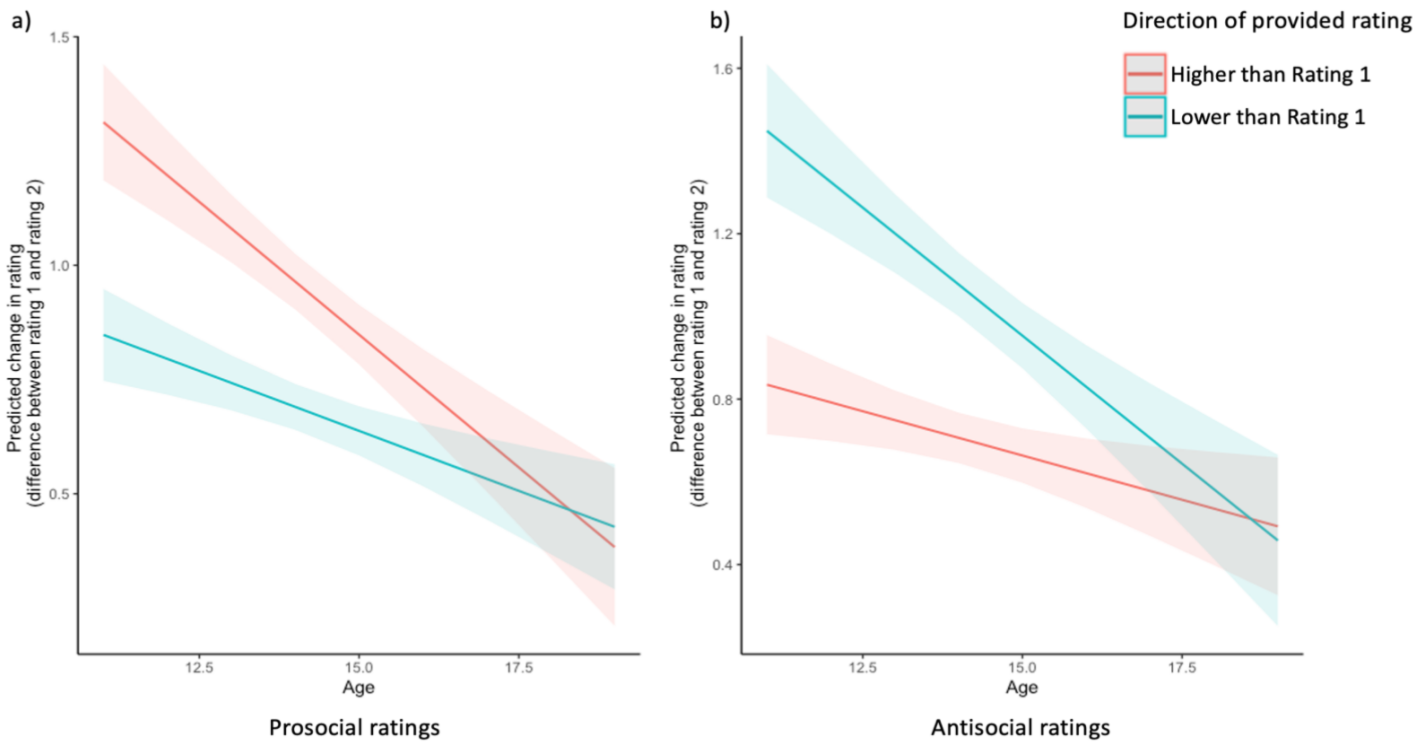

Figure 2.3. The slopes for the average change in a) prosocial and b) antisocial ratings predicted by direction of influence (provided rating being higher or lower than the participant's Rating 1), shown across age. The slopes were calculated using estimates of the linear mixed-effect model. For a) prosocial ratings, younger adolescents were more influenced when the provided rating was higher than their rating 1 (i.e. more prosocial). For antisocial ratings b) younger adolescents were more influenced when the provided rating was lower than their rating 1 (i.e. less antisocial).

__Analyses without controlling for IQ (Hypothesis 3)__

We conducted the same analyses for hypothesis 3 (direction of influence) without controlling for IQ. The model was otherwise the same as the main analysis, and is shown below:

Change in rating = direction of influence + age + gender +
(direction of influence x age) + (1|subject/scenario)

For prosocial scenarios, there was a significant main effect of direction and a significant interaction between direction and age on change in rating (see Table 2.5). This indicated that, when the provided rating was higher than their rating 1, participants were more likely to change their rating 2 in line with the provided rating and this difference in the direction of influence decreased with age.

For antisocial scenarios, there was also significant main effect of direction and a significant interaction between direction and age on change in rating (see Table 2.5). This indicated that when the provided rating was lower than their rating 1, participants were more likely to change their rating 2 in line with the provided rating and this difference in the direction of influence decreased with age. This is in line with the main analyses.

	Prosocial			Antisocial		
	χ^2	Estimate	SE	χ^2	Estimate	SE
Intercept	81.718	2.446***	0.271	27.388	1.263***	0.241
Direction of influence	16.516	-1.144***	0.281	19.924	1.495***	0.335
Age	32.573	-0.107***	0.019	5.318	-0.039*	0.017
Gender	0.321	-0.015	0.026	1.277	0.032	0.028
Direction of influence x Age	9.984	0.062**	0.020	11.956	-0.080***	0.023

Table 2.5. Chi square and parameter estimates (and standard errors) of the models (prosocial and antisocial condition separately) predicting *change in rating* (absolute difference between Rating 1 and Rating 2) as a function of the main effects (direction of influence, age) and the interactions between the main effects when controlling for gender. Note: *** p<.001; ** p<.01; * p<.05

2.3.3 Puberty analysis

To investigate Hypothesis 4 *(puberty-related differences in susceptibility to social influence),* we divided participants according to their pubertal status and gender.

For boys, the Δrating x puberty interaction was significant (*p*=.006, see Table 2.6), suggesting that the extent to which male participants changed their ratings was associated with pubertal status, independent of age. There was no significant interaction between Δrating and social condition (*p*=.237) or a three-way interaction between Δrating, social condition and puberty on change in ratings (*p*=.338, see Table 4 and Figure 2.4a). Planned comparisons indicated that the early/mid pubertal group were significantly more socially influenced than the late/post pubertal group (*t*(304)=2.77, *p*=.006; see Figure 2.4a).

For girls, although the Δrating x puberty interaction was not significant (*p*=.540), there was a significant interaction between Δrating and social condition (*p*=.013) and a significant three-way interaction between Δrating, social condition and puberty, on change in ratings (*p*=.018, see Table 4 and Figure 2.4b). Planned comparisons indicted that this was driven by the early/mid group being significantly more socially influenced by prosocial than antisocial scenarios (*t*(3401)=3.02, *p*=.003); see Figure 2.4b). All other differences were non-significant (*ps*>.150).

	Males			Females		
	χ^2	**Estimate**	**SE**	χ^2	**Estimate**	**SE**
Intercept	13.380	1.339***	0.366	94.454	2.328***	0.240
Delta rating	4.788	0.039*	0.018	13.262	0.042***	0.012
Pubertal status	0.360	0.028	0.046	3.876	0.062*	0.032
Social condition	0.001	0.001	0.034	3.898	0.049*	0.025
IQ	8.195	-0.005**	0.002	16.470	-0.005***	0.001
Age	0.557	-0.016	0.021	34.201	-0.082***	0.014
Delta rating x Pubertal status	7.668	-0.050**	0.018	0.376	-0.007	0.012
Delta rating x Social condition	1.401	0.014	0.012	6.229	-0.019*	0.008
Delta rating x Pubertal status x Social condition	0.917	-0.008	0.008	5.591	0.012*	0.005

Table 2.6. Chi square and parameter estimates (and standard errors) of the models (males and females separately) predicting *change in rating* (absolute difference between Rating 1 and Rating 2) as a function of the main effects (Δrating, pubertal status, social condition) and the interactions between the main effects when controlling for IQ. Note: *** p<.001; ** p<.01; * p<.05

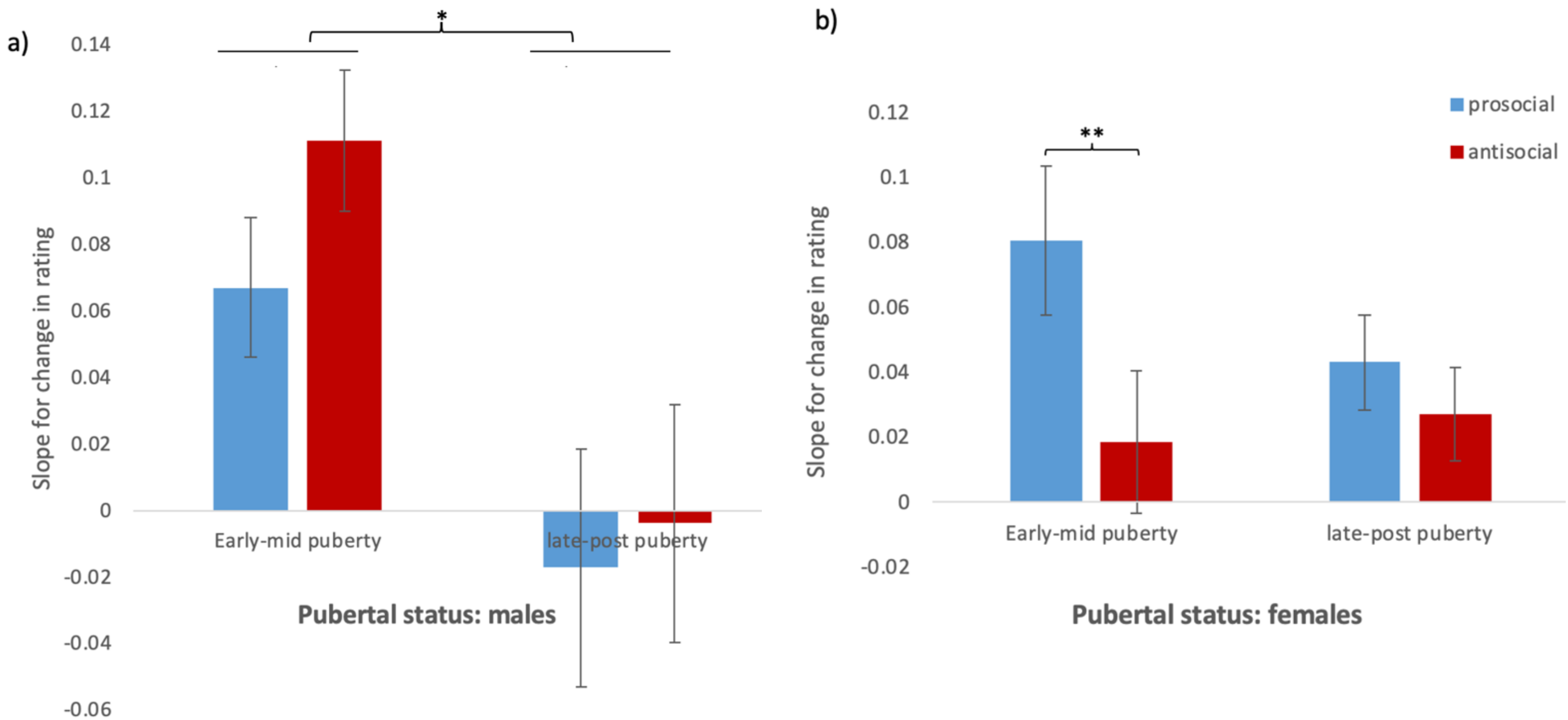

Figure 2.4. The slope for change in rating by pubertal status for males (a) and females (b). The Y-axis shows the slopes for the average change in ratings (difference between rating 1 and rating 2) predicted by the difference between the provided rating and the first rating (Δrating). The slopes were calculated using estimates of the linear mixed-effect models. Error bars represent standard error (**p<.005, *p<.05 Bonferroni-corrected).

Analyses without controlling for IQ (Hypothesis 4)

We conducted the same analyses for hypothesis 4 (Pubertal differences in susceptibility to social influence) but without controlling for IQ. The model was otherwise the same as the main social influence analysis, and can be represented as follows:

Change in rating = Δrating + puberty + social condition + age + gender +
(Δrating X puberty) + (Δrating X social condition) +
(Δrating X social condition X puberty) + (1|subject/scenario)

For boys, the Δrating x puberty interaction was significant, suggesting that the extent to which boys were socially influenced was affected by pubertal status, independent of age (see Table 2.7), in line with the analysis controlling for IQ. There was no significant interaction between Δrating and social condition or a three-way interaction between Δrating, social condition and puberty on change in ratings, also in line with the analysis controlling for IQ. Planned comparisons indicated that the early/mid pubertal group were significantly more socially influenced than the late/post pubertal group (p=.014).

For girls, although the Δrating x puberty interaction was not significant, there was a significant interaction between Δrating and social condition and a significant three-way interaction between Δrating, social condition and puberty, on change in ratings (see Table 2.7). Planned comparisons indicted that this was driven by a significant difference between antisocial and prosocial scenarios within the early/mid female group (p=.003).

	Males			Females		
	χ^2	**Estimate**	**SE**	χ^2	**Estimate**	**SE**
Intercept	5.968	0.751*	0.307	79.583	1.757***	0.197
Delta rating	4.709	0.040*	0.018	12.862	0.042***	0.012
Pubertal status	0.250	0.023	0.046	3.833	0.062	0.032
Social condition	0.005	0.002	0.034	4.037	0.050*	0.025
Age	0.360	-0.013	0.021	33.300	-0.081***	0.014
Delta rating x Pubertal status	7.323	-0.050**	0.018	0.363	-0.007	0.012
Delta rating x Social condition	1.359	0.014	0.012	6.523	-0.020*	0.008
Delta rating x Pubertal status x Social condition	0.902	-0.008	0.008	5.779	0.012*	0.005

Table 2.7. Chi square and parameter estimates (and standard errors) of the models (males and females separately) predicting *change in rating* (absolute difference between Rating 1 and Rating 2) as a function of the main effects (Δrating, pubertal status, social condition) and the interactions between the main effects. Note: *** p<.001; ** p<.01; * p<.05

2.4 Discussion

The current study investigated the effects of age and puberty on susceptibility to prosocial and antisocial influence in adolescence. We found that both prosocial and antisocial influence decreased with age between 11-18 years, with younger adolescents reporting that they were more likely to be engaging in prosocial behaviours and less likely to engage in antisocial behaviours after seeing others' ratings. Antisocial and prosocial influence significantly decreased across pubertal maturation (independent of age) for boys but not girls.

2.4.1 Age and social condition

Our main hypothesis was that social influence would decrease with age *(Hypothesis 1: Age differences in susceptibility to social influence).* After providing their first rating (Rating 1), participants were shown ratings purported to be from other adolescents and were then asked to rate the scenario again (Rating 2). Participants were socially influence in that they changed their second rating more when there was a greater difference between their first rating and the rating they believed came from other adolescents. This is in line with previous studies showing that adolescent participants were socially influenced by others' perceptions of risk (Knoll et al., 2017; 2015) and others' prosocial behaviour (Foulkes et al., 2018). However, unlike the current study, these previous studies investigated negative outcomes (perception of risky behaviours) and positive outcomes (prosocial behaviour) separately rather than in a single paradigm within the same individuals. Our findings revealed a significant negative linear association between age and the susceptibility to prosocial and antisocial influence. In the study by Foulkes et al. (2018), children (8–11 years), young adolescents (12–14 years) and mid-adolescents (15–18 years) all showed susceptibility to prosocial influence, but prosocial influence did not significantly decrease between these three age groups. One possible explanation for the discrepancy is that the sample size of the adolescent group in the Foulkes et al. (2018) study was almost half of that in the present study, thus having lower power. In addition, the testing environments of the two studies were different: the Foulkes et al. study took place in a museum whereas the present study took place in school classrooms. There were differences between the type of study participants and the testing environment that the participants were in: the Foulkes et al. (2018) study consisted of museum visitors who were tested in a quiet room with a small number of strangers, whereas in the present study students were tested in classrooms along with other students. Moreover, the current study also used antisocial scenarios as well as prosocial scenarios, and this may have affected how participants responded. Alternatively, the findings of the current study might be explained by overall changes in the ability to resist peer influence and make more independent decisions in late adolescence (Steinberg & Monahan, 2007; Sumter et al., 2009).

Our findings also support previous studies which have shown that susceptibility to antisocial influence decreases with age across adolescence. The majority of previous studies have focussed on direct forms of antisocial behaviour, for example, greater exposure to antisocial peers increases adolescent offending behaviours (Tatar, Cavanagh & Cauffman, 2016) and bullying (Doehne et al., 2018), with few studies investigating indirect antisocial behaviour such as ostracising others (Sijtsema et al., 2014). Even though the social influence effects in the present study pertain specifically to changes in hypothetical antisocial actions, and not actual behaviours, our findings support these previous findings by showing that antisocial influence decreases with age.

2.4.2 Direction of influence

Another aim of the current study was to understand whether social influence would be affected by the *direction* of other adolescents' ratings and whether this differs across social condition and age (*Hypothesis 3: direction of influence*). We found that social influence was affected by lower and higher ratings and such influence decreased with age. Specifically, younger participants were more socially influenced when the prosocial provided rating was higher than their initial rating (i.e. more prosocial) and when the antisocial provided rating was lower than their initial rating (i.e. less antisocial) (see Figure 2.3), in line with our hypothesis. In Knoll et al.'s (2017) risk perception paradigm, younger participants were more strongly influenced by ratings provided by teenagers than by adults, but only when the teenage provided rating was more risky than the participant's own rating. Whilst this measure of risk perception is different to the prosocial and antisocial measures in the current study, both studies demonstrate that younger adolescents are more easily influenced by other adolescents who report being more risk averse or more prosocial than the participant. Our findings suggest that adolescents reported to be more likely to engage in prosocial behaviours and less likely to engage in antisocial behaviours after seeing ratings of other adolescents, and that this social influence declines with age, possibly reflecting genuine socialisation effects as opposed to arbitrary changes in ratings. We speculate that this is at least partly because younger adolescents are still trying to come to terms with larger school contexts and “fitting in” by using positive impression management (Fine, 2004; McElhaney, Antonishak & Allen, 2008).

2.4.3 Dissociable effects of age and puberty

Previous work investigating social influence has primarily focused on changes across chronological age. However, puberty has been shown to have dissociable effects from age on social-affective development (Bramen et al., 2010; Crone & Dahl, 2012; Forbes et al., 2010; Goddings et al., 2012; Wierenga et al., 2018). In the present study, we measured pubertal status to assess puberty-related differences in susceptibility to social influence *(Hypothesis 4)* in boys and girls separately. Our hypotheses were speculative as there is no previous research on susceptibility to social influence and pubertal status. Our results showed that boys in early/mid puberty were more socially influenced than boys in the late/post pubertal group on both antisocial and prosocial scenarios, independent of age. In contrast, early/mid pubertal girls were more influenced by prosocial than antisocial scenarios, independent of age. This suggests that the extent to which boys changed their ratings was affected only by pubertal status (regardless of social condition), whereas for girls the extent of social influence depended on both pubertal status and social condition. It is not clear why the three-way interaction between Δrating, social condition and puberty was only seen in girls and not in boys. Further research is required to examine the relationship between gender, pubertal development, and type of social influence.

The finding that social influence did not significantly decrease with increasing pubertal maturity for girls is in line with studies suggesting that girls are more susceptible to implicit social influence (Hanish et al., 2005; Iscoe et al., 1963). In the present study, the provided ratings can be considered as implicit social influence as they were from unknown adolescents and referred to hypothetical actions. This could have a stronger influence effect on girls as boys appear to be more affected by explicit and overt attempts of pressure from their peers (Berndt, 1979; McCoy et al., 2019; Rose & Rudolph, 2006).

2.4.4 Limitations

A number of limitations of the present study need to be mentioned. With morally relevant behaviour such as prosocial behaviour, there is some evidence that what people report they will do and what they actually do differs (e.g., Teper, Inzlicht, & Page-Gould, 2011). For example, children and adolescents say they will give more than the amount they actually give in Dictator games (Blake, 2018). Young people may boast about engaging in antisocial behaviours as they may be considered as status enhancing (Sijtsema, Garofalo, Jansen & Klimstra, 2019). Furthermore, the source of influence in the present study were unfamiliar adolescents. However, studies have shown that peer acceptance and friendship quality affect how readily adolescents conform to their friends' behaviours: Urberg, Luo, Pilgrim and Degirmencioglu (2003) found that, for cigarette and alcohol use, adolescents who reported high levels of positive quality in their closest friendship were more influenced by that relationship than were those whose relationships were less positive. Future researchers may wish to address the questions asked in the current study using real ratings from close peers.

Due to time constraints, only 16 out of the possible 82 scenarios were administered during the task and therefore the extent to which adolescents changed their ratings may have been impacted by the topic of the randomly selected scenarios that they saw. We attempted to control for this issue by including subject-specific and scenario-specific intercepts as random effects in the model so that general effects relating to specific scenarios are accounted for (in line with the analyses of our previous studies (Foulkes et al., 2018; Knoll et al., 2017; 2015). The limited number of scenarios and two specified random effects may have underpowered the linear mixed-effects models and potentially biased the parameter estimates. We ran a new model that did not include these random effects and ran a model comparison with the original model (including random effects). We found that the original model with the two random effects had a significantly smaller Akaike Information Criterion (AIC=24879) compared to the model without any random effects (AIC=25980; $p<.001$) and was therefore the best fit. Nevertheless, future studies should aim to include a larger number of scenarios.

Future studies could also include a larger range of prepubertal to post-pubertal participants as well as measures of environmental factors, such as position within the peer group, friendship quality, and degree of autonomy. This would clarify whether the heightened susceptibility to peer influence in adolescence is the result of biological (hormonal) processes associated with puberty or social factors associated with advanced puberty and increasing age. Longitudinal designs would enable these relationships to be assessed over time.

2.4.5 Implications

Understanding what makes some adolescents more susceptible than others to peer influence is important for the design of effective prevention programs aimed at reducing antisocial behaviour and promoting prosocial behaviour. Indeed, studies that target social norms through peer-led interventions have shown positive outcomes across a number of domains such as bullying (Paluck, Shepherd & Aronow, 2016) and smoking (Campbell et al., 2008). In one study, 56 middle schools in the USA (with children aged 11-16 years) were randomly allocated to either a peer led anti-bullying programme or practise as usual. In this programme, a number of students who had a large number of positive social connections among their peers (socially referent students) attended an anti-conflict programme and were encouraged to lead grassroots anti-bullying campaigns within their schools. Compared with control schools, the schools in which the anti-bullying programmes were led by students saw a 25% reduction in conflict over the ensuing year. The effect was strongest in schools with a higher proportion of socially referent students leading the campaigns. The study demonstrated the power of peer influence in changing behaviour in adolescents. The findings of the current study suggest that targeting young, early pubertal adolescents may be even more effective.

2.5 Conclusion

The present study investigated susceptibility to prosocial and antisocial influence across adolescence and found that both types of social influence decreased with age, with younger adolescents reported greater tendencies to engage in prosocial behaviours and less tendencies to engage in antisocial behaviours after seeing others' ratings. Pubertal maturation was independently associated with a decrease in social influence in boys but not girls. Overall, the findings demonstrate the relationship between social influence and maturity is dependent on the nature of the social influence (positive versus negative) and on gender. The current findings highlight the importance of measuring puberty as well as age when understanding decision-making and changes in social cognition across adolescence. In the next chapter, I will describe a study that investigated whether susceptibility to prosocial and antisocial influence is affected by mindfulness training (versus an active control training programme) in adolescence.

CHAPTER 3: SUSCEPTIBILITY TO PROSOCIAL AND ANTISOCIAL INFLUENCE IN ADOLESCENCE FOLLOWING SOCIAL-EMOTIONAL TRAINING PROGRAMMES

The study presented in this chapter has been accepted in a peer review journal: **Leung, T.J.***, Piera Pi-Sunyer, B.*, Ahmed, S.P.*, Foulkes, L., Griffin, C., Sakhardande, A., Bennett, M.P., Dunning, D.L., Griffiths, K., Parker, J., MYRIAD, Kuyken, W., Williams, J.M.G., Dalgleish, T. & Blakemore, S-J. (2022). Susceptibility to prosocial and antisocial influence in adolescence following mindfulness training. *Infant and Child Development. E2386.*

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3.1 Introduction

In the previous chapter, I described a study that investigated susceptibility to prosocial and antisocial influence in adolescence. In this chapter, I will describe a study that investigated whether this form of social influence is affected by mindfulness training.

Mindfulness training has shown promising effects in promoting positive behaviour (e.g. helping behaviour) and reducing antisocial tendencies in adolescents (Bögels et al., 2008; Donald et al., 2019; Franco et al., 2016). Mindfulness refers to the regulation of attention to focus on an individual's present moment experiences with a curious and open attitude (Bishop et al., 2004). A recent systematic review of 16 studies found that mindfulness-based training led to an increase in prosocial behaviours in children and adolescents (Cheang et al., 2019). Mindfulness training can also be efficacious in reducing antisocial behaviours in adolescents (Bögels et al., 2008; Dunning et al., 2018; Franco et al., 2016), with one study finding that a 10-week mindfulness programme reduced self-reported aggression in 12-19 year olds relative to a wait list control group. (Franco et al., 2016). However, a meta-analysis showed that mindfulness did not have a significant impact on negative behaviour (e.g. aggression and hostility) relative to active controls (Dunning et al., 2018). While some of these studies provide evidence that mindfulness training might encourage prosocial behaviours and reduce antisocial behaviours, less is known about how training affects susceptibility to prosocial and antisocial *influence*.

It has been suggested that the benefits of mindfulness might be attributable to executive processes, specifically self-control – the ability to inhibit prepotent responses in order to effectively respond to goal-relevant information (Elkins-Brown et al., 2017; Masicampo & Baumeister, 2007). Moderate correlations (*r*=.46) between self-reported mindfulness and self-control have been reported in adolescents aged 12-14 years (Riggs, Black & Ritt-Olson, 2015). In a study of children aged 9-11 years, higher scores on the mindfulness attention awareness measure were associated with greater accuracy on an inhibitory control task (Oberle et al., 2012). Another study on a sample of 908 participants aged 12-15 found that participants with higher levels of self-control were less susceptible to peer influence (Meldrum, Miller & Flexon, 2013). Taken together, these studies suggest that self-control skills taught during mindfulness training might help to reduce susceptibility to social influence.

The current study

The aim of the current study was to investigate the effect of mindfulness training (versus an active control training programme) on the susceptibility to prosocial and antisocial influence in adolescents. Participants were randomly allocated to an 8-week programme of mindfulness training or student skills training. Both programmes are active in teaching social, self-management and cognitive skills such as improving memory. However, mindfulness training is expected to target executive functioning by learning mindfulness skills, where the active control training programme contained no mindfulness skills training (e.g. breathing exercises or reflecting activities were removed from the student skills training; adapted from Student Success Skills; Atlantic Education Consultants, 2013).

Therefore, the mindfulness, but not the control training, consisted of activities focusing on breathing, decentring and better focus (MiSP, 2009). Participants completed a social influence task before and after the training. In the task, participants first rated how likely they would be to engage in a prosocial or antisocial behaviour (first-rating) and were then presented with the average rating for the same behaviour purportedly from other similar-aged participants (the 'provided rating', which was in fact randomly generated). Participants then re-rated how likely they would be to engage in the same behaviour (second-rating). The outcome of interest was the difference between participants' first-ratings and their second-ratings after seeing the provided ratings. The greater the difference between the first- and second-ratings, the greater the influence.

Based on the research described above, we hypothesised that:

1. Self-reported prosocial behaviour (first-ratings in the prosocial condition) would increase, and self-reported antisocial behaviour (first-ratings in the antisocial condition) would decrease following mindfulness training relative to the active control training.
2. Mindfulness training would be associated with a reduction in social influence such that the change from first-rating to second-rating would be smaller post-training relative to pre-training.

   2a. This reduction in social influence would be different across prosocial and antisocial conditions.

   2b. This reduction in social influence would be greater for mindfulness training group than for the active control training group.

3.2 Methods

3.2.1 Participants

Participants were recruited through their school as part of a study investigating the mechanisms of change in adolescent mindfulness training (https://osf.io/6xg59). Researchers reached out to schools directly and advertised the study through social media. A total of 12 schools from Greater London and Cambridgeshire were recruited (between October 2016 and July 2019). The schools recruited contained a combination of non-selective, state maintained schools (8 mixed and 2 single gender) and selective, independent schools (1 mixed and 1 single gender). Special schools, alternative provision settings and schools that teach mindfulness to all students were excluded. Pre-training data from 449 participants was included in the analysis (299 females; mean age = 13.89 years, SD = 1.38; age range = 11.0 – 16.5 years) and from 354 participants post-training (226 females; see Table 3.1 for participant demographics). See Figure 3.1 for the flow of participants through each stage of the study. IQ was measured using Cattell's Culture Fair Intelligence test (Institute for Personality and Ability, 1973). The test consists of four types of spatial problems (series completions, odd-one-out, matrices, topology), and was completed under timed conditions. Mean IQ across the groups pre-training was 110.03, SD = 16.81, range = 62-155. The study was approved by the University Research Ethics Committee. Informed consent from parents and assent from participants was obtained. Participants were compensated £15 for each testing session, £5 for attending each training lesson and submitting the corresponding homework sheet, and a bonus £10 for attending six or more training lessons and both testing sessions.

3.2.2 Testing procedure and group randomisation

Testing sessions at both pre- and post-training each lasted 3 hours and took place at the school in small groups (between 7-15 participants; group size at Time 1 and Time 2 is included in the statistical model; see more details in Supplemental information 1 in the Supplemental Material). During these sessions, participants completed the social influence task alongside several other cognitive tasks and questionnaires (see https://osf.io/6xg59/ for details). Participants were then randomly assigned to mindfulness training (MT) or the student skills training (SST; see below for training details; see Figure 3.1). The randomisation was conducted by a statistician independent of the research team and researchers involved in the testing sessions were blind to the training group allocation. To minimise selection bias, participants were not randomised to condition until after they completed the pre-training data collection. Details of the two groups can be found in Table 3.1.

	Mindfulness training	Student skills training	Comparison (t-test)
N	228 (76 males)	221 (74 males)	
Mean age in years (SD)	13.88 (1.38)	13.89 (1.39)	t(446.34)=.06, *p*=.951
Age range (years)	11.0-16.4	11.0-16.5	
Mean IQ (SD)	110.47 (17.54)	109.58 (16.07)	t(435.94)=-.55, *p*=.581
Mean lesson attendance out of 8 lessons (SD)	6.40 (2.47)	6.41 (2.23)	t(444.88)=.06, *p*=.955
Mean homework completion out of 7 pieces (SD)	5.09 (2.31)	4.55 (2.39)	t(445.17)=-2.44, *p*=.015

Table 3.1. Pre-training descriptives for participants in each training group. Age, IQ, gender, attendance, and homework completion were included as covariates in the sensitivity analyses.

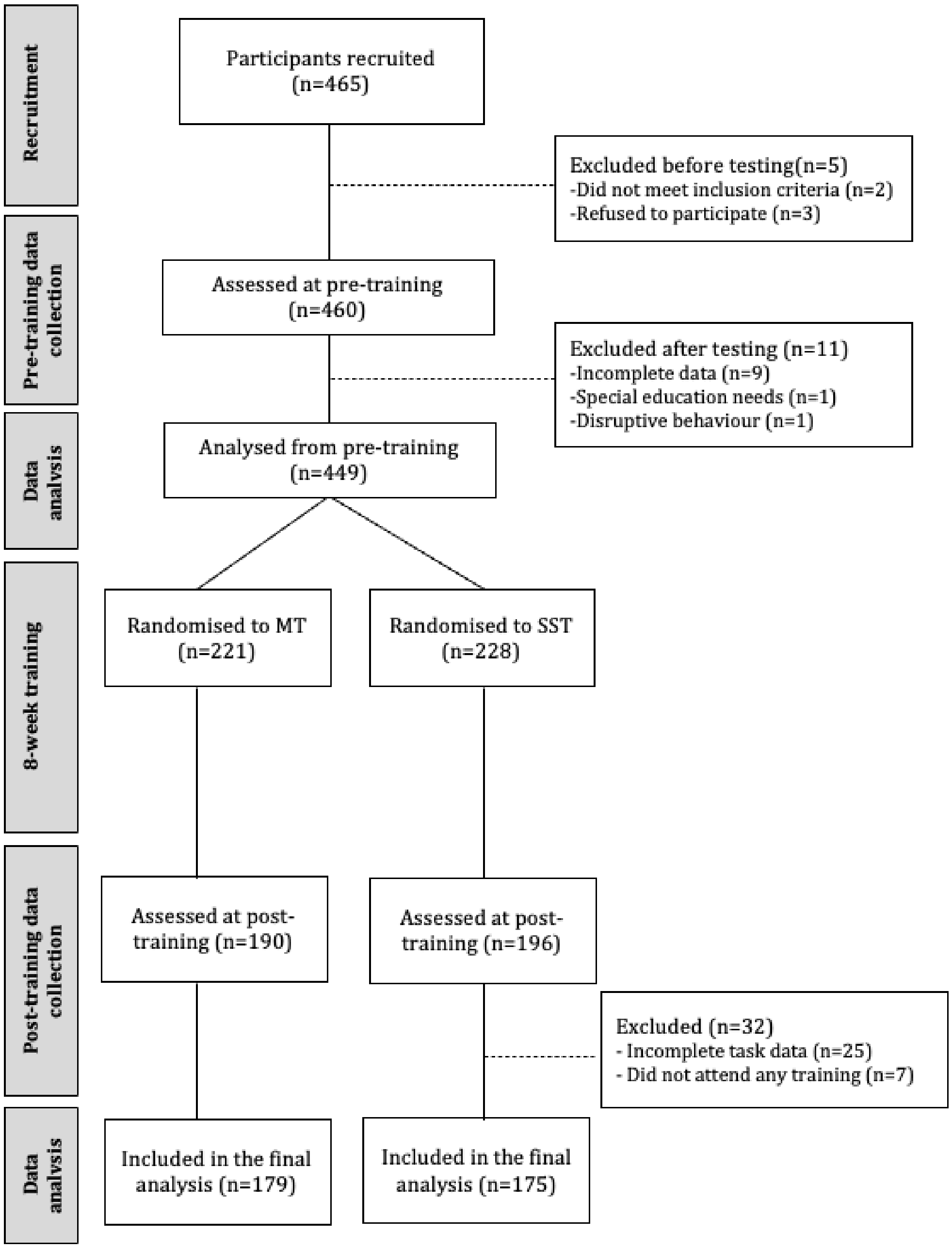

Figure 3.1. CONSORT diagram showing the flow of participants through each stage of the study. Participants were split into two groups after the pre-training data collection session; one group received MT, and the other group received SST.

3.2.3 Training

Mindfulness training (MT)

MT was an adapted version of .b (dot-be; MiSP, 2009), which is a 10-week mindfulness course developed by the Mindfulness in Schools Project in the UK for adolescents aged 11-18 years. The MT curriculum was drawn from mindfulness-based stress reduction (MBSR; Kabat-Zinn, 1990) and mindfulness-based cognitive therapy (MBCT; Segal, Williams & Teasdale, 2002), with the aim of enabling adolescents to learn mindfulness skills. The curriculum was adapted from a 10-week course to an 8-week course to allow the training and the pre- and post-training testing sessions to be completed within a single school term.

There were eight lessons: Playing Attention; Taming the Animal Mind; Recognising Worry; Being Here Now; Stepping Back; Befriending the Difficult; Taking in The Good; and Pulling it All Together. Each lesson was 45-mins long and was taught by existing mindfulness teachers who have previously been trained in the MT curriculum. Teachers also attended a two-day workshop where they received additional training on the MT curriculum used in the study.

Control training: Student skills training (SST)

The SST was an adapted version of Student Success Skills (Atlantic Education Consultants, 2013), an 8-week course developed in the USA. SST was designed to help students improve on their academic and social performance by focusing on key cognitive, social and self-management skills. An independent mindfulness instructor reviewed the SST to ensure all elements associated with mindfulness (e.g. breathing exercises or reflecting activities) were removed from the SST. There were eight lessons: Casting Your Net; Get in Formation: Remember Not to Forget; What's the Story; If You've Got Nothing Nice to Say; Together We Can Do So Much; Rewind & Replay Part 1; Rewind & Replay Part 2.

The same teachers (N=13) who delivered the MT curriculum also delivered the SST curriculum. All teachers underwent a two-day training course prior to taking part in the study. The workshop covered the following: an introduction to the research study, the evidence supporting each training programme, good research practice, the adaptation to the MT training used in the study and the SST training programme. The workshop was delivered by members of the research team, an independent mindfulness instructor and staff from the Mindfulness in Schools Project (MiSP). All teachers completed a declaration form for any affiliation with MiSP and Student Success Skills (no potential conflict of interest was declared).

Both training curriculums were matched in terms of duration and level of engagement. Training was delivered once a week in groups of 10-13 participants. Each lesson lasted 45 mins and was delivered in a school classroom, either after school or at an agreed time during the school day. Lessons were taught with presentation slides, which included notes for the teacher, learning objectives and instructions for activities. Participants were asked to complete homework after each lesson for both types of training. Students' training adherence was assessed by their attendance at lessons and the number of homework assignments completed and submitted. The fidelity of the teaching was assessed by recording videos of the lessons. Each training group (10-13 students; training group size included in statistical model; see Supplemental information 1 in the Supplemental Material) had one lesson recorded at random. An independent rater - who was trained in teaching the MT and SST curriculums - rated the videotapes based on adherence to the key elements of each training lesson (see Supplemental information 2 in the Supplemental Material for the assessment criteria). MT received 95.4% adherence and SST received a 94.5% adherence rate. See https://osf.io/6xg59/ for further details regarding the training.

3.2.4 Tasks and measures

Social influence task

The design of the social influence task reported in this study is described in detail elsewhere (see Figure 2.1 in Chapter 2; Ahmed et al., 2020). Participants were presented with 16 randomly selected scenarios (8 prosocial and 8 antisocial) out of the possible 82, each describing a social behaviour (41 prosocial and 41 antisocial). Prosocial scenarios included helping and sharing behaviours towards friends, family, and strangers (e.g., “Give money to charity”, “Help a friend with their schoolwork”). Antisocial scenarios included a range of situations relevant to adolescents, including violation of privacy, indirect and direct aggression, theft and vandalism (e.g., “Make fun of a classmate”, “Talk about a friend behind their back”; see Table S1 in Supplemental Materials for the full list of scenarios).

Participants read the task instructions on the computer screen and completed a practice trial. Each participant then completed 16 trials in a random order. On each trial, participants were shown a short sentence and image depicting either a prosocial or antisocial behaviour (see Figure 2.1 in Chapter 2). They were then asked to rate how likely they would be to engage in that behaviour, by using a computer mouse to move a slider to the left side (Never) or to the right side (Always) on a visual analogue scale. The slider first appeared at a random position on the scale to avoid any consistent anchoring bias and there was no time restriction for participants to respond. The position chosen by the participant was recorded to two decimal places as first-rating (Never = 0.00; Always = 10.00). After making the first rating, participants were shown a rating of the same scenario that was purportedly the average answer provided by other 11-16-years-olds. This rating was in fact a randomly generated number between 2 and 8; this range was used to ensure the number was plausible as an average rating (provided rating). Finally, participants were asked to rate the same scenario again (second-rating). The task was programmed using Cogent 2000 (University College London Laboratory of Neurobiology; http://www.vislab.ucl.ac.uk/cogent_2000.php), and run in MATLAB (version R2015a; Mathworks Inc., Natick MA). At the end of the second testing session, participants were debriefed and informed that the provided ratings were in fact computer generated.

3.2.5 Statistical analysis

Our analyses included two dependent variables. We first analysed *participants' first-rating* (Model 1 for Hypothesis 1). First-ratings ranged from 0 to 10. The second dependent variable was the *change in rating* after observing the 'provided' ratings of others (second-rating – first-rating; Model 2 for Hypotheses 2). Change in rating ranged from -10 to 10. A

positive change in rating value meant that the participant increased their ratings, whereas a negative change in rating value meant the participant decreased their ratings.
The main predictors of interest for Model 1 and Model 2 were social condition (prosocial, antisocial), testing session (pre-training, post-training) and training group (MT, SST). In addition, we expected that the change in rating would vary as a function of the discrepancy between the first-rating and the provided-rating, as social influence is proportional to the distance between one's baseline behaviour and the decisions of others (Chierchia et al., 2020; Foulkes et al., 2018; Knoll et el., 2015; Moutoussis et al., 2016). We therefore estimated this discrepancy by calculating a *delta rating* score (i.e. the difference between the provided-rating and first-rating) and included this as a main predictor for Model 2. Finally, Model 2 also included the *direction of the delta rating* (higher, lower) to decipher effects of increasing or decreasing prosocial and antisocial influence.

Raw trial-level data were modelled using linear mixed models with the lme4 package (Bates et al., 2015) in the R programming environment (R Core Team, 2013). Best fitting models for each variable were determined through nested model comparison using the same package. The best fitting Model 1 was one that predicted first-ratings from social condition only. The best fitting Model 2 was one that predicted change in rating from the interaction between the delta rating score, the direction of the delta rating and the social condition; the interaction between the delta rating score, the social condition, and the testing session; as well as main effects and lower-level interactions. As random effects, both Model 1 and Model 2 clustered data by participant (i.e., as random intercepts) and additionally included maximal random slopes for the within-subject factors (Barr et al., 2013). Main effects and interactions were inspected using omnibus Type III Wald χ^2 tests, with planned and post-hoc comparisons performed using the *emmeans* package (Version 1.6.1; Lenth et al., 2018).

Nested model comparisons and model syntaxes

We ran a series of nested model comparisons to find the best fitting model to predict variance in *first ratings* (Model 1) and *change in ratings* (Model 2). We progressively included predictors to a null model for each dependent variable to investigate whether these would improve model fit.

Model 1: First Ratings. We included the predictors in the following order: social condition, testing session and type of training. We found that including social condition predicted first ratings better than a null model not including this term ($\Delta\chi^2(3) = 3580.1$, $p < .001$). Interacting social condition with testing session did not improve the model fit ($\Delta\chi^2(2) = 1.79$, $p = .408$), and neither did including testing session as a main effect ($\Delta\chi^2(1) = .94$, $p = .332$). This was also the case when interacting social condition with the type of intervention ($\Delta\chi^2(2) = 1.09$, $p = .580$), as well as including this term as a main effect ($\Delta\chi^2(1) = .67$, $p = .413$). Therefore, the best model is one that predicts first ratings from social condition only. Random effects of social condition were clustered by participant as this was the only (within-subjects) predictor included as a fixed effect.

The equation for the best fitting Model 1 is as follows:

$$First\ Rating_i$$
$$= Intercept + \ Random\ Intercept_i$$
$$+(\beta_1 + \ Random\ Slope_{\ 1i})X\ Social\ Condition_i + error_i$$

The R syntax for Model 1 is as follows:

$$First\ Rating \sim Social\ Condition + (Social\ Condition \mid Participant)$$

Model 2: Change in Ratings. We included the predictors in the following order: delta rating, social condition, direction of influence, testing session and type of intervention. Delta rating was included as the first and main predictor of Model 2, and we operationalised social influence as the effect of delta rating on change in rating (see Foulkes et al., 2018; Knoll et al., 2017; 2015). Therefore, all variables were interacted with change in rating, as we were primarily interested in the effect of all predictors on social influence. We found that delta rating predicted change in rating better than a null model ($\Delta\chi^2(1)$ = 1586.1, $p < .001$). Interacting social condition with the delta rating fit better than a model without this interaction ($\Delta\chi^2(4)$ = 497.52, $p < .001$). In addition, interacting the delta rating and social condition with the direction of influence improved model fit ($\Delta\chi^2(7)$ = 848.45, $p < .001$), as well as further interacting these terms with testing session ($\Delta\chi^2(23)$ = 158.07, $p < .001$). Further, interacting delta rating, social condition, direction of influence and testing session with the type of intervention did not improve model fit ($\Delta\chi^2(16)$ = 22.61, $p = .125$), and neither did a model adding the lower-level interaction of type of intervention and delta rating ($\Delta\chi^2(2)$ = 4.10, $p = .129$). For this reason, *type of intervention* was not included as a predictor in Model 2. Finally, a simpler model including the three-way interaction of delta rating, social condition, and direction of influence, as well as the three-way interaction of delta rating, social condition and testing session improved model fit compared to a model including the four-way interaction between these terms ($\Delta\chi^2(4) = 3.20$, $p = .525$), and therefore the simpler model was chosen as the best fitting model for change in rating. The maximal random slopes of the within-subject factors included in the final model (i.e. social condition, testing session and direction of influence; Barr et al., 2013) were the interactions between social condition and testing session, and the interaction between direction of influence and testing session, both clustered by participant.

The equation for the best fitting Model 2 is as follows:

$$
\begin{aligned}
&Change\ in\ Rating_i \\
&= Intercept + \ Random\ Intercept_i + (\beta_1)\ X\ Delta\ Rating_i \\
&+(\beta_2 + Random\ Slope_{2i})\ X\ Social\ Condition_i \\
&+(\beta_3 + Random\ Slope_{3i}) X\ Direction\ of\ Influence_i \\
&+(\beta_4 + Random\ Slope_{4i}) X\ Testing\ Session_i \\
&+(\beta_5)\ X\ Delta\ Rating_i\ X\ Social\ Condition_i \\
&+(\beta_6)\ X\ Delta\ Rating_i\ X\ Direction\ of\ Influence_i \\
&+(\beta_7)\ X\ Social\ Condition_i\ X\ Direction\ of\ Influence_i \\
&+(\beta_8)\ X\ Delta\ Rating_i\ X\ Testing\ Session_i \\
&+(\beta_9 + Random\ Slope_{9i})\ X\ Social\ Condition_i\ X\ Testing\ Session_i \\
&+(Random\ Slope_{10i})\ X\ Direction\ of\ Influence\ _i\ X\ Testing\ Session_i \\
&+(\beta_{11})\ X\ Delta\ Rating_i\ X\ Social\ Conditon_i\ X\ Direction\ of\ Influence_i \\
&+(\beta_{12})\ X\ Delta\ Rating_i\ X\ Social\ Condition_i\ X\ Testing\ Session_i + error_i
\end{aligned}
$$

The R syntax for Model 2 is as follows:

$$
\begin{aligned}
&First\ Rating \sim \\
&Delta\ Rating\ X\ Social\ Condition\ X\ Direction\ of\ Influence \\
&+ Delta\ Rating\ X\ Social\ Condition\ X\ Testing\ Session \\
&+ \left(\begin{matrix} Social\ Condition\ X\ Testing\ Session \\ +Direction\ of\ Influence\ X\ Testing\ Session \end{matrix} \middle| \ Participant \right)
\end{aligned}
$$

Sensitivity analyses. We inspected whether the omnibus effects remained in a number of sensitivity analyses including relevant factors through nested model comparisons. These included participants' age, gender, IQ, training attendance, amount of homework completed, testing group size at both pre- and post-training, average training group size and extreme values for both Model 1 and Model 2. In addition, we also ran a sensitivity analysis for Model 2 accounting for participant first-ratings. IQ was included to account for potential age-related differences in cognitive ability that might affect the outcome variable (Buitelaar et al., 1999; Choudhury et al., 2006; Hirosawa et al., 2020).

3.3 Results

3.3.1 Self-report prosocial and antisocial behaviours (Model 1)

The linear mixed-effects model revealed a significant main effect of social condition on first-ratings ($\chi^2(1) = 572.33$, $p<.001$; see Model 1 output in Table 3.2). Planned contrasts showed that participants produced significantly higher prosocial first-ratings than antisocial first-ratings (contrast $_{\text{Prosocial – Antisocial}}$ = 2.65, SE = .11, $p < .001$; Figure 3.3). Notably, nested model comparisons that included testing session ($\Delta\chi^2(1) = .94$, $p = .332$) and type of intervention ($\Delta\chi^2(1) = .67$, $p = .413$) as additional predictors did not fit better than a model omitting these terms. Therefore, contrary to hypothesis 1, our results found no significant differences in first-ratings post-training for either the MT or the SST.

	X²	***Df***	***p-value***
Intercept	10302.36	1	<0.001
Social Condition	572.33	1	<0.001

Table 3.2. Model 1 output – first ratings

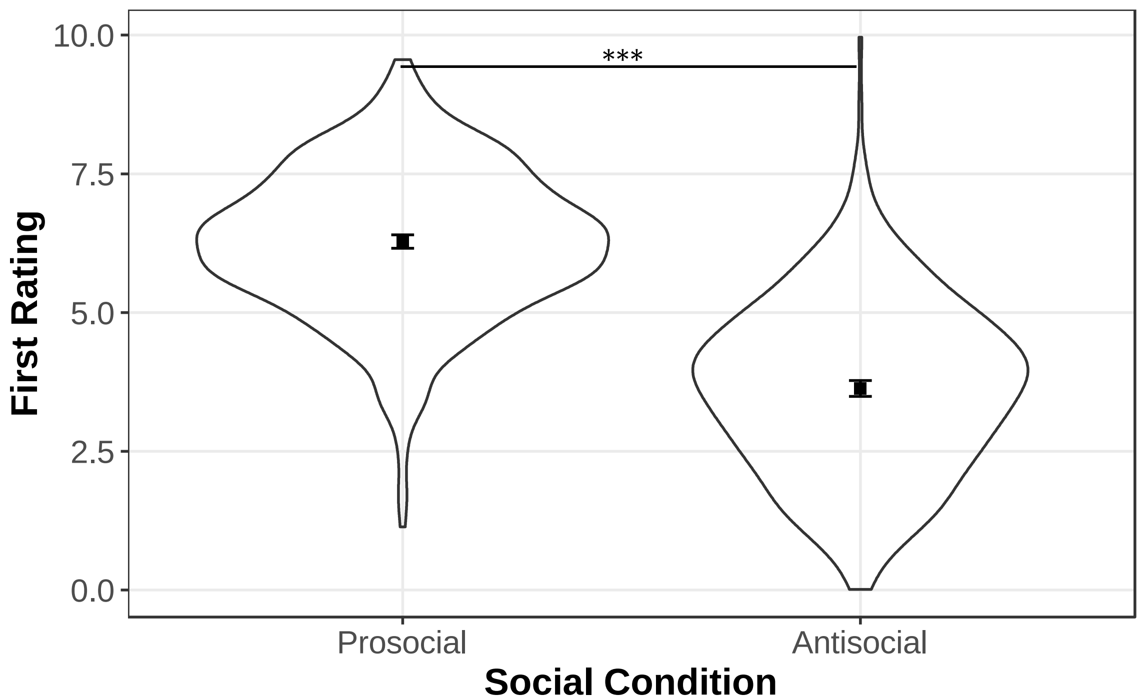

Figure 3.3. Difference in First-ratings between Social Conditions (prosocial, antisocial).

The figure shows higher prosocial first-ratings than antisocial first-ratings. The violin plots represent kernel probability density of first-rating values under the prosocial (blue) and antisocial (orange) conditions. Black squares represent the linear mixed model predicted means and error bars show the corresponding 95% intervals. ***p < .001

Sensitivity analyses

The main effect of social condition on first-ratings was robust to all sensitivity analyses, including age, gender, IQ, number of lessons attended, amount of homework completed, testing group size pre- and post-training, average training size, as well as after the exclusion of extreme values (all *ps* < .001, see Table 3.3 for Model 1 and sensitivity analyses model estimates). A model adjusting for age additionally revealed a significant interaction between age and social condition ($\chi^2(1) = 22.96$, $p < .001$). This was driven by prosocial first-ratings decreasing with age (slope = -.10, SE = .04, $p = .029$), and antisocial first-ratings increasing with age (slope = .28, SE = .05, $p < .001$, see Figure 3.4).

In addition, sensitivity analyses showed an interaction between gender and social condition ($\chi^2(1) = 8.18$, $p = .004$). This was driven by females showing higher prosocial first-ratings ($\text{contrast}_{\text{Female – Male}} = .35$, SE = .12, $p = .007$), and lower antisocial first-ratings ($\text{contrast}_{\text{Female – Male}} = -.32$, SE = .15, $p = .041$), than males (see Figure 3.5). For this reason, we additionally account for social condition in the sensitivity analyses for Model 2 when investigating gender and age differences in social influence.

	Main Model	**CM1)** Main Model + Age	**CM2)** Main Model + Gender	**CM3)** Main Model + IQ	**CM4)** Main Model + Attendance	**CM5)** Main Model + Homework	**CM6)** Main Model + Group Size at T1	**CM7)** Main Model + Group Size at T2	**CM8)** Main Model + Average Training Size	**CM9)** Main Model + Outliers
Intercept	6.28*** (0.06)	7.64*** (0.62)	6.40*** (0.08)	6.64*** (0.26)	6.30*** (0.13)	6.30*** (0.1)	6.67*** (0.24)	6.51*** (0.17)	6.16*** (0.14)	6.28*** (0.06)
Social Condition (Antisocial)	-2.65*** (0.11)	-7.87*** (1.09)	-2.87*** (0.13)	-2.66*** (0.11)	-2.65*** (0.11)	-2.65*** (0.11)	-2.65*** (0.11)	-2.80*** (0.12)	-2.64*** (0.11)	-2.65*** (0.11)
Age		-0.1* (0.04)								
Age x Social Condition (Antisocial)		0.38*** (0.08)								
Gender (Male)			-0.35** (0.13)							
Gender (Male) + Social Condition (Antisocial)			0.66** (0.23)							

IQ	0 (0)					
Attendance		0 (0.02)				
Homework			-0.01 (0.02)			
Group Size at T1				-0.03· (0.02)		
Group Size at T2					-0.01 (0.01)	
Average Training Size						0.01 (0.01)

Table 3.3. Model 1 and CM estimates – first ratings

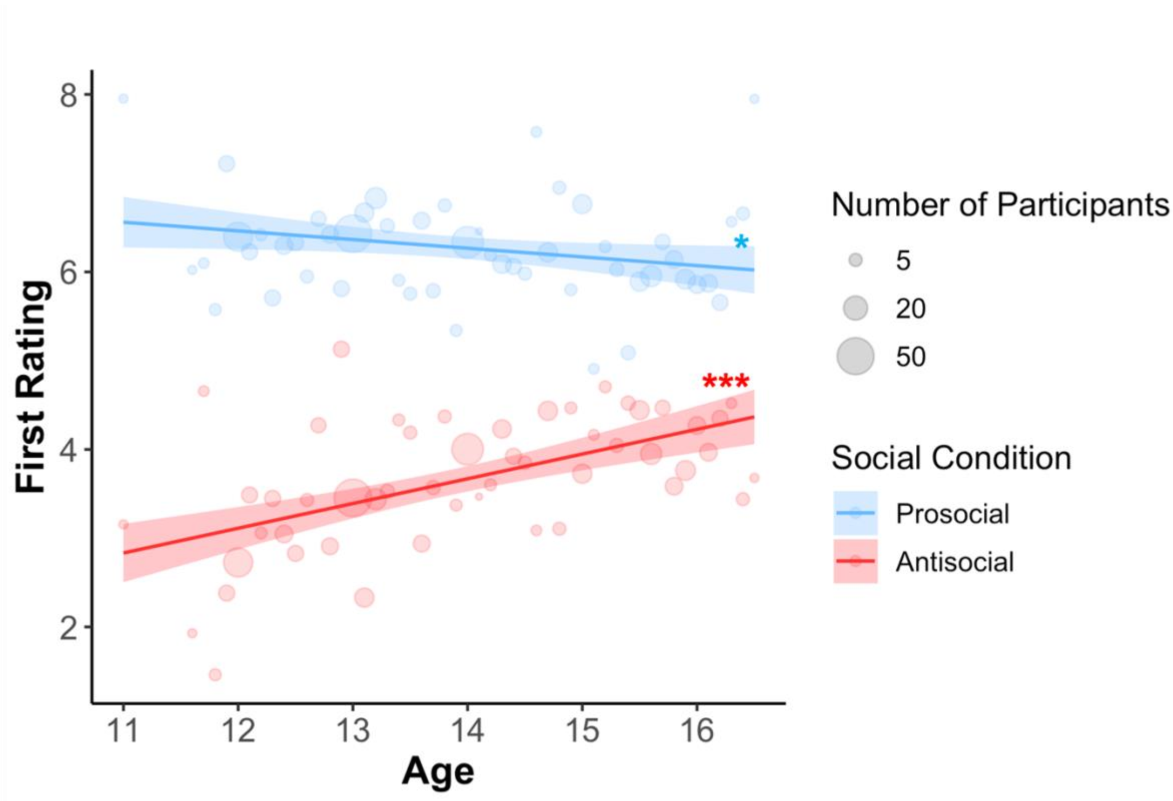

Figure 3.4. Effect of Age and Social Condition on First Ratings. The figure shows mean participant-level first ratings grouped by decimal age (bubbles) across prosocial (blue) and antisocial (red) conditions. The lines show model predicted estimates of age on prosocial (blue) as well as antisocial (red) first ratings and corresponding 95% confidence intervals (shaded area). Antisocial first ratings increase significantly with age, while prosocial ratings decrease significantly with age. *p < .05 ***p < .001

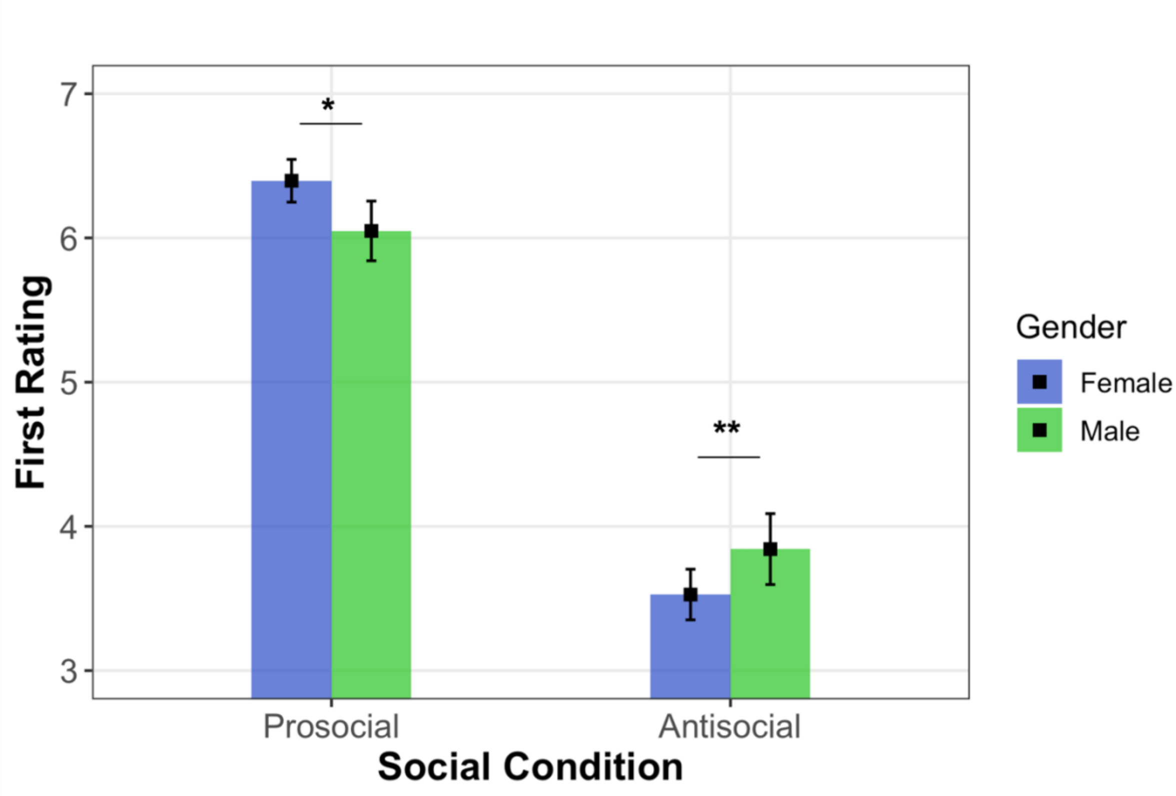

***Figure 3.5. Effect of Gender and Social Condition on First Ratings*.** The figure shows mean first ratings of male (green) and female (blue) participants between social conditions. The squares show model predicted mean estimates of first ratings, by gender and social condition. The error bars represent corresponding 95% confidence intervals. Females show higher mean prosocial first ratings, as well as lower mean antisocial first ratings, than males. Asterisks indicate *$p < .05$ **$p < .01$

3.3.2 Training effects on social influence (Model 2)

The linear mixed-effects model revealed a significant main effect of the delta rating on change in rating ($\chi^2(1) = 122.64$, $p < .001$; see Model 2 output in Table 3.4), such that greater delta ratings were associated with greater change in ratings (slope = .15, SE = .01, $p < .001$). This main effect of delta rating on the change in rating has been previously termed the *social influence effect* (e.g. Foulkes et al., 2018; Knoll et al., 2017, 2015). In addition, there was a significant three-way interaction between delta rating, social condition, and direction of influence ($\chi^2(1) = 36.34$, $p < .001$; Figure 3.6). Post hoc comparisons showed that participants were more socially influenced to increase prosocial ratings than to decrease them ($\text{contrast}_{\text{Higher – Lower}} = .07$, SE = .02, $p < .0001$), as well as to decrease antisocial ratings than to increase them ($\text{contrast}_{\text{Higher – Lower}} = -.07$, SE = .02, $p < .0001$; see all contrast estimates in Table 3.5). This effect was present across both time points and interventions.

	X^2	Df	p-value
Intercept	36.17	1	<0.001
Delta Rating	122.64	1	<0.001
Social Condition	15.12	1	<0.001
Direction of Influence	33.00	1	<0.001
Testing Session	0.08	1	0.777
Delta Rating X Social Condition	11.84	1	<0.001
Delta Rating X Direction of Influence	17.48	1	<0.001
Social Condition X Direction of Influence	2.79	1	0.095
Delta Rating X Testing Session	1.36	1	0.243
Social Condition X Testing Session	0.03	1	0.865
Delta Rating X Social Condition X Direction of Influence	36.34	1	<0.001
Delta Rating X Social Condition X Testing Session	6.57	1	0.010

Table 3.4. Model 2 output – change in rating

Social Condition	***Direction of Influence***	***Delta Rating Estimate***	***SE***	***p-value***
Prosocial	*Higher*	0.15	0.01	<0.001
Prosocial	*Lower*	0.08	0.01	<0.001
Antisocial	*Higher*	0.07	0.01	<0.001
Antisocial	*Lower*	0.15	0.01	<0.001

Table 3.5. Interaction between delta rating, social condition, and direction of influence (model 2) – contrast estimates

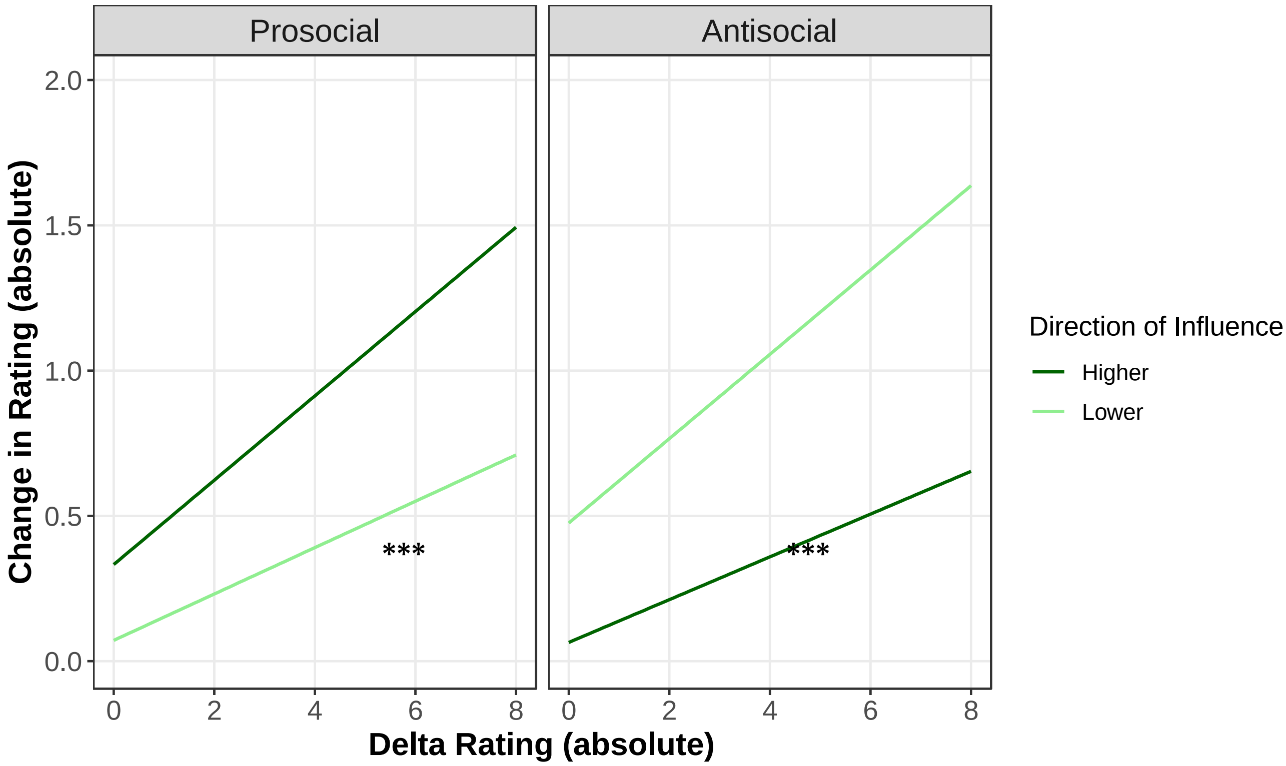

Figure 3.6. Effect of the Direction of Social Influence (higher, lower) in each Social Condition (prosocial, antisocial). The plot shows that participants were more socially influenced to increase prosocial ratings rather than to decrease them (left panel), and to decrease antisocial ratings rather than to increase them (right panel). The lines represent the predicted slopes of social influence from higher delta ratings (dark green) and lower delta ratings (light green). The shaded areas represent 95% confidence intervals. All values have been converted to absolute terms (i.e. multiplied by -1 if negative) for visualisation purposes. *** $p < .001$.

Contrary to hypothesis 2, there was no significant effect of testing session on social influence ($\chi^2(1) = 1.36$, $p = .243$), indicating that there was no overall difference in social influence pre- and post-training, across all conditions. However, there was a significant three-way interaction between delta rating, social condition and testing session ($\chi^2(1) = 6.57$, $p < .010$; Figure 3.7). This suggests that there was a difference in social influence pre- and post-training, and that this depended on the specific social condition, supporting hypothesis 2a. Planned contrasts showed that this effect was driven by a decrease in antisocial influence post-training compared to pre-training ($\text{contrast}_{\text{Pre-training – Post-training}} = .04$, SE = .01, $p < .001$), which was not the case for prosocial influence post-training ($\text{contrast}_{\text{Pre-training – Post-training}} = .01$, SE = .01, $p = .243$; see all contrast estimates in Table 3.6).

Nested model comparisons showed that including intervention type as an additional predictor in this model did not fit better than a model omitting this term ($\Delta\chi^2(2) = 4.10$, $p = .129$). Therefore, contrary to Hypothesis 2b, the results did not show significant differences between mindfulness training and control training on social influence effects.

Social Condition	***Testing Session***	***Delta Rating Estimate***	***SE***	***p-value***
Prosocial	*Pre-Training*	0.12	0.01	<0.001
Prosocial	*Post-Training*	0.11	0.01	<0.001
Antisocial	*Pre-Training*	0.13	0.01	<0.001
Antisocial	*Post-Training*	0.09	0.01	<0.001

Table 3.6. Interaction between delta rating, social condition, and testing session (model 2) – contrast estimates

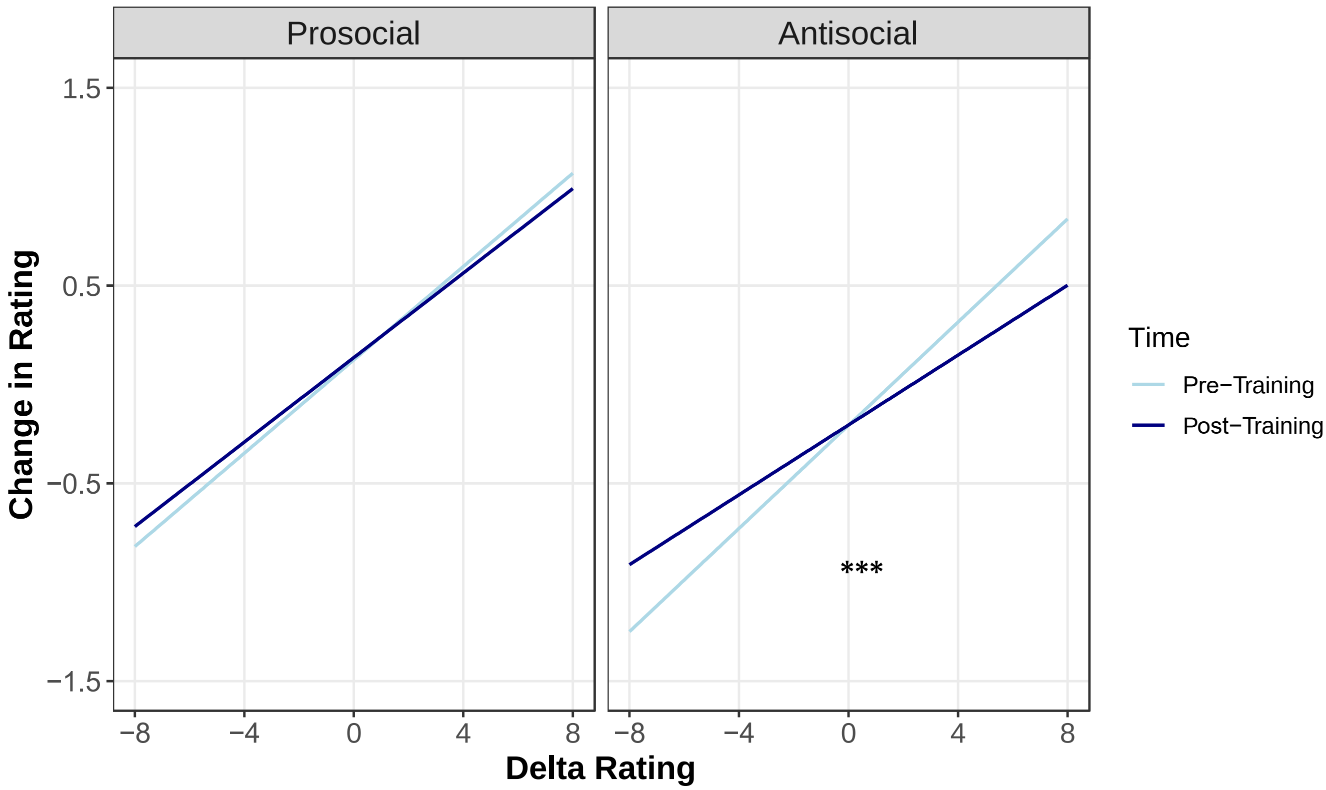

Figure 3.7. Difference in Social Influence between Testing Sessions (pre-training, post-training) in each Social Condition (prosocial, antisocial). The plot shows a significant decrease in social influence at post-training relative to pre-training for the antisocial condition (right panel), and no significant difference in social influence pre- and post-training for the prosocial condition (left panel). Lines represent the predicted slopes of social influence pre-training (light blue) and post-training (dark blue) and shaded areas represent 95% confidence intervals. *** $p < .001$.

Sensitivity analyses

All effects of interest were maintained after adjusting for the relevant factors, including age, gender, IQ, participant first-ratings, number of lessons attended, amount of homework completed, testing group size pre- and post-training, average training size, as well as the exclusion of extreme values (see Model 2 and sensitivity analyses model estimates in Table 3.7). Both the interaction between delta rating, social condition and direction of influence, and the interaction between delta rating, social condition and testing session, were robust to all sensitivity analyses. This included models accounting for age and gender differences in social influence between the prosocial and antisocial conditions, both of which were flagged during sensitivity analyses for Model 1 (see relevant section above). These models additionally suggested significant gender differences ($\chi 2(1) = 4.87$, $p = .027$), and this was driven by females being less socially influenced by antisocial ratings than males (contrast $_{\text{Females – Males}}$ = - .02, SE = .01, $p = .022$; see Figure 3.8).

	Main Model	**CM1)** Main Model + Age	**CM2)** Main Model + Gender	**CM3)** Main Model + IQ	**CM4)** Main Model + Attendance	**CM5)** Main Model + Homework	**CM6)** Main Model + Group Size at T1	**CM7)** Main Model + Group Size at T2	**CM8)** Main Model + Average Training Size	**CM9)** Main Model + Outliers	**CM10)** Main Model + First Rating
Intercept	0.33***	0.33***	0.33***	0.32***	0.33***	0.33***	0.33***	0.35***	0.33***	0.40***	0.32***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.05)	(0.04)	(0.06)
Delta Rating	0.15***	0.25***	0.15***	0.28***	0.17***	0.17***	0.16***	0.17***	0.15***	0.08***	0.15***
	(0.01)	(0.05)	(0.01)	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)	(0.01)
Social Condition (Antisocial)	-0.26***	-0.26***	-0.26***	-0.26***	-0.26***	-0.26***	-0.26***	-0.31***	-0.26***	-0.30***	-0.26***
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.05)	(0.07)
Direction of Influence (Lower)	-0.40***	-0.41***	-0.40***	-0.41***	-0.40***	-0.40***	-0.40***	-0.41***	-0.40***	-0.52***	-0.40***
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.06)	(0.07)
Testing Session (Post-Training)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.01	0.01	0.01	0.01
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)
Delta Rating x Social Condition (Antisocial)	-0.06***	-0.06	-0.06***	-0.05**	-0.06***	-0.06***	-0.06***	-0.06**	-0.06***	-0.01	-0.06***
	(0.02)	(0.06)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)
Delta Rating x Direction of	-0.07***	-0.07***	-0.07***	-0.07***	-0.07***	-0.06***	-0.07***	-0.06***	-0.07***	-0.02	-0.08***

Influence (Lower)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)
Social Condition (Antisocial) x Direction of Influence (Lower)	-0.14· (0.08)	-0.13 (0.08)	-0.14· (0.08)	-0.13 (0.08)	-0.14· (0.08)	-0.14· (0.08)	-0.14· (0.08)	-0.09 (0.09)	-0.14· (0.08)	-0.08 (0.07)	-0.14· (0.08)
Delta Rating x Testing Session (Post-Training)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.02 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)
Testing Session (Post-Training) x Social Condition (Antisocial)	-0.01 (0.06)	-0.01 (0.06)	-0.01 (0.06)	-0.02 (0.06)	-0.01 (0.06)	-0.01 (0.06)	-0.01· (0.06)	0.03 (0.06)	-0.01 (0.06)	-0.02 (0.04)	-0.01 (0.06)
Delta Rating x Social Condition (Antisocial) x Direction of Influence (Lower)	0.14*** (0.02)	0.14*** (0.02)	0.14*** (0.02)	0.13*** (0.02)	0.14*** (0.02)	0.14*** (0.02)	0.14*** (0.02)	0.15*** (0.02)	0.14*** (0.02)	0.05** (0.02)	0.14*** (0.02)
Delta Rating x Testing	-0.03*	-0.03*	-0.03**	-0.03**	-0.03*	-0.03*	-0.03*	-0.03*	-0.03*	-0.02*	-0.03*

Session (Post-Training) x Social Condition (Antisocial)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Delta Rating x Age		-0.01* (0)									
Delta Rating x Age x Social Condition (Antisocial)		0 (0)									
Delta Rating x Gender (Male)			0 (0.01)								
Delta Rating x Gender (Male) x Social Condition (Antisocial)			0 (0.01)								
Delta Rating x IQ				-0.003*** (0)							

Delta Rating x Attendance					0 (0)						
Delta Rating x Homework						0· (0)					
Delta Rating x Group Size at T1							0 (0)				
Delta Rating x Group Size at T2								0 (0)			
Delta Rating x Average Training Size									0 (0)		
Delta Rating x First Rating											0 (0)

Table 3.7. Model 2 and CM estimates – change in rating

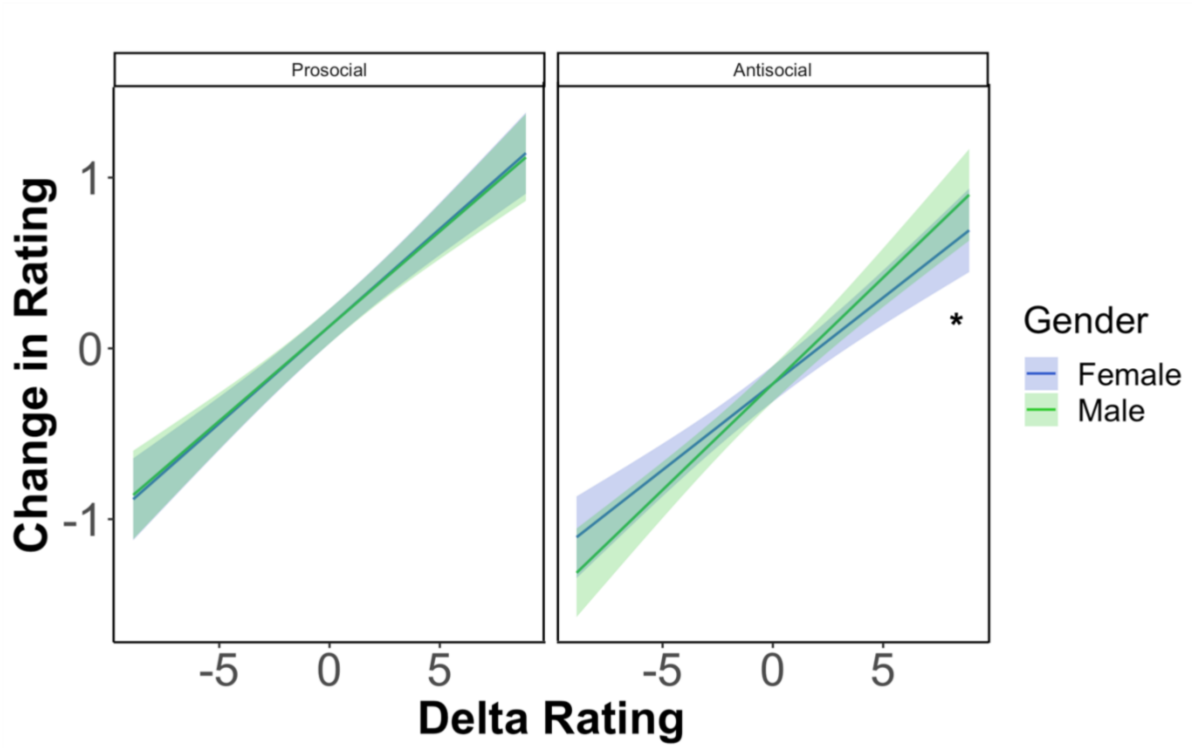

Figure 3.8 Effect of Gender and Social Condition on Social Influence. The figure shows differences in model predicted change in rating as a function of delta rating between males (green) and females (blue) and corresponding 95% confidence intervals (shaded area), separately by the prosocial (left panel) and antisocial (right panel) conditions. Female participants show less susceptibility to antisocial influence than males. Asterisks indicate $^*p < .05$

There were no significant age differences in social influence between social conditions ($\chi2(1) = .01$, $p = .933$). However, there was an effect of age ($\chi2(1) = 3.90$, $p = .049$), as well as an effect of IQ ($\chi2(1) = 25.39$, $p < .001$), on social influence. Older participants and participants with a higher IQ were less socially influenced across both social conditions and time points (slope $_{age}$ = - .007, SE = 3.54e^{-3}, $p = .049$; slope $_{IQ}$ = -.001, SE = 2.33e^{-4}, $p < .001$; see Figure 3.9 and Figure 3.10).

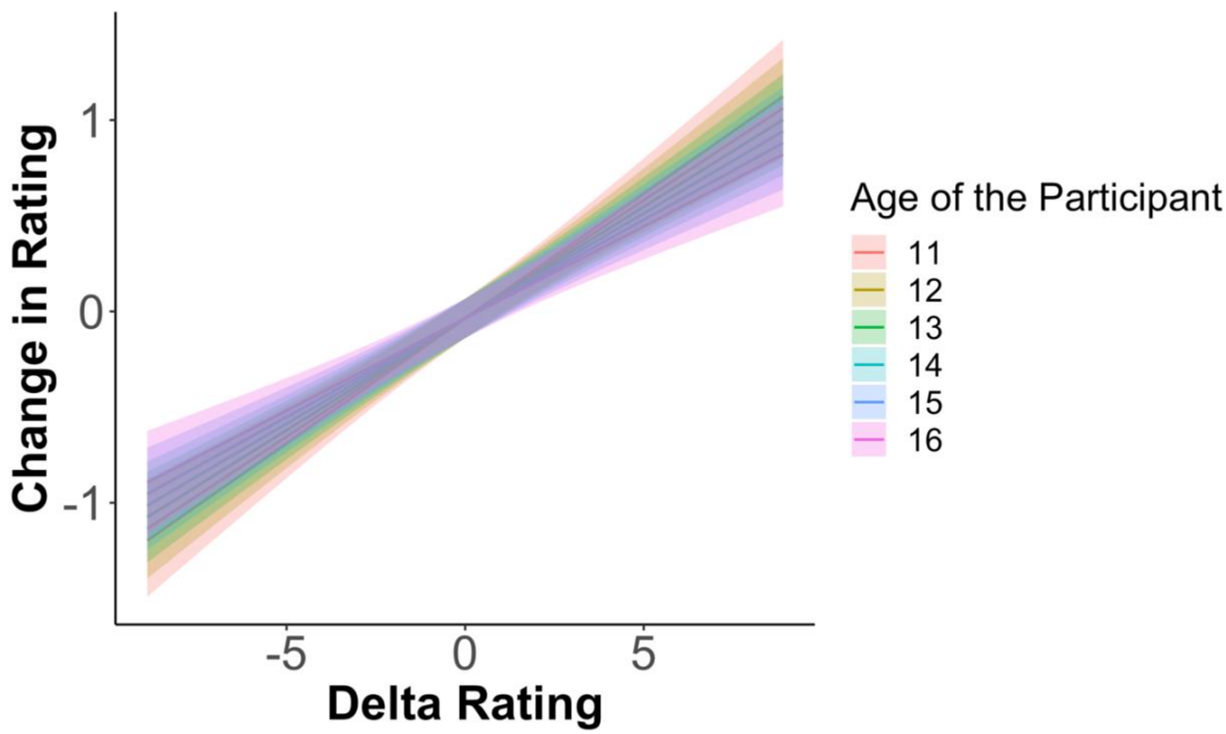

Figure 3.9. Effect of Age on Social Influence. The figure shows age differences in model predicted change in rating as a function of delta rating. Each colour represents an age group (11-16), and each line represents age-specific slopes of change in rating as a function of delta rating. Younger participants show a stronger effect of delta rating on change in rating, as indicated by a steeper slope (red, yellow, and green). As age progressively

increases, the slope becomes flatter (blues and pink), indicating a smaller effect of delta rating on change in rating.

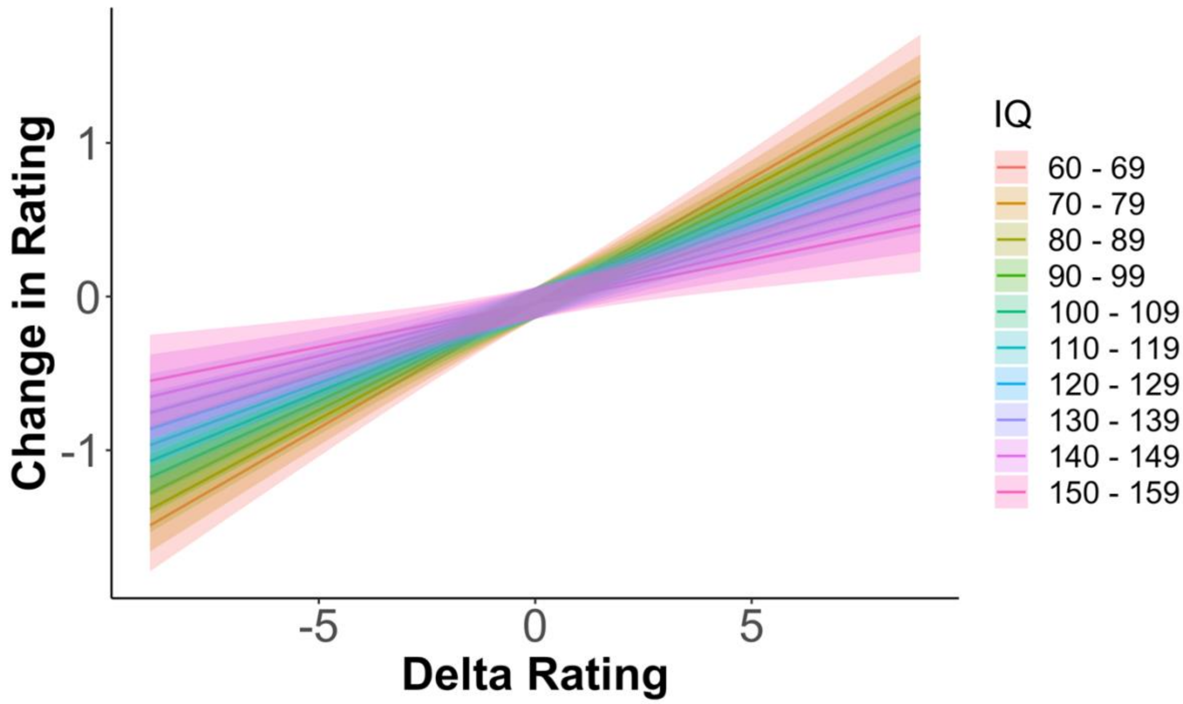

Figure 3.10. Effect of IQ on Social Influence. The figure shows IQ differences in model predicted change in rating as a function of delta rating. Each colour represents an IQ interval (60-159; 10 intervals), and each line represents IQ interval-specific slopes of change in rating as a function of delta rating. Participants with a lower IQ show a stronger effect of delta rating on change in rating, as indicated by a steeper slope (red, orange, and yellow). As IQ progressively increases, the slope becomes flatter (purple and pinks), indicating a smaller effect of delta rating on change in rating.

3.4 Discussion

The aim of the current study was to examine whether mindfulness training specifically, compared with an active control, was associated with a change in the self-reported likelihood of engaging in prosocial and antisocial behaviours and susceptibility to prosocial and antisocial influence. We found that participants' prosocial tendencies were higher than their antisocial tendencies at both time points. In addition, participants were more socially influenced to increase prosocial ratings than to decrease them, and more socially influenced to decrease antisocial ratings than to increase them at both time points. Despite previous studies demonstrating the beneficial effects of mindfulness on adolescents' prosocial and antisocial behaviours (Bögels et al., 2008; Donald et al., 2019; Franco et al., 2016; Cheung et al., 2019), we did not find any significant differences in prosocial or antisocial behaviour (first-ratings) following an 8-week mindfulness training programme (or after the control training programme; hypothesis 1). We also found no unique effect of mindfulness (vs. control) training on susceptibility to social influence (hypothesis 2). Instead, participants were less influenced by antisocial, but not prosocial, ratings after *both* training programmes.

Contrary to hypothesis 1, there was no significant change in prosocial and antisocial behaviour following MT, relative to the SST. This is in line with a meta-analysis that found that, while negative behaviour (e.g. aggression and hostility) was reduced by mindfulness training in studies including a passive control group only, this was not the case for studies that included an active control group (Dunning et al., 2018). However, this meta-analysis found an effect of age, whereby younger children showed greater improvements than older children and adolescents following mindfulness-based interventions. Given that we used nested model comparisons, we did not look at age differences in the null effect of mindfulness on prosocial and antisocial behaviour. Furthermore, the age range included in our sample (11 to 16 years) differed from the samples included in the meta-analysis (mean ages ranging from 4.7 to 17.4 years).

A second aim of the current study was to investigate the impact of mindfulness training on social influence in adolescence. Importantly, before discussing mindfulness training effects on social influence, our results support previously reported findings on social influence during adolescence. To begin, we found that participants revised their ratings to a greater extent as these became increasingly discrepant from observed ratings (i.e. greater delta ratings). This social influence effect is in line with previous studies showing that adolescents are influenced by others' endorsements of prosocial behaviours (Choukas-Bradley et al., 2015; van Hoorn et al., 2016) and antisocial behaviours (Monahan et al., 2009; Sijtsema & Lindenberg, 2018), and that this social influence effect is stronger when there is a greater disparity between participants' initial responses and others' responses (Chierchia et al., 2020; Foulkes et al., 2018; Knoll et al., 2017). While the social influence effect was still present after accounting for age and IQ, we found that older participants and participants with a higher IQ score were less susceptible to social influence, which replicates previous findings (Chierchia et al., 2020; Foulkes et al., 2018; Knoll et al., 2015, 2017).

In addition, we also found that the social influence effect was stronger for positive influence than for negative influence. This means that participants were more socially influenced to increase prosocial ratings than to decrease them, as well as to decrease antisocial ratings than to increase them. This suggests that adolescents conform to a greater extent to become more prosocial than more antisocial when presented with information about other people's ratings. This finding builds on recent work suggesting that adolescents are more likely to conform when their parents and peers endorse positive attitudes and resist conformity when they endorse negative ones (Do et al., 2020). In line with previously observed gender differences in prosocial and antisocial behaviours (Burt, Slawinski & Klump, 2018; for reviews, see Sutter et al., 2019; Van der Graaff et al., 2018), females had lower antisocial and higher prosocial first-ratings than males. We also found that females were less socially influenced by antisocial ratings than males. While this finding that emerged from the sensitivity analyses was not part of our main hypotheses, it is in line with a school-based study which, using self-report and peer nominations of antisocial behaviour, found that girls who were characterised by consistently elevated levels of antisocial behaviour were less affected by deviant peers than boys (Van Lier et al., 2005). These sensitivity analyses highlight the importance of considering gender when investigating prosocial and antisocial decision-making during adolescence.

To investigate the impact of mindfulness training in reducing antisocial and prosocial influence, the current study compared the effectiveness of mindfulness training and a control training programme in a sample of adolescents. We hypothesised that MT would have had an impact on susceptibility to both types of social influence *(hypothesis 2)*. We found that participants were less influenced by antisocial, but not prosocial, ratings following mindfulness training *(hypothesis 2a).* However, this was also true for SST training, and therefore the effect of MT was not significantly different from the active control training *(hypothesis 2b)*.

We expected mindfulness training to have a greater impact on social influence than an active control training as it has been previously correlated with executive processes, especially self-control (Elkins-Brown et al., 2017; Masicampo & Baumeister, 2007). However, contrary to literature on the role of self-control in decreasing susceptibility to social influence (Meldrum, Miller & Flexon, 2013), our results suggest that mindfulness training might not impact social influence through a mechanism that is distinct to other types of socioemotional training. Rather, it is possible that the observed decrease in influence in the antisocial condition is driven by common elements in both training programmes. For example, both training programmes focus on building self-esteem and cultivating kindness and gratitude, which are associated with less antisocial behaviour (Bono et al., 2019; Donnellan et al., 2005; Gao et al., 2020). It is possible that cultivating kindness, gratitude and increasing self-esteem as a result of undergoing one or the other of the programmes led to a reduction in social influence in the antisocial condition.

Given that a passive no-training control group was not included in this study, we cannot exclude possibilities of potential confounds. One possible confound is age, and previous research on social influence suggests that susceptibility to both prosocial and antisocial influence decreases with age across adolescence (Foulkes et al., 2018; Knoll et al., 2015, 2017). Therefore, the reduction in influence in the antisocial condition observed pre- and post-training could be due to the increase in age over the weeks between the two testing sessions. However, this seems unlikely for two reasons. First, there is no evidence that age-related changes in social influence can occur over such a short time-period (9-10 weeks). Second, there is no evidence from other studies, or in our baseline data (Ahmed et al., 2020), that increasing age is associated with a change in antisocial influence more than prosocial influence. A second explanation for the reduction of influence in antisocial ratings pre- to post-training is an effect of practise as participants become more familiar with the task. To our knowledge, no previous studies have investigated changes in susceptibility to social influence over a short period (in any age group). In addition, as above, this would not explain the asymmetry in the results as practise or carry-over effects might be expected to affect prosocial as well as antisocial influence.

3.5 Conclusion

The present study compared the effect of mindfulness training with a control student skills training programme on adolescents' susceptibility to prosocial and antisocial influence. We found that participants were less influenced by antisocial, but not prosocial, ratings following both training programmes. This result highlights the importance of considering the type of social behaviours (whether behaviours are prosocial or antisocial) when understanding social influence during adolescence. However, it is important to note that the basis of this change cannot be discerned without including a no-training control group. Future studies should investigate whether and how social-emotional training interventions might be effective at reducing susceptibility to antisocial influence in adolescence.

In the next chapter, I describe a study that employed a different type of affective control training to investigate whether improving affective control through a computerized affective control training app would benefit adolescent mental health.

CHAPTER 4: THE EFFECTIVENESS OF AFFECTIVE CONTROL TRAINING IN ADOLESCENCE

The study presented in this chapter has been submitted to peer review journal and is currently under review: Schweizer, S*, **Leung, T.J.*,** Trender, W., Kievit, R., Hampshire, A. and Blakemore, S-J. (submitted). Changes in Affective Control Covary with Changes in Mental Health Difficulties Following Affective Control Training (AffeCT) in Adolescents.

4.1 Introduction

The previous chapter described a study that compared the effect of mindfulness training with a control student skills training programme on adolescents' susceptibility to prosocial and antisocial influence. The present chapter describes a study that tested whether an app-based affective control training programme benefits adolescents' mental health.

Negative and positive affective states are more labile during adolescence (10–24 years; Sawyer et al., 2018) compared with in adulthood (Bailen et al., 2019; Green et al., 2021; Griffith et al., 2021). Dysregulated affect is a core characteristic of common mental health disorders, including depressive and anxiety disorders. Regulation of affective states depends on the deployment of situationally appropriate emotion regulation strategies (Silvers & Guassi Moreira, 2019). The ability to select adaptive regulatory strategies depending on contextual demands (e.g., engaging in reappraisal of a situation when it is not changeable) relies on affective control. Affective control refers to the application of cognitive control in affective contexts, which is the capacity to inhibit affective information that is in conflict with current goals whilst attending and responding to goal relevant environmental and internal inputs (Schweizer et al., 2020). Affective control is still developing during adolescence (Aïte et al., 2018) and might constitute a promising target for prevention and early intervention (Schweizer, Gotlib, et al., 2020). Here, we explore the preventative potential of affective control training for reducing mental health symptoms in adolescents.

Computerized affective control training has been shown to improve emotion regulation capacity and mood in healthy and clinical adult samples (Krause-Utz et al., 2020; Lotfi et al., 2021; Pan et al., 2020; Veloso & Ty, 2021). Neuroimaging evidence has shown that these training-related affective benefits are associated with increased recruitment of the cognitive control network, particularly the ventrolateral node (Schweizer et al., 2013). This region, the inferior frontal gyrus of the ventrolateral prefrontal cortex, is recruited more frequently during affective control when compared with neutral (cool) cognitive control (Schweizer et al., 2019). The cognitive control network develops throughout adolescence, with the inferior frontal gyrus being one of the structures to show the latest structural maturation (Dong et al., 2021). Training affective control during adolescence might be especially advantageous as brain development is experience-dependent (Frankenhuis & Walasek, 2020). Training could offer additional opportunities to apply affective control during a stage when this capacity and its underlying neural substrates are still developing.

Before discussing the affective control training used in the current study, it should be noted that 'cool' cognitive control training, where cognitive control is trained on valence-neutral tasks (including digits, letters, and other valence neutral stimuli), has also been shown to benefit mental health in both adolescents and adults. For example, working memory training (with no affective component) was shown to reduce the onset of depressive symptoms in a school-based sample of adolescents (Beloe & Derakshan, 2020). Research with adults has shown that cognitive control training improves both negative affect and affect regulation (Calkins et al., 2015; Hoorelbeke et al., 2016; Onraedt & Koster, 2014;). Considering the efficacy of cool cognitive training, is there a need to train affective control?

Preliminary evidence suggest so: Affective control has been shown to be uniquely – that is, over and above cool cognitive control – associated with clinical endpoints that are central to the onset, relapse and maintenance of depression in young people, such as rumination (Hilt et al., 2017; Hilt & Pollak, 2013). Training affective control, therefore, may confer benefits to mental health over and above those observed for cool cognitive control interventions.

In the present study we trialled AffeCT (Schweizer et al., 2022), which trains affective control on an affective working memory task. The training requires participants to continuously update affective information (words and faces) in working memory. AffeCT includes three tasks. These include two single modality (separate auditory and visuospatial) *n*-back tasks as well as one dual *n*-back task in which the two modalities have to be attended to simultaneously. The *n*-back paradigm requires individuals to indicate whether the current stimuli they are seeing and/or hearing are the same as those presented a specified number of trials ago (i.e., *n*-back). Together, these AffeCT tasks train engagement with task-relevant affective information (auditory modality) and disengagement from task-irrelevant affective properties (visuospatial modality), or both.

To evaluate the efficacy of affective control training in improving our clinical outcomes of interest (mental health, affect and emotion regulation), we adopted the 'Science of Behaviour Change framework' experimental medicine approach (Nielsen et al., 2018). The premise of the framework is to evaluate interventions by identifying a target mechanism, in this case affective control, and investigate whether change in the target mechanism drives change in the clinical outcome of interest. To this end, a reliable assay of the target mechanism is required. Like cognitive control, affective control has different facets: affective inhibition, affective shifting and affective working memory (Schweizer et al., 2020). Any training that successfully improves affective control might lead to improvements in any, or all, of the facets of affective control. The present study therefore included a multifaceted assessment of affective control, including the affective backward digit span task (Schweizer et al., 2019) as a measure of affective working memory updating, the affective Stroop task as a measure of affective inhibition (Preston & Stansfield, 2008), and the affective card sorting task (Schweizer et al., 2020) as a measure of affective shifting. In addition to examining the effect of training on each facet separately, we examined the structure of affective control in this sample to extract a meaningful assay of affective control. This index of affective control is essential to test whether any improvements in the clinical outcomes of interest vary as a function of changes in the index of affective control. As per protocol (Schweizer, Leung, et al., 2019), we predicted that performance on these affective control tasks would dissociate into separable affective control and cognitive control factors. This bi-factorial model was compared to a single factor model, which would indicate that there is no difference between affective control applied in affective or neutral contexts.

Pre- to post-training changes on these indices of affective control were compared between the AffeCT group and a group undergoing placebo training (Placebo). The Placebo group received the same narrative regarding the potential benefits of training on mental well-being and affect regulation. Placebo training was included to control for any effects of engaging repeatedly in a computerized cognitive training activity purported to benefit well-being and emotion regulation.

This design allowed us to test the following pre-registered hypotheses: *Affective control training hypothesis (H1):* affective control can be improved in adolescents. To examine the first hypothesis, we compared pre- to post-training affective *n*-back performance across the two training groups. *Affective control facets hypothesis (H2):* Compared to Placebo, AffeCT would lead to greater improvements in all facets of affective control. To investigate this hypothesis, changes in performance on the affective transfer tasks were compared between the training groups. *Age-related change hypothesis (H3):* Training-related changes in affective control would vary as a function of age. *Mental health hypothesis (H4):* Improved affective control from pre- to post-training would be associated with fewer self-reported mental health problems, emotion regulation difficulties and self-control ability.

4.2 Methods

4.2.1 Participants

242 participants aged 11-19 years old were recruited from 11 schools from Greater London, as well as through advertisements at University College London and the University of New South Wales. 43 participants were excluded due to technical issues or not meeting inclusion criteria: for details, see the participant inclusion flowchart in Figure 4.1. The final sample included 199 participants (159 female, mean age = 14.32, SD = 2.31, see Table 4.1 in the result section for participant characteristics) who were randomized to one of the two

training groups: Affective Control Training (AffeCT; n = 101), and Active Control Training (Control; n = 98). Training allocation was based on a computer-generated condition assignment (using Sealed Envelope simple randomisation service) stratified by age (young adolescents 11–14 years and mid-late adolescents 15–19 years).

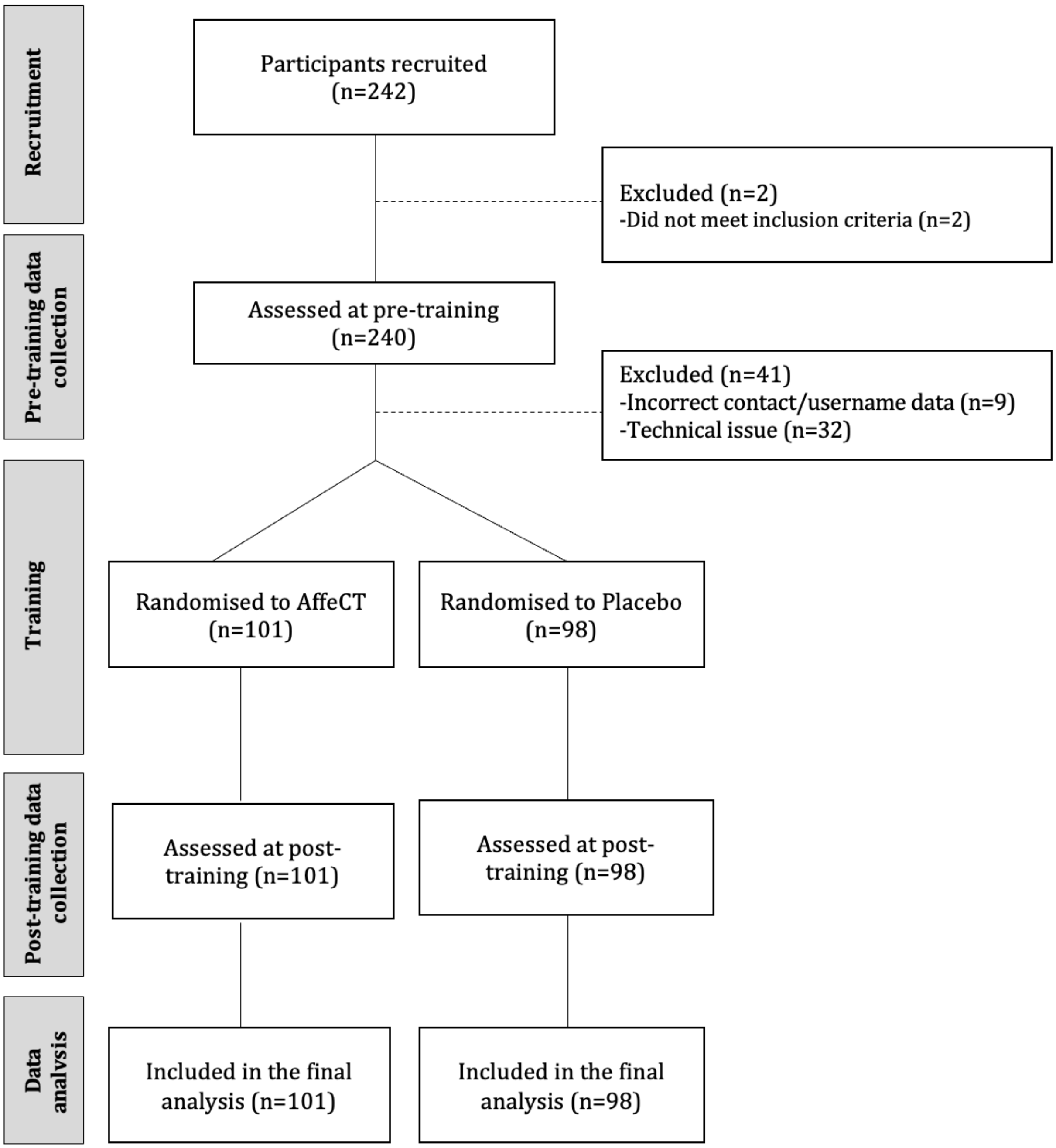

Figure 4.1. Participant flow chart

The study was approved by the University College London [Ref: 12753/002] and University of New South Wales' Research Ethics Committees [HC3231]. Informed consent was obtained from parents if the participant was under 18 years and from participants aged 18 or over; participants under 18 also provided informed assent. Participants were compensated £10 for each pre- and post-training testing session, £2 per completed training day (up to £5 per day if they completed more than one training session in a single day), and £5 for both online follow-up sessions.

4.2.2 Testing procedure

The pre- and post-training sessions each lasted 1.5 hours and took place at the school or in the research lab in groups between 2 to 42 participants (with 1-4 researchers in each session). During each session, participants completed a range of cognitive tasks and questionnaires. The tasks were hosted on an online platform developed by Cognitron (https://www.cognitron.co.uk) and questionnaires were completed online using Qualtrics (https://www.qualtrics.com). Standardised instructions were given by the researcher at the beginning of the session to the entire group and the instructions for each task were also presented on screen at the beginning of that specific task. After the pre-training session, participants were randomly allocated to the AffeCT or Placebo groups. Participants were asked to complete 14 days of online training within a 4-week period. Training was completed individually on the participant's own device (smartphone or tablet) in any place and at any time that suited them, though they were asked to seek a quiet space with few distractions to complete the training. Researchers involved in the post-training sessions were blinded to the participants' training group allocation. Online follow-up questionnaires were emailed to the participants at one-month and one-year after the post-training session.

4.2.3 Training procedure

During the training period, participants from both training groups were presented with three versions of the training task (versions A-C, see below for details). Participants were asked to complete a different version of the task each day for the first three days, in a fixed presentation order. From the fourth day onwards, participants were free to choose any version of the training tasks. Participants in both training groups (AffeCT and placebo) were told that they should spend as much time as possible training on version C due to its benefits to attention, memory, and emotion regulation. However, to maximise engagement in the training we offered the option to continue engaging in the single span training versions only. The ratio of participants' engagement with the dual I and single (A and B) training versions was recorded to include as covariate if it differed between the groups. The full training session took between 20-30 mins, depending on the levels achieved. Participants were given the option to end the training after 10 mins. Training sessions under 10 mins were not considered as a full training session and were not included in the analyses (452 training sessions out of 2,314 sessions were excluded for this reason).

Participants received a daily training reminder at 8am. Those who did not complete the training by 5pm received an additional reminder.

4.2.4 Tasks and measures

Affective control training task. AffeCT consisted of a visuospatial (A), auditory (B), and dual (including both modalities; C) version of the *n*-back task. Across all three versions of the task, stimuli were presented on a 4 x 4 grid and/or over headphones. Participants had to respond via a “Match” or “No match” button press to indicate if the stimuli matched the corresponding stimuli presented *n* trials back. The first three days of the training started at *n* = 1, and from day 4 onwards the training started at the average level achieved in the previous training session. Difficulty level increased across training blocks within a session if performance accuracy reached 70% and above, and it decreased if performance accuracy was 30% or below. Feedback was provided after each response, with a red border around the grid for false alarms (pressing “Match” on non-target trials) or misses (pressing “No match” on target trials or no response), and a green border for correct trials.

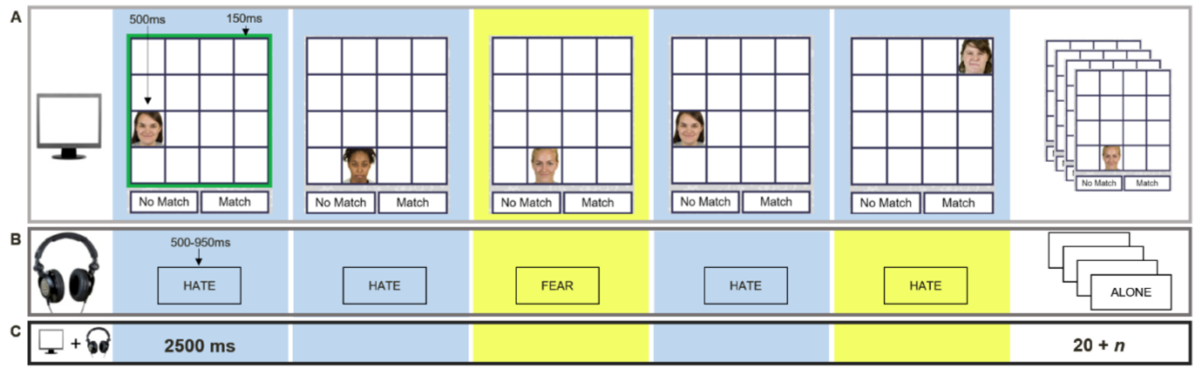

Figure 4.2. AffeCT Tasks Including a Visuospatial (A), Auditory (B) and Dual (C) n-back Task. The figure depicts sample trials for each of the three training tasks: A) visuospatial *n*-back, B) auditory *n*–back, and C) dual *n*-back task. Trials depicted with a light blue background require a “No Match” response. Yellow backgrounds indicate “Match” (i.e., target) trials. After each trial participants received feedback with the grid border changing colour – green for correct trials (as illustrated in the first panel of the figure) and red for incorrect trials. The example block in Figure 4.2 is depicted for *n* = 1. Match trials for the visuospatial n-back training task are trials in which the current face is presented in the same location as the face *n* positions back. In the auditory *n*-back task, trials require a match response if the same word is presented as the one *n* trials back. The dual *n*-back task trials can match for auditory, visuospatial or both content. 2500 ms = the maximal (duration is self-paced up to 2500 ms) time between onset of one stimulus and the next (i.e., total trial time); 500 ms = face presentation time; 150 ms = feedback presentation time; 500-950 ms = word presentation time. 20 + n = each block consists of 20 + n trials.

Affective control tasks. To assess the different facets of affective control, three measures of affective inhibition, updating and shifting were included. These measures were administered before and immediately after training.

Inhibition. The affective Stroop task was used to assess inhibition of affective interference (Preston & Stansfield, 2008). Pictures of faces were presented to the participants with words superimposed on the image. Then, participants were asked to indicate whether the adjectives were happy or sad. Feedback was provided after each trial with a red or green border around the image for 200 ms to indicate an incorrect or correct response. The task was self-paced and there were 96 trials in total. Trials were considered inaccurate if no response was detected after 4 s. The performance of the task was operationalised as task accuracy (i.e., percentage trials correct) and reaction time was recorded.

Updating. The affective backward digit-span task was used to assess updating. Participants were presented with a series of digits (1500 ms) displayed over negative or neutral background images. Participants were then asked to recall the digits in reverse order. The task started at two digits, with each span level presented twice. To progress to the next span level, participants had to get at least one out of the two trials correct. The task was terminated if both trials were incorrect. The performance of the task was operationalised as the highest span level achieved in the negative and neutral condition.

Set-shifting. The affective set-shifting task, which was adapted from the Madrid Card Sorting Task (Schweizer, Parker, et al., 2020), was used to assess individual's capacity to switch between task demands. Participants were dealt with a card and were asked to assign it to one of the four decks according to the three possible sorting rules: 1) card colour, 2) number of items on the card, and 3) shapes (for neutral condition) or emotional expressions (for affective condition). There were 96 trials in total and the sorting rule changed randomly after 6 to 9 trials. Participants had to respond within 30 s or the trial would be recorded as error. Performance of the task was operationalised as random errors, which refers to errors that occur on any trial in the series from the third trial onwards (as the first two trials were needed to establish the correct sorting rule).

Self-reported mental health, emotion and self-regulation. Participants' mental health, emotion and self-regulation were measured using four self-report questionnaires. The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) was used to assess mental health difficulties. The questionnaire includes 25 questions, divided into five subscales that assess prosocial behaviours, emotional symptoms, conduct problems, hyperactivity/inattention, and peer relationship problems. Total difficult score is calculated by adding scores from all the subscales except for the prosocial subscale measured on a 3-point likert scale. The total difficult score can range from 0 to 40. The measure has been shown to have good psychometric properties in the age group that was recruited for the current study (Cronbach's α of 0.80), as well as good sensitivity, specificity and prospective utility (Becker et al., 2015; Goodman & Goodman, 2011).

Emotion regulation was assessed using the Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004). The scale consists of 36 items comprising 6 subscales: 1) nonacceptance: the propensity to experience secondary negative emotions in response to negative emotions; 2) goals: difficulties engaging with goal-directed behaviours when upset; 3) impulse: the ability to control one's behaviour when experiencing negative emotions; 4) awareness: the tendency to attend to emotions; 5) strategies: individuals' perception that emotions cannot be controlled; and 6) clarity: individuals' ability to correctly identify their emotions. An emotion regulation score is calculated by adding the sum of each question, with higher scores suggesting greater problems with emotion regulation (range 36-180). The scale has shown high internal consistency, Cronbach's α = 0.94 (Gratz & Roemer, 2004) and has been reliably used in the age range included in the current study (Neumann et al., 2010).

Self-regulation was assessed using the Brief Version of the Self-Control Scale (Tangney et al., 2004). The scale involved 13 statements and participants had to indicate, on a 5-point scale from "Not at all" to "Very much", how much each of the statement described them. A self-control score is calculated by adding up the score for each statement, with higher scores representing higher levels of self-control (range 5-65). The scale has shown good internal consistency in adolescents and adults (Finkenauer, Engels, & Baumeister, 2005; Righetti & Finkenauer, 2011).

Fluid intelligence. At pre-training we additionally administered the 12-item version of the Raven's Advanced Progressive Matrices to compare the groups on pre-training differences in fluid intelligence (Raven et al., 1988). Participants were instructed to complete the task as quickly as possible. The measure has good psychometric properties (Raven, 2000).

4.2.5 Statistical analysis

To investigate gain on the affective control training task, our protocol specified that this would be analysed investigating *d*-prime (*d'*) scores as performance index. However, the inclusion of a no-match button in the task design meant that hit rates were at ceiling, rendering the *d*' scores non-informative. We therefore opted to examine the maximum level of *n*-back achieved instead, as is conventional for *n*-back training studies (Soveri et al., 2017).

The protocol specified a multivariate mixed effects model for the analyse of the three facets. However, as the primary outcomes varied across tasks (accuracy for the affective digit span task and reaction time for the affective Stroop and Card Sorting tasks) the facets were analysed in individual mixed effects models. The results were Bonferroni-corrected (.05/3) for three separate comparisons, thus the statistical threshold was α =.17.

4.3 Results

4.3.1 Baseline characteristics

Bayesian *t*-tests (continuous variables) and *Chi* square tests (categorical variables) revealed no significant group differences on any baseline characteristics (Table 4.1).

	Placebo		AffeCT			
	M / N	*SD / %*	*M / N*	*SD / %*	*t/X²*	*p*
Age	14.32	2.35	14.38	2.34	−0.20	.84
Gender					1.60	.45
Female	79	80.61	80	78.43		
Male	16	16.32	21	20.58		
Other	3	3.06	1	0.98		
Parental education (SES proxy)					6.36	.78
General secondary education	9	9.18	8	7.84		
Advanced secondary education	14	14.28	13	12.74		
Undergraduate degree	19	19.38	19	18.62		
Postgraduate degree	18	18.36	21	20.58		
Missing	38	38.77	41	40.19		
Ethnicity					1.30	.73
Asian	19	19.38	23	22.54		

Black	13	13.26	18	17.64		
White	53	54.08	49	48.03		
Mixed/Other	13	13.26	12	11.76		
Fluid intelligence	8.34	2.13	7.89	2.27	1.37	.17
Mental health difficulties	14.89	3.80	16.08	4.72	−1.86	.06
Emotion regulation difficulties	46.85	15.97	50.22	20.73	−1.28	.20
Self-control	23.82	6.52	23.02	7.22	0.82	.42
Group size	21.94	13.38	21.71	14.83	0.13	.90

Table 4.1. Baseline characteristics across groups. Fluid intelligence = IQ score derived from the Raven's Advanced Progressive Matrices (Raven et al., 1988); Mental health difficulties = Difficulties score on the Strengths and Difficulties Questionnaire (Goodman, 1997); Emotion regulation difficulties = Total score on the Difficulties in Emotion Regulation Scale (Gratz & Roemer, 2004); Self-control = Total score on the Brief Self-control Scale (Tangney et al., 2004); Parental education = Highest parental education was measured as a proxy of socioeconomic status (SES); Asian = Included individuals selecting any of these answer options: Asian-other, Bangladeshi, Chinese, Indian, Pakistani; Black = Black is a term used in Britain to refer to citizens of African or African-Caribbean decent, here it included individuals who selected any of the following to describe their ethnicity: Black-African, Black-British, Black-Other; White = here refers to individuals who identified as White-British or White-other; Mixed/Other = here includes individuals who identified as being of mixed or other ethnicity than the available options by selecting Mixed/Other; Group size = average number of participants in the pre- and post-training assessment sessions.

4.3.2 Baseline affective control

In line with our pre-registration, we examined the structure of affective control at baseline. Specifically, we predicted that affective control and cognitive control would be correlated but separate factors. The predicted two-factor model including performance on the transfer measures of shifting, inhibition and updating did not converge, even after scaling the reaction time data. Removing the latent congruency factor from the latent affective control factor allowed the model to converge, but it showed a very poor fit ($X^2(96)$ = 800.81; CFI = .37; TLI = .21; RMSEA = .21; SRMR = .20; AIC = 567.38). We therefore examined the structure for accuracy and reaction time separately. The two-factor structure provided a good fit for the reaction time data. However, the fit was not significantly better when compared to a model including a single cognitive control factor, ΔX^2 (3) = 4.27; p = .23. For accuracy, the two-factor showed borderline acceptable fit (Table 4.2). The fit of a single cognitive control factor was significantly poorer, ΔX^2 (3) = 41.32; $p < .001$. The latent affective control factors (from the two-factor models) for accuracy and reaction time were retained to examine hypothesis 4, as per protocol.

	X^2	*Df*	CFI	TLI	RMSEA	SRMR	AIC
Reaction time							
Two-factor model	48.84	31	.98	.97	.06	.05	−176.18
One-factor model	53.11	34	.98	.97	.06	.06	−177.10
Accuracy							
Two-factor model	100.75	31	.81	.73	.11	.10	−434.56
One-factor model	133.50	34	.74	.66	.14	.11	−403.07

Table 4.2. Fit indices of two-factor (affective and cognitive control) vs. one-factor (cognitive control) models. The table reports the model fit indices for the model structure of task performance on the affective Stroop (Preston & Stansfield, 2008), affective card storing task (Schweizer, Parker, et al., 2020) and affective backward digit span task (Schweizer, Leung, et al., 2019). Specifically, the models compared the predicted two-factor structure (i.e., separate affective control and cognitive control factors) to the more parsimonious one-factor structure (general cognitive control factor). For reaction time, in the two-factor model, the observed variables included in the affective control factor for reaction time were: sad and happy incongruent and congruent Stroop trials, affective card sorting condition. The cognitive control factor included reaction time on for neutral Stroop trials and the neutral version of the card sorting task. For accuracy, the two-factor model included the affective control factor with: affective backward digit span level, sad and happy incongruent and congruent Stroop trials, affective card sorting condition. The cognitive control factor included neutral backward digit span level neutral Stroop trials and the neutral version of the card sorting task. CFI = comparative fit index; TLI = Tucker-Lewis Index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; AIC = Akaike Information Criterion.

4.3.3 Training characteristics and results

There were no significant differences in training adherence except for average number of sessions completed, which was significantly higher in the Placebo (*M*=12.08, *SD*=13.39) compared to the AffeCT group (*M*=7.19, *SD*=9.12; $t(187)=2.09$, $p=.004$). Number of training sessions completed was therefore included as a covariate.

The groups did not significantly differ in the total mins trained, t (90) = 0.93, p =.350. Individuals in the Placebo group trained for 17.63 mins on average (SD = 32.3), whereas the AffeCT group trained for 12.32 mins on average (SD =20.27).

The groups did not significantly differ in the ratio of time spent on the more challenging – and, as per the rationale provided to participants, more beneficial - C version of the training task versus the A and B versions of the training tasks, t (90) = 0.50, p = .618. The ratio was controlled for overall minutes trained (i.e. ((time spent on C – time spent on A+B)/total time spent training)). In the case of the Placebo group, the C version of the task was not actually more challenging or beneficial than the A and B versions.

In line with our *affective control training hypothesis*, which predicted that the AffeCT group would perform better on the affective *n*-back task following training, there was a Training group x Time interaction, $\beta = 0.48$, $SE = 0.13$, $t = 3.70$, $p <.001$. The interaction remained significant when controlling for differences in the number of sessions trained and group size, $\beta = 0.47$, $SE = 0.13$, $t = 3.55$, $p <.001$ (see Table 4.3).

		Maximum n-back	
Predictors	*Estimates*	*CI*	*p*
Intercept	1.60	1.29 – 1.92	**<0.001**
Time	0.12	-0.06 – 0.30	0.203
Group	-0.51	-0.93 - -0.09	**0.017**
Number of training sessions	0.02	0.01 – 0.03	**<0.001**
Time x Group	0.47	0.21 – 0.73	**<0.001**

Table 4.3. Effects of Time and Training Group on performance on the training task.

Time = Pre-training vs. post-training; Group = AffeCT vs. Placebo; Number of training sessions = number of sessions completed that were 10 minutes or longer. Bold print indicates a significant result, $p < .05$. Marginal R^2 = .09; Conditional R^2 = .41.

4.3.4 Effects of training on the three components of affective control

We found no support for our second *affective control facets* hypothesis: AffeCT did not lead to greater gains in affective inhibition, shifting or updating. As indicated by non-significant interactions between the effects of training group (AffeCT vs. Placebo) and time (Pre vs. Post-training) reported in Table 4.4.

	Accuracy				Reaction time			
	β	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
Affective inhibition								
Intercept	–0.01	0.01	–1.46	.15	–889.64	12.01	–74.10	<.001
Time	0.00	0.00	0.25	.81	41.47	6.80	6.10	<.001
Group	–0.00	0.01	–0.05	.96	16.89	12.01	1.41	.18
Time x Group	0.00	0.01	0.46	.65	0.36	6.08	0.60	.55
Affective shifting								
Intercept	0.00	0.02	0.14	.89	–1953.00	104.80	–18.63	<.001
Time	–0.02	0.01	–1.23	.22	343.35	90.70	3.79	<.001
Group	–0.00	0.02	–0.13	.90	80.70	149.35	0.54	.59
Time x Group	0.00	0.01	0.26	.80	–0.30	129.51	–0.00	1.00
Affective updating								
Intercept	–0.21	0.10	–2.12	.04	--	--	--	--
Time	–0.04	0.09	–0.51	.61	--	--	--	--
Group	–0.04	0.10	–0.21	.84	--	--	--	--
Time x Group	–0.00	0.09	–0.06	.95	--	--	--	--

Table 4.4. Mixed Effects Models Investigating the Effects of Training Group on Affective Control Facets from Pre- to Post-Training. The table reports the estimates from the mixed effects model reporting the effects of Time (Pre-training vs. Post-training); Group (AffeCT vs. Placebo) and the interaction of these factors (Time x Group). The models are reported for accuracy and reaction time performance on affective inhibition, shifting and updating task. Affective inhibition was measured

as incongruency index (accuracy/reaction time on incongruent trails – accuracy/reaction time on neutral trails) on the Stroop task, which requires adjectives to be categorised as happy or sad over incongruent background faces (affective condition) or scrambled background faces (neutral condition) (Preston & Stansfield, 2008). Affective shifting was indexed by subtracting the number of errors made/reaction time in the colour and number trials of the neutral condition (i.e., condition including shapes) from the number of errors made/reaction time in the affective condition (i.e., condition including faces with emotional expressions). Affective updating was operationalised by subtracting the backward digit span length in the neutral condition (i.e., digits presented over neutral background images) from the span length affective in the affective condition (i.e., digits presented over affective background images). For means and standard deviations across the different conditions at pre- and post-training on the affective inhibition, shifting and updating tasks see Table 4.5.

	Pre-training				Post-training			
	AffeCT		*Placebo*		*AffeCT*		*Placebo*	
	Accuracy *M (SD)*	*RT* *M (SD)*	*Accuracy* *M (SD)*	*RT* *M (SD)*	*Accuracy* *M (SD)*	*RT* *M (SD)*	*Accuracy* *M (SD)*	*RT* *M (SD)*
Affective inhibition								
Happy	-0.02 (0.11)	-0.91 (0.19)	0 (0.07)	-0.93 (0.22)	-0.02 (0.07)	-0.84 (0.19)	0 (0.06)	-0.86 (0.18)
Sad	-0.01 (0.09)	-0.93 (0.20)	-0.02 (0.09)	-0.96 (0.21)	-0.01 (0.09)	-0.85 (0.19)	0.01 (0.11)	-0.90 (0.19)
Affective shifting								
Affective	0.25 (0.22)	2.94 (1.59)	0.27 (0.25)	2.94 (1.49)	0.20 (0.21)	1.69 (0.91)	0.20 (0.20)	1.97 (1.02)
Neutral	0.24 (0.19)	2.14 (0.92)	0.25 (0.21)	2.28 (1.48)	0.23 (0.21)	1.61 (0.79)	0.21 (0.21)	1.65(0.66)
Affective updating								
Affective	5.28 (1.38)	--	5.32 (1.79)	--	5.15 (1.69)	--	5.59 (1.95)	--
Neutral	5.37 (1.49)	--	5.47 (1.51)	--	5.42 (1.66)	--	5.84 91.78)	--

Table 4.5. Mean and standard deviations across different conditions at pre- and post-training on the affective inhibition, shifting, and updating tasks. Affective inhibition was measured as incongruency index (accuracy/reaction time on incongruent trails – accuracy/reaction time on neutral trials) on the Stroop task, which requires adjectives to be categorised as happy or sad over incongruent background faces (affective condition) or scrambled background faces (neutral condition) (Preston & Stansfield, 2008). Affective shifting was indexed by subtracting the number of errors made/reaction time in the

colour and number trials of the neutral condition (i.e., condition including shapes) from the number of errors made/reaction time in the affective condition (i.e., condition including faces with emotional expressions). Affective updating was operationalised by subtracting the backward digit span length in the neutral condition (i.e., digits presented over neutral background images) from the span length in the affective condition (i.e., digits presented over affective background images). RT = reaction time (in second).

4.3.5 Age-related differences in affective control training

In line with our third *age-related change* hypothesis, there were age-related differences in training gains on the affective *n*-back task. That is, age group moderated the significant group by time interaction reported in H1, $\beta = 0.24$, $SE = 0.07$, $t = 3.56$, $p < .001$ (for the full model estimates see Table 4.6). This effect was reduced but remained significant when correcting for the number of training sessions completed, $\beta = 0.06$, $SE = 0.02$, $t = 3.50$, $p < .001$. Analyses of the estimated marginal means trends revealed a significant age by time interaction effect in the AffeCT group, $\beta = -0.17$, $SE = 0.08$, $t = -2.30$, $p = 0.02$, but not in the Placebo group, $\beta = 0.08$, $SE = 0.07$, $t = 1.23$, $p = 0.22$. Specifically, the significant age effect in the AffeCT group revealed that increasing age was associated with greater improvements on the affective *n*-back task, $r = .22$, $p = .07$.

	Maximum n-back		
	Estimates	*CI*	*p*
Intercept	0.55	-0.74 – 1.84	0.404
Time	2.32	0.92 – 3.71	**0.001**
Group	0.61	-1.19 – 2.42	0.504
Age	0.11	0.02 – 0.20	**0.016**
Number of training sessions	0.02	0.01 – 0.03	**<0.001**
Time x Group	-2.83	-4.82 – -0.84	**0.005**
Time x Age	-0.15	-0.24 – -0.05	**0.002**
Group x Age	-0.05	-0.17 – 0.08	0.467
Time x Group x Age	0.23	0.10 – 0.37	**0.001**

Table 4.6. Effects of Time, Training Group and Age on Performance on the Training Task. Time = Pre-training vs. post-training; Group = AffeCT vs. Placebo; Number of training sessions = number of sessions completed that were 10 minutes or longer. Bold print indicates a significant result, $p < .05$. Marginal R^2 = .16; Conditional R^2 = .62.

4.3.6 The effect of training on mental health, emotion regulation and self-control

Applying a multi-group latent growth curve model showed that AffeCT, but not Placebo, training led to significant covariance of change in affective control index identified at baseline in the reaction time and accuracy model (i.e. this includes reaction time and accuracy on sad and happy Stroop trials, as well as affective condition of the card sorting task and additionally digit span for accuracy) and mental health difficulties (see Table 4.7). The formal comparison of the free model to a model with constrained variance of the latent variables was significant for both reaction time (X_{Diff}^2 = 11.07, p = .004) and accuracy (X_{Diff}^2 = 9.76, p = .008) indices of affective control. Extracting the indices of change from the latent growth curve model revealed that post-training mental health difficulties in the AffeCT group were negatively associated with change in affective control (reaction time: r = −.48, p <.001; accuracy: r = −.57, p<.001) . That is, greater change in affective control was associated with fewer mental health problems. In contrast, the Placebo group showed a small, non-significant association between change in affective control and post-training mental health difficulties (reaction time: r = .21, p = .06; accuracy: r = −.28, p = .02). However, the effects of training on mental health difficulties were not maintained at the one-month follow up (reaction time: X_{Diff}^2 = 4.54, p = .10; accuracy: X_{Diff}^2 =2.43, p = .30) or at the one-year follow up (reaction time: X_{Diff}^2 = 0.87, p = .65; accuracy: X_{Diff}^2 =0.89, p = .64).

There was no effect of AffeCT compared to Placebo on emotion regulation difficulties or self-control capacity. This was true for latent growth curve models including the latent affective control index for reaction time (emotion regulation: X_{Diff}^2 = 3.61, p = .16; self-control: X_{Diff}^2 = 3.67, p = .16) and accuracy (emotion regulation: X_{Diff}^2 = 0.00, p = .99; self-control: X_{Diff}^2 = 4.98, p = .09).

	X^2	*Df*	CFI	TLI	RMSEA	SRMR	AIC	*β*	*SE*	*z*	*p*
REACTION TIME											
Free model fit			1.00	1.00	.02	.09	1221.23				
Constrained model fit			.99	.99	.03	.10	1225.97				
Placebo group											
Regression											
Δmental health											
~Affective control pre-training								−0.02	1.94	−0.01	.99
~Mental health pre-training								−0.31	0.09	−3.56	<.001
Δaffective control											
~Mental health pre-training								0.01	0.01	2.30	.02
~Affective control pre-training								−0.36	0.09	−4.17	<.001
Covariance											
Affective control pre-training ~~ Mental health pre-training								0.13	0.07	1.74	.08
Δaffective control ~~ Δmental health								0.03	0.04	0.61	.54
AffeCT group											
Regression											
Δmental health											
~Affective control pre-training								−1.68	1.91	−0.88	.38

~Mental health pre-training						−0.17	0.11	−1.50	.14
Δaffective control									
~Mental health pre-training						−0.01	0.00	−1.99	.05
~Affective control pre-training						−0.33	0.09	−2.04	.04
Covariance									
Affective control pre-training ~~ Mental health pre-training						0.02	0.10	0.23	.82
Δaffective control ~~ Δmental health						−0.19	0.09	−2.04	.04
ACCURACY									
Free model fit	.69	.66	.14	.19	-115.19				
Constrained model fit	.69	.66	.14	.19	-109.43				
Placebo group									
Regression									
Δmental health									
~Affective control pre-training						-0.88	1.48	-0.59	.55
~Mental health pre-training						-0.30	0.09	−3.35	.001
Δaffective control									
~Mental health pre-training						-0.03	0.01	-2.87	.004
~Affective control pre-training						-0.17	0.17	-0.98	.33
Covariance									
Affective control pre-training ~~ Mental health pre-training						0.14	0.13	1.15	.25
Δaffective control ~~ Δmental health						0.02	0.12	0.18	.86

AffeCT group				
Regression				
Δmental health				
~Affective control pre-training	-0.05	1.18	-0.04	.97
~Mental health pre-training	-1.19	0.10	-1.98	.05
Δaffective control				
~Mental health pre-training	-0.01	0.01	-0.69	.49
~Affective control pre-training	-0.19	0.14	-1.46	.17
Covariance				
Affective control pre-training ~~ Mental health pre-training	-0.08	0.24	-0.32	.75
Δaffective control ~~ Δmental health	-0.67	0.21	-3.13	.002

Table 4.7. ***Multi-group (AffeCT vs. Placebo) latent growth curve models of affective control and mental health difficulties from pre- to post-training.*** CFI = comparative fit index; TLI = Tucker-Lewis Index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; AIC = Akaike Information Criterion.

4.4 Discussion

Identifying novel and scalable avenues for prevention of mental problems is essential (Hagan et al., 2015), as mental ill health has become the leading burden of disease in young people worldwide (Gore et al., 2011). The present study tested the potential of an app-based affective control training to benefit adolescents' mental health. The study found that adolescents' performance on an affective control training task improved from pre- to post-training, with older adolescents benefiting more from training compared to younger adolescents. These training gains did not lead to improvements on non-trained measures of affective control, across affective updating, inhibition and shifting. However, variance of change in affective control was related to reduced mental health difficulties at pre-training in the AffeCT group (and not in the Placebo group), but this benefit was not maintained one-month or one-year later. We discuss the implications of these findings for the potential of app-based affective control training in mental health.

4.4.1 Improving affective control with minimal effort

The greater improvement on the affective control training task in the AffeCT compared to the Placebo group was in line with our hypothesis. It is noteworthy, however, that the AffeCT group on average completed half as many training sessions as the Placebo group. Moreover, both groups predominantly completed the "simpler" training tasks. For the AffeCT group, this was the two single modality training versions, and for the Placebo group this was the two task versions that were arbitrarily designated as the simpler task versions. That is, adolescents limited the cognitive effort involved in training by selecting the less demanding option(s). Ganesan & Steinbeis (2021) argued that effort exerted in cognitive (training) tasks is guided by an individual's cost-value computation. This suggests that the perceived value of training, especially on the dual *n*-back version of AffeCT, was insufficient to motivate most participants. Engagement in cognitive training tasks, such as AffeCT, should therefore be motivated by providing appropriate incentives to exert cognitive effort. The incentives are not limited to monetary incentives or other rewards: instead, the relative value of "training" can be increased by changing adolescents' mindset about the benefits of a specific training regime (Yeager et al., 2022).

4.4.2 Age-related training improvement

Pre- to post-training gains in affective control (i.e., change in maximum level of *n* back achieved from pre- to post-training) increased as a function of age. This is in line with non-affective cognitive training findings, which have shown greater benefits of cognitive training in older (16-18 years) compared to younger (11-13 years) adolescents (Knoll et al., 2016). However, a comprehensive review of the literature on brain plasticity in adolescence suggests that brain plasticity-related changes in higher cognitive functions during adolescence are dependent on the brain regions involved in the specific cognitive domain that is being trained, along with a range of other factors (e.g. the type of training and the trained individuals' gender; Laube et al., 2020). Affective control recruits the cognitive control network, in particular the inferior frontal gyrus, which shows protracted development throughout adolescence (Schweizer, Satpute, et al., 2019). The age-related differences in training gains observed in the present study support training-induced functional changes and possibly structural plasticity of the neural substrates of affective control throughout adolescence. However, examinations of training-induced functional or structural brain changes in typically developing adolescents are scarce (Lee et al., 2019). Examining training-induced neural changes may inform further mechanisms of action through which affective control training impacts affective control in adolescents.

4.4.3 Performance on different facets of affective control remains unchanged by AffeCT

AffeCT did not transfer to significantly greater improvements in performance on non-trained measures of the different facets of affective control: affective inhibition (Preston & Stansfield, 2008), affective working memory (Schweizer, Leung, et al., 2019) and affective shifting (Schweizer, Parker, et al., 2020). The lack of training-related transfer to untrained measures of affective control is in line with meta-analytic reviews of the cognitive control training literature, which show that training leads to improvements on the trained task but typically does not extend to untrained measures of neutral cognitive control (e.g., Soveri et al., 2017). Transfer effects (i.e., training-induced changes) to *affective* control have received comparatively less attention. In older adolescents (16-24 years), Roberts et al. (2021) showed that neutral, but not affective control training, led to improvements in affective updating. In adults, cognitive (Cohen et al., 2016; Sari et al., 2016) and affective (Schweizer et al., 2011, 2013) control training paradigms have been shown to improve affective inhibition. While the current study showed no transfer on untrained affective control measures, the existent literature suggests that with appropriate training regimes facets of affective control may be malleable and benefit from computerized control training.

4.4.4 Affective control gains and mental health

Despite the lack of training-related transfer to the individual facets of affective control, pre- to post-training change on a composite index of affective control and pre- to post-training change in mental health problems (emotional problems, conduct problems, hyperactivity, and peer problems as measured using the SDQ total difficulties score) covaried in the AffeCT group but not the Placebo.
That is, greater improvement in affective control was associated with mental health benefits in adolescents who had trained with AffeCT but not Placebo. This is in line with a review of the literature showing that computerized cognitive control training, in particular training that induces improvements in affective control, is associated with benefits in symptoms of depression and anxiety children and adolescents (Edwards et al., 2022) and adults (Koster et al., 2017).

Of note is the per protocol use of multi-group latent growth curve modelling to analyse the impact of training. Traditional methods to analyse training effects have typically included repeated measures analyses of variance and mixed effects models that examine average performance or symptom levels (Soveri et al., 2017). Multi-group latent growth curve modelling instead compared the groups on the extent to which individual variance in the change in affective control was associated with variance in change in mental health benefits. In other words, the model investigated whether pre- to post-training changes in the affective control factor established at baseline are associated with fewer self-reported mental health problems. This effect of training would not have been captured by traditional inference methods and, although it did not extend beyond the immediate post-training assessment, it warrants future investigation into the potential of affective control training as a preventative intervention in adolescent mental health. One avenue that warrants particular investigation is whether the training benefits of AffeCT can be augmented in magnitude (i.e., more reduction in symptoms) and temporally extended when increasing engagement and participation in the more demanding version of the training task (i.e., dual vs. single *n*-back). Beyond increasing engagement by an improved rationale for training as proposed above, participation can be boosted through gamification. Gamification refers to the process of enhancing training with affordances to create engaging experiences (Hamari, 2013). Meta-analytic evidence demonstrates that it is an effective tool to reliably encourage attentional engagement and motivation to increase rates of training (Lumsden et al., 2016).

The present findings need to be considered within the context of the study's limitations. While the study was adequately powered, limited per protocol engagement with the task restrict the inferences that can be drawn regarding the effectiveness of affective control training. Moreover, for over half of the sample, the one-year follow-up was conducted during the COVID-19 pandemic, so the potential to detect training-effects over and above the adverse impact that the pandemic has had on adolescent mental health (Racine et al., 2021) is limited.

In sum, the present study showed that affective control training in adolescents, especially older adolescents, led to improvements in performance on the training task, but did not transfer to untrained measures of individual facets of affective control. Encouragingly, the covariance of change on the non-trained composite index of affective control and mental health difficulties from pre- to post-training showed a significant benefit of AffeCT over Placebo. That is, the present study provides preliminary evidence that affective control training may confer short-term preventative benefits for adolescent mental health. App-based training is easy to disseminate and can therefore be delivered at scale. Even small and short-term benefits are therefore potentially meaningful if they can be delivered at the population level. If engagement with affective control training can be further boosted through gamification and other incentives, these benefits may be extended beyond the period immediately following training.

CHAPTER 5: GENERAL DISCUSSION

The studies presented in this thesis contribute to a growing body of evidence suggesting that adolescence is a unique period of development, during which the continued development of social cognitive processes could be a promising intervention target to improve mental health outcomes. In this chapter, I will first summarise and discuss the findings from the three experimental studies presented in the thesis, followed by a discussion of the methodological considerations and limitations. I will then discuss future directions for research, and how the findings from this thesis might have wider implications for policy and practice.

5.1 Summary and discussion of findings

The study described in Chapter 2 used a social influence paradigm to examine the effect of age and puberty on susceptibility to social influence in 520 adolescents aged 11 to 18 years. The findings highlighted that susceptibility to both prosocial and antisocial behaviours decreased linearly with age, with younger adolescents being more likely than older adolescents to change their (hypothetical) prosocial and antisocial behaviour in the direction of others' ratings of the same behaviour. Understanding the underlying factors that contribute to susceptibility to peer influence is important for the design of effective prevention programs aimed at reducing antisocial behaviour and promoting prosocial behaviour.

One of the main findings from this study suggested that as adolescents get older, they become less susceptible to both prosocial and antisocial influence. This age-related difference is in line with previous studies showing that adolescents were more susceptible to influence from other people's perception of risks (Knoll et al., 2017; 2015) and other's prosocial tendencies (Foulkes et al., 2018) than were adults. This accords with studies described in Section 1.3.2, where I discussed the large body of research showing that adolescents are particularly susceptible to peer influence when compared with adults. While the findings of Chapter 2 are in line with previous studies, most of the previous research tended to examine negative outcomes and positive outcomes separately rather than in a single paradigm within the same individual. The study presented in Chapter 2 showed a negative linear relationship between age and susceptibility to both prosocial and antisocial influence in a single paradigm.

Another aim of the study in Chapter 2 was to understand whether social influence would be affected by the *direction* of others' ratings and whether this differs across age and different types of social behaviours. We found that social influence was present for both lower and higher ratings and such influence decreased with age. Specifically, younger participants were more socially influenced when others' ratings were more prosocial and less antisocial than participants' initial ratings, compared with older participants. One explanation for this is that younger adolescents are still trying to negotiate the new school context, having recently moved from smaller primary schools to larger secondary schools, and there is pressure to "fit in" by using positive impression management (Fine, 2004; McElhaney, Antonishak & Allen, 2008). This is in line with evidence described in Section 1.3.2, which suggested an explanation for the heightened susceptibility to social influence during adolescence is the fear of social rejection. Evidence has shown that social rejection, especially from peers, is associated with poorer mental health in adolescence (Beeri & Lev-Wiesel, 2012). Therefore, interventions designed to target social norms and resilience to social exclusion might be effective in this age group. Indeed, studies that target social norms through peer-led interventions have shown positive outcomes across a number of domains such bullying (Paluck, Shepherd & Aronow, 2016) and smoking (Campbell et al., 2008). In one study, 56 middle schools in the US (with students aged 11-16 years) were randomly allocated to either a peer led anti-bullying programme or practise as usual (Paluck, Shepherd & Aronow, 2016). In this programme, students who had a large number of positive social connections among their peers (socially referent students) attended an anti-conflict programme and were encouraged to lead grassroots anti-bullying campaigns within their schools. Compared with control schools, the schools in which the anti-bullying programmes were led by students saw a 25% reduction in conflict over the ensuing year. The effect was strongest in schools with a higher proportion of socially referent students leading the campaigns, demonstrating the power of peer influence in changing behaviour in adolescents.

Mindfulness training programmes have been shown to encourage prosocial behaviours and reduce antisocial tendencies in adolescents (Bögels et al., 2008; Donald et al., 2019; Franco et al., 2016). However, less is known about whether mindfulness training affects susceptibility to prosocial and antisocial *influence*. Chapter 3 presented a study that investigated a) self-reported prosocial and antisocial tendencies and b) susceptibility to prosocial and antisocial influence following either one of two 8-week social emotional training programmes (a mindfulness training programme and an active control training programme) in 465 adolescents aged 11-16 years. Pre- and post-training, participants completed the same social influence task as reported in Chapter 2.

The two aims of the study described in Chapter 3 were to examine whether mindfulness training specifically, as compared with an active control training, was associated with a change, first, in the likelihood of engaging in hypothetical prosocial and antisocial behaviours and, second, in the susceptibility to prosocial and antisocial influence. The findings suggested that self-reported likelihood of engaging in prosocial and antisocial behaviours (participants' initial rating in the task) did not change post-training, regardless of training group. In addition, participants were less influenced by antisocial ratings following both training programmes.

The findings from this study contribute to the literature described in Section 1.5.1, which suggests that mindfulness training can promote positive behaviour (e.g. helping behaviour) and reduce antisocial tendencies in adolescents. However, in contrast to some previous studies, we did not find any significant differences in prosocial or antisocial behaviour following an 8-week mindfulness training programme (or after the control training programme). This differs from previous studies demonstrating beneficial effects of mindfulness on adolescents' prosocial and antisocial behaviours. One reason for this difference might be that our study involved self-reported behaviour in hypothetical situations, whereas the previous studies measured real life behaviour.

The second aim of the study reported in Chapter 3 was to investigate the effect of mindfulness training on prosocial and antisocial influence. The findings indicated that participants became less influenced by antisocial ratings following mindfulness training. However, this was also true for active control training, and therefore there were no differential effects of the two training programmes. As discussed in Section 1.5.1, we predicted mindfulness training would have a greater impact on social influence than the active control training as mindfulness training has been shown to improve executive control processes, especially self-control (Elkins-Brown et al., 2017; Masicampo & Baumeister, 2007). Adolescents with higher levels of self-control have shown to be less susceptible to peer influence (Meldrum, Miller & Flexon, 2013). However, our results suggest that mindfulness training might not impact social influence through a mechanism that is not targeted by other types of socioemotional training. Rather, it is possible that the observed decrease in influence in the antisocial condition is driven by common elements in both training programmes. For example, both training programmes focus on building self-esteem and cultivating kindness and gratitude, which are associated with less antisocial behaviour (Bono et al., 2019; Donnellan et al., 2005; Gao et al., 2020). It is possible that cultivating kindness, gratitude and increasing self-esteem as a result of undergoing one or the other of the programmes led to a reduction in social influence in the antisocial condition. However, it should be noted that this study did not include a no-training control group, and therefore it is possible that the change in social influence was due to factors other than the social emotional training, such as time or practise. For example, without a no-training control group, it is impossible to discern whether the effect of social emotional training observed in the study was simply due to participants completing the tasks more than once.

The experimental study described in Chapter 4 examined the effectiveness of an affective control training paradigm (as compared to a placebo training paradigm) in 242 adolescents aged 11-19 years. The study aimed to investigate whether improving affective control through a computerised affective training programme (AffeCT) would benefit adolescents' mental health when compared to an active control training programme (placebo). Participants in the AffeCT group showed significantly greater improvements than the active control group in affective control on the trained tasks. The AffeCT training programme did not, relative to the placebo training programme, lead to better performance on the *untrained* affective control tasks. The results also suggested pre- to post-training change in affective control covaried with pre- to post-training change in mental health problems in the AffeCT training group, but not in the placebo group. These mental health benefits in the AffeCT group, however, were not observed at one-month or one-year post-training follow up.

For those in the affective control training group, performance on the affective control training task improved from pre- to post-training, with older adolescents benefiting more from training when compared with younger adolescents. This is in line with evidence presented in Section 1.4, which demonstrated that affective control can be improved, as well as findings from non-affective cognitive training, which have shown greater benefits of cognitive training in older (16-18 years) adolescents than in younger (11-13 years) adolescents (Knoll et al., 2016).

However, these training gains did not transfer to improvements on non-trained measures of affective control, across affective updating, inhibition and shifting. The lack of training-related transfer to untrained measures of affective control is in line with meta-analyses of cognitive control training, which show that training generally leads to improvements on the trained task but typically does not extend to untrained measures of cognitive control (e.g., Holmes et al., 2019; Soveri et al., 2017). Transfer effects (i.e., training-induced changes in non-trained tasks) for *affective* control have received comparatively less attention. Roberts et al. (2021) showed that neutral, but not affective, control training led to improvements in affective updating in older adolescents aged 16-24. In adults, cognitive (Cohen et al., 2016; Sari et al., 2016) and affective (Schweizer et al., 2011; 2013) control training paradigms have been shown to improve affective inhibition.

Despite the lack of training-related transfer to the individual facets of affective control, the findings suggested that greater improvement in affective control was associated with mental health benefits in adolescents who were in the affective control training group (AffeCT) but not in those within the active control group (placebo). Building on the evidence described in Section 1.5.2, the results were in line with a review of the literature showing that computerized cognitive control training, in particular training that induces improvements in affective control, was associated with benefits in symptoms of depression and anxiety children and adolescents (Edwards et al., 2022) and adults (Koster et al., 2017).

5.2 Wider considerations and methodological limitations

Taken together, the findings presented in this thesis suggest that adolescence is a period of particular importance to social emotional development. However, the work presented should be interpreted within the context of wider considerations and a number of limiting factors. Apart from the specific methodological limitations discussed at the end of each experimental chapter, there are some wider considerations that need to be taken into account in future studies.

5.2.1 Cross-sectional versus longitudinal designs

The experimental design, specifically the choice between cross-sectional and longitudinal designs, directly affects the conclusion we can draw from the study findings. Cross-sectional studies collect outcome measures from participants of different ages at a single time point, whereas longitudinal studies take a cohort of participants and measure the outcome variables repeatedly over a set period of time.

While the training studies presented in Chapter 3 and Chapter 4 had a longitudinal component, Chapter 2 used a cross-sectional design to explore adolescents' susceptibility to prosocial and antisocial influence. The benefit of a cross-sectional design is that it allows us to collect data in a cost- and time-effective manner. This, however, limits our ability to make inferences about within-individual developmental changes across time. Therefore, we are unable to say anything about individual developmental trajectories of susceptibility to prosocial and antisocial influence. The same criticism also holds for the training studies described in Chapter 3 and Chapter 4. The study presented in Chapter 4 examined the age-related training improvements cross-sectionally and it was therefore not possible to explore the effect of developmental changes on training gains. While both studies took repeated measures within the same individuals across a period of time, neither study included a no-training control group, and therefore we have no measure of how the cognitive processes studied change over time or with age. Future work should seek to study development longitudinally.

5.2.2 Limited age ranges

The age range used in the three experimental studies presented above varied. In Chapter 2, I looked at the effect of age and puberty on susceptibility to prosocial and antisocial influence in a sample of adolescents aged 11-18 years. In Chapter 3, I examined the effect of socio-emotional training on prosocial and antisocial influence in a sample of adolescents aged 11-16 years. The reason for the different age ranges in the two studies was mostly due to practical limitations of setting up the training programme. 11–16-year-olds were selected for the study in Chapter 3 because this age group is associated with a peak in the onset of mental health problems (e.g., depression) and therefore when prevention is still possible. They are also cognitively mature enough to understand the concepts in the two training programmes, and to organise practise. Similarly in Chapter 4, the study included a sample of adolescents aged 11-19. Again, this age group was chosen for the study because of its association with heightened mental health problems. Additionally, this age group is comparable with the samples used in previous research on affective control training (e.g., Schweizer et al., 2017).

As discussed in Chapter 1, it has been proposed that adolescence should be defined from the age of 10 to around 24 years (Sawyer et al., 2018). It is therefore important to point out that the age ranges in the experimental studies in this thesis are somewhat arbitrarily formed and are not entirely consistent with the definition by Sawyer et al. (2018). As a result, this limits the ability to make direct comparisons across the studies presented. In order to fully examine the nature of developmental trajectories (e.g., linear or non-linear) and their association with the impact of social emotional training, future studies should ideally include a wider age range within the same study design. This will allow comparisons between age groups and provide a deeper understanding of the impact of developmental stage on the effect of social emotional training during adolescence and early adulthood.

5.2.3 The lack of real-life measures

Both studies in Chapter 2 and Chapter 3 looked at susceptibility to prosocial and antisocial influence. With morally relevant behaviour such as prosocial behaviour, there is evidence suggesting that what people report they will do and what they actually do differs (e.g., Teper, Inzlicht, & Page-Gould, 2011). For example, children and adolescents say that they will donate more than the amount they actually donate in Dictator games (Blake, 2018). Young people may also boast and exaggerate about engaging in antisocial behaviours as they may be considered as status enhancing behaviours (Sijtsema, Garofalo, Jansen & Klimstra, 2019). While the study included hypothetical social scenarios designed to be close to what adolescents would be likely to experience, they might not be representative of real-life behaviours.

Furthermore, the source of influence in the studies presented in Chapter 2 and Chapter 3 were unfamiliar adolescents. However, studies have shown that peer acceptance and friendship quality affect how readily adolescents conform to their friends' behaviours. For instance, in cigarette and alcohol use, adolescents who reported high levels of positive quality in their closest friendship were more influenced by that friend than were those whose relationships were less positive (Urberg, Luo, Pilgrim & Degirmencioglu, 2003). Therefore, future studies may benefit from collecting data in real life scenarios and using real ratings from close versus less close peers to compare findings.

5.2.4 Sample diversity and generalisability

A limitation affecting the generalisability of the research described in this thesis was the diversity and representativeness of the samples. The participants who took part in the studies were recruited from a variety of sources. In Chapters 2 and 3, because the research groups were based in both London and Cambridge, participants were recruited via schools in both Greater London and Cambridgeshire. In Chapter 4, participants were mostly recruited from schools in Greater London, but some were recruited through online advertisements at University College London and the University of New South Wales (Australia), as a collaborator had moved to Sydney during the project.

While all participants in the samples described in Chapters 2 to 4 were recruited from a combination of non-selective, state-maintained schools and selective, independent schools to attempt to capture a representative sample, the sample recruitment might be biased from inherent self-selection as well as the reliance on parental support and consent. Further, retention to the studies might also have been non-random. It is also possible that the sample might not be representative of UK, Cambridge, or Greater London. For example, accordingly to the UK Census data in 2021, there are 48.62% of female adolescents aged between 11-19 years (Office for National Statistics, 2023). However, our samples tend to have a higher proportion of females compared to the national statistics (68.27% for Chapter 2, 66.59% for Chapter 3, and 79.90% for Chapter

4). Similarly, the ethnicity distribution for the sample in Chapter 4 was not fully representative of the UK population of the same age groups (see Table 5.1). This limits the extent to which findings can be applied to the general population.

Ethnicity	Sample in Chapter 4	National statistics for 10-17 years old
Asian	19.38%	11.78%
Black	13.16%	5.92%
White	54.08%	73.86%
Mixed / Others	13.26%	8.44%

Table 5.1. Ethnicity comparison between national statistics and the sample in Chapter 4. National statistics from UK Census 2021 data (Office for National Statistics, 2023).

In particular, the lack of diversity and generalisability in the sample might impact the effectiveness of the training programmes described in Chapters 3 and 4. Socioeconomic factors (e.g., housing, food security, household income) are significant determinants of health, and students who come from more deprived backgrounds are at increased risk of mental health problems (Deighton et al, 2019; Marmot, 2020; Mansfield et al., 2021). This has implications for the study findings. For example, without a representative sample, the baseline mental health measures could be biased and affect the effectiveness of the training programme. It is also possible that a non-representative sample could lead to systematic dropouts (e.g., lack of time due to other commitments, limited access to digital devices to complete computerised training). It is therefore important for future studies to include a more diverse and representative sample, and account for social disparities between individuals to better understand the impact of interventions on social and mental health outcomes across the whole of society.

5.2.5 Role of universal school-based social-emotional training

Schools play a crucial role in adolescent development as they provide an unparalleled opportunity to implement universal (delivered to all individuals) preventative interventions at a relatively low cost, compared to more targeted (delivered to vulnerable or 'high risk' individuals only) and intensive interventions (Ford et al., 2021; Weare & Nind, 2011). While previous research has demonstrated the positive impact of universal school-based interventions on adolescents' social and emotional skills, positive behaviours and mental health outcomes (Durlak et al., 2011; Wells et al., 2003), there is a growing body of evidence suggesting null results, or small effect sizes, and the long term effectiveness of these interventions have been questioned (Mackenzie & Williams, 2018; Werner-Seidler et al., 2021).

For example, the recent findings of a large-scale school-based mindfulness training (85 schools in the UK with 8376 adolescents) suggested that teaching mindfulness in schools does not reduce depressive symptoms, social-emotional-behavioural functioning or wellbeing in adolescents aged 11-14 years, relative to teaching as usual (Kuyken et al., 2022). This is similar to findings from the studies described in Chapter 3, in which mindfulness training did not increase adolescents' tendencies to engage in prosocial or antisocial behaviour. It also compliments findings from the study in Chapter 4, in which improvements in affective control from affective control training did not transfer to untrained tasks, and the mental health benefits from the affective control training were not maintained at one-month and one-year follow up. Therefore, future studies should look at ways to better improve the content and engagement of universal school-based interventions (e.g., peer-led interventions, co-design intervention with adolescents) to enhance their effectiveness. As described in Section 5.1, providing adolescents with the autonomy to design and deliver their own interventions, especially with a focus on changing peer attitudes, could have positive outcomes (Campbell et al., 2008; Paluck, Sheperd & Aronow, 2016). To maximise the chance that the intervention is accessible, engaging and effective, it is crucial to meaningfully involve young people in the intervention development and implementation.

5.2.6 Incentives for adolescents to engage in training

No matter how well designed an intervention is, if it does not reach and engage with the target individuals, its impact will be limited. In order to maximise the chance that the intervention is accessible, engaging and effective, it is crucial for the intervention to speak to the targeted audience's concerns, preferences and ways of learning. Otherwise, it will likely result in low reach and engagement, inevitably reducing its effectiveness.

In the study presented in Chapter 4, while we found greater improvement on the trained affective control measure in the affective control training group (AffeCT) when compared to the active control group (Placebo), the AffeCT group on average only completed half as many training sessions as the Placebo group. Moreover, adolescents from both groups predominantly completed the 'easier' version of the training tasks instead of the more cognitive demanding tasks. This means that adolescents limited the cognitive effort involved in training by selecting the less cognitive demanding option. Other studies have also found low uptake and adherence to cognitive training by adolescents, perhaps due to low incentives to persevere (Beloe & Derakshan, 2020; Knoll et al., 2016). This therefore limits the potential benefits of these interventions.

Ganesan and Steinbeis (2021) have argued that effort exerted in cognitive (training) tasks is guided by an individual's cost-value computation. This suggests that the perceived value of training, especially on the more cognitive demanding version of the training task for the AffeCT group, was insufficient to motivate most participants. Engagement in cognitive training tasks should therefore be motivated by providing appropriate incentives to exert cognitive effort. The incentives are not limited to monetary incentives or other rewards; the relative value of 'training' could be increased by changing adolescents' mindset about the benefits of a specific training regime (Yeager et al., 2022). For example, interventions that emphasise a growth mindset, which centres on the belief that ability (e.g., cognitive ability) is not fixed but can be enhanced, have been shown to be effective in reducing stress and improving academic performance in adolescents aged 13-21 years (Yeager et al., 2022).

Future work should seek to improve adolescents' engagement with the training programmes to ensure that it reaches the wider population and maximises its benefits. For example, the app-based training described in Chapter 4 is easy to disseminate and can therefore be delivered at scale at relatively low cost. This means that even small and short-term benefits could potentially be meaningful if they can be delivered at the population level. One way to boost engagement and adherence to the training programme among this age group is through gamification. Gamification provides a medium that captures the attention of adolescents, encouraging both attentional engagement and motivation to increase training rate (Lumsden et al., 2016).

Co-designing interventions with adolescents is another way to improve engagement. To create training programmes that young people will find engaging and will continue to use, young people themselves will need to be included in the development of the intervention (Yeager et al., 2018). By co-designing interventions with young people, more engaging, feasible, acceptable and effective interventions may be produced (Bevan Jones et al., 2020). If engagement with cognitive training can be further boosted through gamification and other incentives, these benefits may be extended beyond the period immediately following training.

5.4 Wider applications

5.4.1 Implications for public health

A proportion of the research presented in this thesis was conducted and written up during the COVID-19 global pandemic. This provides an opportunity to discuss how findings from this thesis, together with evidence from developmental science, could inform public health policy and practices. During the pandemic, there was widespread implementation of social distancing measures around the world, including temporary closure of public recreational sites and schools, with the aim to limit face-to-face interactions to prevent spread of the virus. While many people adhered to the government guidelines, some did not.

Adolescence is a period of pronounced social reorientation that is associated with heightened sensitivity to peer rejection and peer influence (Chapter 1). Thus it could be particularly challenging for adolescents to adhere to some of the social distancing rules. For example, as described in Section 1.3.2, a large body of research has demonstrated that adolescents are particularly susceptible to peer influence, especially in the context of risk-taking behaviour, such as dangerous driving, smoking and drinking (Eaton et al., 2012; Tomova & Pessoa, 2018). However, adolescent peer influence does not always have negative consequence. Adolescents have been shown to be more socially influenced than adults to engage in prosocial behaviours – particularly females (Foulkes et al., 2018) and are more likely to volunteer in the community if they are told that their peers do the same (Choukas-Bradley et al., 2015). As described in Chapter 2, compared to older adolescents, younger adolescents were more socially influenced when their peers rated social scenarios to be more prosocial and less antisocial than they did. This has implications for public health behaviours as this demonstrates that peer influence could be used to harnessed to promote prosocial behaviours (or reduce antisocial behaviours) in the context of public health (Andrews et al., 2020).

5.4.2 Implications for adolescents' mental health

As described in Chapter 1, adolescence represents a time of increased vulnerability to mental health problems. Even brief and relatively mild mental health difficulties can cause significant and long-lasting disruptions to a young person's development. This is often associated with impairments in social functioning, educational attainment, substance misuses and negative outcomes in adulthood (Gibb, Fergusson & Horwood, 2010). Therefore, an increased focus on adolescence, a developmental period characterised by both elevated risk but also a potentially enhanced ability to benefit from interventions, has the potential to greatly impact upon health, productivity and social outcomes in the society (reviewed in detail in McGorry, Goldstone, Parker, Rickwood, & Hickie, 2014).

Instead, the UK mental health system is arguably weakest at this point, partly due to the fact that it is structured around legal categorizations of adulthood. There are substantial differences between child and adolescent versus adult mental health services, such as treatment approaches and the extent to which mental health is considered from a developmental perspective, in which mental illness is more likely to be characterized by co-morbidity and changing patterns of symptoms (McGorry et al., 2014). However, many adolescents requiring continuation of mental health care after reaching 18 years do not successfully transition to adult mental health services. This may be particularly detrimental at a period in life at which the individual is still developing and often making important developmental transitions such as leaving home and living independently for the first time.

The majority of mental illnesses have their onset before the age of 24 years (Kessler et al., 2007). Many of the cognitive processes, and their associated neural systems, that undergo pronounced development during adolescence (see Chapter 1) are implicated in mental illnesses, for example, motivational processing and learning (Maia & Frank, 2011), compromised cognitive control (Luna & Sweeney, 2004) and difficulty regulating affective responses (see Section 1.4). Therefore, increasing our understanding of developmental changes of these cognitive processes, and how they vary between individuals, may provide insight into why adolescence is a period of elevated mental health vulnerability, who may be most at risk and how best to design interventions (Kadosh, Linden, & Lau, 2013). In particular, affective control is still developing during adolescence and evidence suggested improvements in affective control are associated with a reduction in mental health difficulties (see Chapter 4). Affective control therefore constitutes a promising target for prevention and early intervention. A better understanding of individual differences in the developmental trajectories of emotional regulation processes and affective control, and their associated neural systems, could be useful for determining when such interventions may be most effective.

5.5. Conclusion

Adolescence is a period of social reorientation in which individuals become more sensitive to socially and emotionally salient stimuli in the environment. Adolescence has also been described as a time of "storm and stress" (Hall, 1904), and is a period of increased vulnerability to mental health problems (Giedd, Keshavan & Paus, 2008). This thesis investigated the developmental changes of social cognitive processes in adolescence and examined how social cognitive training effects adolescents' social and cognitive processing and their mental health. The findings reveal adolescence to be a period that is characterised by heightened propensity to prosocial and antisocial influence, thus highlighting the potential of social emotional training in reducing susceptibility to antisocial influence. The thesis also demonstrated that it is possible to improve affective control in adolescence, and that benefits from training are related to reduction in mental health difficulties in adolescence.

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APPENDICES

A1. Appendix for Chapter 2

Method

Full list of prosocial scenarios

Visit a friend when they are ill

Care for a friend when they are ill

Give up your seat for a friend on the bus

Give up your seat for a family member on the bus

Give up your seat to a stranger on the bus

Give up your seat for a friend on the train

Give up your seat to a stranger on the train

Carry a friend's bag for them

Carry a family member's bag for them

Make a friend a birthday card

Make a family member a birthday card

Buy a friend a birthday card

Buy a family member a birthday card

Stand up for a classmate when they are being teased

Defend a classmate when they are being bullied

Give something you like to charity

Lend a friend your favourite book

Let a friend go ahead of you in a queue

Let a classmate go ahead of you in a queue

Lend a friend your favourite clothes

Raise money for charity

Buy a friend a birthday present

Give money to charity

Show a stranger where to go if they are lost

Make a friend a present

Make a family member a present

Offer to help around the house

Lend a friend money

Lend a family member money

Volunteer for a charity

Help a stranger if they have fallen

Help a friend with their schoolwork

Help a classmate with their schoolwork

Share your revision notes with a friend

Share your revision notes with a classmate

Like a friend's post on Facebook

Compliment a family member

Message a friend to see how they are

Sponsor a friend for charity

Sponsor a classmate for charity

Sponsor a family member for charity

Full list of antisocial scenarios

Shout at a family member in an argument

Shout at a friend in an argument

Take something that doesn’t belong to you

Laugh at a friend when they make a mistake

Laugh at a classmate when they make a mistake

Laugh at a family member when they make a mistake

Look through a friend's phone without asking

Look through a classmate's phone without asking

Look through a family member's phone without asking

Push in front of friend in a queue

Gossip about a classmate

Gossip about a friend

Gossip about a friend online

Talk about a friend behind their back

Talk about a classmate behind their back

Laugh at someone's clothes

Laugh at someone's work

Look through a family member's room when they are away

Make a mess at home and not clear it up

Ignore a friend online

Ignore a friend's Whatsapp messages

Make fun of a friend

Make fun of a classmate

Tease a friend

Tease a family member

Tease a classmate

Tell someone's secret

Trip up a classmate as a joke

Trip up a friend as a joke

Hit a friend when you are angry

Lie to a teacher to get out of trouble

Lie to a parent to get out of trouble

Write or draw on a desk at school

Answer back to a teacher in a rude way

Pretend you are someone else online

Ignore what a teacher asks you to do

Blame a friend for something you did wrong

Blame a classmate for something you did wrong

Blame a family member for something you did wrong

Swear at a friend in an argument

Swear at a family member in an argument

A2. Appendix for Chapter 3

Supplemental Information

Sensitivity analyses

We ran a series of sensitivity analyses, or Control Models (CMs), to account for a number of potentially important factors that could have influenced our findings. We did this by including an additional regressor to the best fitting model for each dependent variable and then using Type III Wald χ^2 tests to test the robustness of our findings. Additionally, one CM used Type III Wald χ^2 tests on the best fitting model excluding a subset of trials containing extreme values in the relevant dependent variable. The CMs for both Model 1 and Model 2 were as follows:

CM1) Age, as well as its interaction with social condition. Age has consistently been found to be a predictor of decreased social influence (Knoll et al., 2017; 2015; Foulkes et al., 2018) and was therefore included to account for potential variance in social influence explained by participants of different ages (fixed effect). We additionally interacted age with social condition, as age differences in antisocial and prosocial behaviour have been previously reported (Ahmed et al., 2020).

CM2) Gender (female = 0) and CM3) IQ, were added based on literature suggesting gender differences in social processing (e.g. Flannery & Smith, 2016), effects of initial preferences on social influence (e.g. Wei et al., 2016) and effects IQ on social cognition (Choudhury, Blakemore & Charman 2006). Gender was additionally interacted with social condition, as gender differences in prosocial and antisocial behaviour have been previously reported (Ahmed et al., 2020).

CM4) Number of homework assignments completed, and CM5) Total attendance were added as covariates as they could reflect participation in the training programmes. Any conclusions about the effectiveness of the interventions should consider these factors.

CM6) Testing group size at pre-training, CM7) Testing group size at post-training, and CM8) Average training group size, were added based on literature suggesting that social influence could be influenced by the mere presence of peers (e.g. van Hoorn et al., 2016 and Gardner & Steinberg, 2005).

CM9) Excluding extreme values, as determined by excluding trials in rating 1 and change in rating with a z-score > 4 (Chierchia et al., 2020). This CM did not converge during Model 2 sensitivity analyses, and thus the random effects structure was progressively simplified, with the final model only including social condition and testing session random slopes to vary by participant.

C10) First Ratings (Model 2 only) was included to account for differences in social influence that could emerge from baseline ratings (Knoll et al., 2015). Given that first ratings varied across social condition differently across age and gender in our Model 1 CM1 and CM2 (see Figure S1 and S2), we interacted these terms with first ratings in the Model 2 CM1 and CM2.

Significant omnibus tests were robust to all control models.

Based on a reviewer's suggestion, we also ran an exploratory analysis predicting how self-control differed between interventions. We compared nested linear mixed effects models using data collected using the emotional control and inhibition subscales of the Behaviour Rating Inventory of Executive Functioning (BRIEF), which are both relevant to self-control. The results show that a model including the type of intervention as a predictor does not explain additional variance in either inhibition ($\chi^2(2) = .22$; $p = .896$) or emotional control ($\chi^2(2) = 2.70$ $p = .259$). Therefore, mindfulness training did not seem to influence these aspects of self-control measured by the BRIEF differently from the active control training.

Assessment criteria for rating videotapes

Instructions. This adherence checklist has each key element for each lesson so the rater can tick off that it was delivered. There are a few things in each lesson which are MUST HAVES, and there are a lot of NICE TO HAVES. ** are placed next to the things that are the MUST HAVES. Everything else is NICE TO HAVES. For example, a teacher should not be evaluated negatively if, say, they don't use the black-cab example at the start. They might decide this would not connect with their class and leave it out. On the other hand, they must do the 'hands' activity, or an equivalent, as this is the first real practice that kids do. The teacher might begin a lesson with a review of home practice. This can be very effective when enough pupils have done the home practice and the teacher is able to harvest feedback, but it is not a requirement.

Mindfulness Training Checklist

Lesson 1

☐ **Clear introduction and rationale

☐ **Teacher tailors the introduction to the group, in terms of key dimensions such as engagement/motivation, level, size, conscript vs volunteer

☐ Black Cab example

☐ Identify neuroscientific link between changes in the brain and amount / frequency of practice ie. brain training

☐ **Mindfulness of hands practice.

☐ How the mind and body are inextricably linked. Mind/body connection is taught / illustrated.

☐ Kung Fu Panda clip is used and facilitates discussion about it

☐ **brief .b practice. May only be a few seconds long, but if shorter evidence that it builds on earlier mindfulness practices.

☐ Getting out of a ‘bad place’

☐ **[Lack of] Mind control exercises – Polar Bear

☐ Examples of Mindfulness being used which connect with the class.

☐ **Teacher facilitates *intrinsic motivation* for participating in the course without being prescriptive about outcomes. Emphasis on **possibilities**

☐ Ground rules are clear

☐ Clear explanation of ‘Searchlight of attention’ (using torch)

☐ **Practice 1 ‘Play attention’

☐ **Puppy explanation

☐ **Practice 2 – puppy training using a 1- or 2-minute silence

☐ Finger breathing practice and inquiry

☐ **Home Practice

Lesson 2

☐ ‘My mind feels, my body feels…’ practice

☐ Animal minds explanation e.g. monkey, elephant, hippo

☐ **Discussion of importance of –‘turning towards’ the animal mind with curiosity and kindness.

☐ **FOFBOC practice and inquiry

☐ What is the point? Explanation

☐ **Home practice

Lesson 3

☐ Worry – introduction

☐ **7/11 practice

☐ **Two modes of mind

☐ ‘The mind tells stories...’ explanation

☐ ‘Sam was on the way to school’ activity and discussion

☐ **Scenario discussion

☐ **Overthinking and rumination explanation.

☐ Home practice discussion

☐ **Beditation practice and inquiry

☐ **Home practice

Lesson 4

☐ **Autopilot explanation

☐ **‘Savouring chocolate’ eating practice and inquiry

☐ **Anticipation for the ‘Chilli’ eating practice and inquiry

☐ ‘Tingling of likes and dislikes’ explanation

☐ **Explanation of gap between stimulus and response

☐ **‘.b’ practice

☐ **Home practice

Lesson 5 (Highly dependent on space available. This checklist is not used in the summative adherence scores and is collected for the record only.)

☐ Home practice and recap of practices so far

☐ **Introduction to moving mindfully

☐ **Standing practice

☐ Explanation of ‘flow’ or being ‘in the zone’

☐ Video clip

☐ **Mindful walking and inquiry

☐ **Home practice

Lesson 6

☐ Introduction 'How is the traffic in your mind'

☐ Animation clip

☐ **Mindfulness of sounds and thoughts practice: 'Stepping Back' and inquiry

☐ Links between repetitive thought and neural pathways

☐ **'Thought buses' explanation and activity

☐ **'How to stay at the bus stop' Standing practice

☐ **Home practice

Lesson 7

☐ Introduction – Difficulties happen to everyone.

☐ **In what situations do you feel stress?

☐ ** What happens in your mind, body and actions when you are stressed

☐ Explanation of stress and its' effects.

☐ **Experience of Stress Practice and inquiry

☐ **Drawing of stress signature

☐ **Camp-fire practice / or other short 'settling' practice

☐ **Home practice

Lesson 8

☐ **Introduction - mentioning the term 'heartfulness'

☐ **Grape eating practice (or other fruit)

☐ **'Since the day you were born…' activity

☐ Video clip – Alice Hertz-Sommer and/or Soul Pancake clip

Student Success Training Checklist

Lesson 1

☐ Introduction to SSS

☐ Building a caring, supportive and encourage community using the Looks Like, Sounds Like, Feels Like activity

☐ Explain the maze activity and go through optimism cheer

☐ Talk through the Imagine slide

☐ Explain how the term Kaizen is used.

☐ Using the Austin's Butterfly video, explain to students how Austin has improved his initial drawing

☐ Look Good/Feeling Good sheet - show examples of goals and plan.

Lesson 2

☐ Recap what they learned in the last session

☐ Show goose- clip and explain symbolism of V- Shape

☐ Looking Good/ Feeling Good sheet - rate progress and hear about students' successes. Remind them how you expect them to listen (Eyes, Ears, Heart)

☐ Brain Gym - remind students that taking breaks and moving to help boost concentration

☐ Students to read '5 test taking strategies' and discuss which one they are already familiar with and which ones they use or might like to use in the future

☐ Revisit optimism cheer and complete matching activity together

☐ Revisit imagine slide

☐ Complete seven keys sheet

☐ To understand the concept of method if loci using the Homer Simpson example. Help students to memorise the food items

☐ Go through goal setting exercise and for students to practice listening skills and develop empathy

☐ Show pyramid slide

☐ Kaizen activity

Lesson 3

☐ Recap what they learned in the last session

☐ Go through Looking Good/ Feeling Good sheet

☐ Goal reporting, progress monitoring, success sharing and goal setting

☐ Show clip from Disney's Mulan

☐ Revisit optimism cheer

☐ Looks Like, Sounds Like, Feels Like activity

☐ Talk through Imagine slide

☐ Play clip of babies' to music and explain Keep Kool Tunes

☐ Brain gym

☐ Boosting memory (slide 18) activity

☐ Go through seven keys sheet

☐ Goal setting

☐ Show pyramid slide

☐ Revisit Kaizen task

Lesson 4

☐ Recap what they learned in the last session

☐ Go through Looking Good/ Feeling Good sheet

☐ Goal reporting, progress monitoring, success sharing and goal setting

☐ Revisit optimism cheer

☐ Talk through Imagine slide

☐ Brain gym

☐ Explain story outlines

☐ Play Toy Story clip and discuss the 'Middle' of the story

☐ Encouraging things to say and do activity

☐ Go through seven keys sheet

☐ Looks Like, Sounds Like, Feels Like activity

☐ Show pyramid slide

☐ Revisit Kaizen task

☐ Goal setting

Lesson 5

☐ Recap what they learned in the last session

☐ Go through Looking Good/ Feeling Good sheet

☐ Goal reporting, progress monitoring, success sharing and goal setting

☐ Revisit optimism cheer

☐ Talk through Imagine slide

☐ Brain gym

☐ Story outlines and student story telling activity

☐ Go through positive self-talk worksheet

☐ Revisit keep kool tunes

☐ Go through seven keys sheet

☐ Looks Like, Sounds Like, Feels Like activity

☐ Show pyramid slide

☐ Revisit Kaizen task

☐ Goal setting

☐ Preview booster session

Lesson 6

☐ Recap what they learned in the last session

☐ Go through Looking Good/ Feeling Good sheet

☐ Goal reporting, progress monitoring, success sharing and goal setting

☐ Revisit optimism cheer

☐ Talk through Imagine slide

☐ Brain gym

☐ Show video of animals collaborating and discuss with students

☐ Revisit keep kool tunes

☐ Go through seven keys sheet

☐ Looks Like, Sounds Like, Feels Like activity

☐ Show pyramid slide

☐ Revisit Kaizen task

☐ Goal setting

Lesson 7

☐ Recap what they learned in the last session

☐ Go through Looking Good/ Feeling Good sheet

☐ Goal reporting, progress monitoring, success sharing and goal setting

☐ Revisit optimism cheer

☐ Talk through Imagine slide

☐ Brain gym

☐ Story outlines and student story telling activity

☐ Positive self-talk worksheet

☐ Revisit keep kool tunes

☐ Go through seven keys sheet

☐ Looks Like, Sounds Like, Feels Like activity

☐ Show pyramid slide

☐ Revisit Kaizen task

☐ Goal setting

☐ Preview booster session

Lesson 8

☐ Recap what they learned in the last session

☐ Go through Looking Good/ Feeling Good sheet

☐ Goal reporting, progress monitoring, success sharing and goal setting

☐ Revisit optimism cheer

☐ Talk through Imagine slide

☐ Brain gym

☐ Discuss strategies to manage test anxiety

☐ Go through seven keys sheet

☐ Looks Like, Sounds Like, Feels Like activity

☐ Show pyramid slide

☐ Revisit Kaizen task

☐ Goal setting

Supplemental Tables

Table S1. Full list of social influence task scenarios

Prosocial scenarios	**Antisocial scenarios**
Visit a friend when they are ill	Shout at a family member in an argument
Care for a friend when they are ill	Shout at a friend in an argument
Give up your seat for a friend on the bus	Take something that doesn't belong to you
Give up your seat for a family member on the bus	Laugh at a friend when they make a mistake
Give up your seat to a stranger on the bus	Laugh at a classmate when they make a mistake
Give up your seat for a friend on the train	Laugh at a family member when they make a mistake
Give up your seat to a stranger on the train	Look through a friend's phone without asking
Carry a friend's bag for them	Look through a classmate's phone without asking
Carry a family member's bag for them	Look through a family member's phone without asking
Make a friend a birthday card	Push in front of friend in a queue

Make a family member a birthday card	Gossip about a classmate
Buy a friend a birthday card	Gossip about a friend
Buy a family member a birthday card	Gossip about a friend online
Stand up for a classmate when they are being teased	Talk about a friend behind their back
Defend a classmate when they are being bullied	Talk about a classmate behind their back
Give something you like to charity	Laugh at someone's clothes
Lend a friend your favourite book	Laugh at someone's work
Let a friend go ahead of you in a queue	Look through a family member's room when they are away
Let a classmate go ahead of you in a queue	Make a mess at home and not clear it up
Lend a friend your favourite clothes	Ignore a friend online
Raise money for charity	Ignore a friend's Whatsapp messages
Buy a friend a birthday present	Make fun of a friend
Give money to charity	Make fun of a classmate
Show a stranger where to go if they are lost	Tease a friend

Make a friend a present	Tease a family member
Make a family member a present	Tease a classmate
Offer to help around the house	Tell someone's secret
Lend a friend money	Trip up a classmate as a joke
Lend a family member money	Trip up a friend as a joke
Volunteer for a charity	Hit a friend when you are angry
Help a stranger if they have fallen	Lie to a teacher to get out of trouble
Help a friend with their schoolwork	Lie to a parent to get out of trouble
Help a classmate with their schoolwork	Write or draw on a desk at school
Share your revision notes with a friend	Answer back to a teacher in a rude way
Share your revision notes with a classmate	Pretend you are someone else online
Like a friend's post on Facebook	Ignore what a teacher asks you to do
Compliment a family member	Blame a friend for something you did wrong
Message a friend to see how they are	Blame a classmate for something you did wrong
Sponsor a friend for charity	Blame a family member for something you did wrong

Sponsor a classmate for charity	Swear at a friend in an argument
Sponsor a family member for charity	Swear at a family member in an argument