THE ADOLESCENT SOCIAL NETWORK: AN INVESTIGATION OF SOCIAL TIE VARIABLES AS PREDICTORS OF DEVELOPING ECONOMIC DECISION-MAKING AND PERSPECTIVE-TAKING

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A thesis submitted to the University of Birmingham for the degree of

DOCTOR OF PHILOSOPHY

School of Psychology

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May 2020

Abstract

This thesis asks three questions: Do directed and dyadic social tie variables predict adolescent decision-making in economic games? If so, does the strength of this prediction alter with age? If so, what are the cognitive mechanisms driving this development? We combine social network methods and game theory to investigate these three questions in four studies. In study 1, we use the Trust Game to test whether adolescent trust and expected reciprocity is predicted by directed and dyadic social tie variables (*N* = 169, *Nnetworks* = 11, *range* = 16-19). In study 2, we test whether adolescent cooperation in the Prisoner's Dilemma is predicted by directed and dyadic social tie variables, and whether this association alters with age (*N* = 169, *Nnetworks* = 11, *range* = 16-19). In study 3, we employ social network methods to investigate whether late adolescents predict the strength of their relationships more accurately than early adolescents (*N* = 918, *nNetworks* = 58, *age range* = 12-18). Finally, in study 4, we use a novel Dictator Game to test whether directed and dyadic social tie variables predict adolescent giving and expected receiving, whether this association alters with age, and whether late adolescents predict the allocations of their peers more accurately than early adolescents (*N* = 292; *Nnetworks* = 24; *age range* = 12 – 18). We found that directed and dyadic social tie variables were robust predictors of economic decision-making in the Trust Game, Prisoner's Dilemma, and Dictator Games. The strength of this association altered with age in the Prisoner's Dilemma, and Dictator Game, but in the opposite of the hypothesised direction. Finally, we found that late adolescents more accurately predicted the strength of their social relationships than did early adolescents, but no evidence was obtained for a difference when predicting the allocative decisions of classmates in the Dictator Game. This thesis advocates for the utility of the social network approach as a tool for understanding adolescent decision-making at the level of the most integral unit of social interaction: the dyad.

I dedicate this thesis to adolescents – both those I have interacted with and the adolescent I once was. They are inquisitive, kind, interesting, funny, and strange people. My work on this PhD has given me a new appreciation for this bewildering period of life.

Acknowledgements

No man is an island, especially not me. There are many people to thank for their contribution to my life, and their contribution to my work. Both were needed to complete this thesis.

The first piece of advice I received when starting my PhD was that every candidate was smart enough to complete the PhD, otherwise they would not be on the programme, but that the real challenge was dealing with everything else life throws at you during your studies. That turned out to be the most important advice I received, and without the following, I would not have a PhD. I thank Nuala Pollard for teaching me the importance of grasping opportunities, I thank Peter Pollard for teaching me how to solve problems, and I thank Mary and Anthony Pollard for their support, humour, and general nonsense. I also thank them for their financial support; it's difficult to do a PhD or share your research in nice places without money. My first BSc thesis acknowledged the contribution of my recently departed grandparents. I would like to do so again now that they are unfortunately all departed. I thank John and Colette Byford for teaching me to be kind to others and dedicated to my interests. I also thank John and Shirley Pollard for teaching me to be curious, explore the world, and to remember that many crises can be solved with a family gathering. I would also like to thank my friends. Those at home, who reminded me that there's an often more fun and interesting world beyond the lab. Those abroad, who I would never have found or shared amazing experiences with without a jet-setting research life. Those in various universities, who continue to demonstrate the amazing fact that random people from around the country (or world) can be thrown together and have enough in common to maintain friendships for a decade. Those in the PhD office, who shared my struggles and successes. I would like to acknowledge four of these friends in particular: Aimee McMullan (and Tom), who was such an important support to me in Birmingham; David Morris, who was the first PhD student to reach out to me and was a source of constant reassurance; Madhronica Sardjoe, my incredible housemate whose kindness, and sense of humour have kept me going in my key write-up year; and Miriam Hollarek, who is my best friend in Amsterdam, and my first best friend that I met through work. Finally, I want to thank Carrie Dawson for her support when I didn't know what I was doing, and Anna Pintér for her essential support during the most stressful year of my life.

Of course, none of this thesis would have been possible without those I have worked with. When starting a PhD, you don't know what to expect, and all I knew was that the supervisor-student relationship was crucial. There are surely many great supervisors, but I am convinced there are none better than Stephanie Burnett Heyes. She is one of the smartest, kindest, funniest, and insightful people I have ever met. I have seen these individual qualities in others, but not all in the same person. I am indebted to her for what she has given my life. I came to the University of Birmingham with deep anxieties that I didn't belong in the research environment, I will leave with full confidence that I can be an effective researcher. I also thank Ian Apperly, my second supervisor, who gave me some of the most insightful advice I've ever received on how to approach research. Advice I still share with new PhD students. I must also thank my first psychology teacher, Pete Waring. It sometimes surprises people to hear that I originally had no plan to go to university, even for an undergraduate degree. It did not surprise me as an A level student with a D and an E. Mr Waring managed to inspire me to get my first ever B in an exam. Evidently, things dramatically escalated from there. I thank him for saving me from Plan A – working at Sainsbury's. I also thank my other mentors: Caroline Bowman, for teaching me how exciting the scientific process and unexpected results can be; and Denis Schluppeck, for being patient enough to make me a competent coder. Further thanks must go to the research teams I've interacted with. The social networks lab at ETH Zürich, who I had the good fortune to spend a week with in my first year. Many of the early designs of my experiments were worked through with them, and their support and advice were essential - especially from Per Block. I thank Lydia Krabbendam's #SOCONNeCT team in VU Amsterdam, who I was extremely lucky to spend a year with. They gave me excellent advice and showed me how fulfilling it is to work as part of a team studying adolescent social networks. I must also thank the ESRC and Leverhulme trust for their financial support, which allowed me to pursue these research experiences. I thank all the students I have worked with during my research. I did not collect nearly 1000 students' data by myself. I am thankful to the numerous undergraduate and master's students who helped make this research possible and were also fantastic friends to me during this period of my life. It is wonderful to have so many friends with the same professional interests all around the world.

I reserve the final word of thanks for the adolescents themselves that took part in these experiments. Science can be fun, it can be interesting, but it is not always. Especially when sitting in a room completing a battery of questionnaires. I thank them for their patience, their questions, and their insight. During my PhD, I have made a habit of speaking regularly to adolescents both as a researcher and a presenter of adolescent psychology. What I have learnt during this time is that there is no better reviewer than an adolescent. They know what is good about your experimental design, they know what is bad. I thank them for the insight they have given me into my own research, and into their minds.

A three-page acknowledgement may seem long, but it took at least three pages worth of people to complete this thesis. There are not so many opportunities in life to record the contributions others made to your own achievements. For my thesis, this is that record.

Statement of Authorship

All chapters in the presented thesis were authored by David Pollard (DP).

Chapter 2

Research described in Chapter 2 was conceptualised by DP and developed in collaboration with Stephanie Burnett Heyes (SBH). Data collection was conducted by AD, CK, and JK. Data analyses were principally conducted by DP. Further significant contributions were made by AD who contributed to the analyses in Appendix A.

Chapter 3

Research described in Chapter 3 was conceptualised by DP and developed in collaboration with SBH. Data collection was conducted by DP, NM, JG, NM, DW, and LM. Analyses were conducted by DP.

Chapter 4

Research described in Chapter 4 was conceptualised by DP and developed in collaboration with SBH. Data collection was conducted by DP, SC, SBH, NM, JG, NM, DW, LM, AD, CK, and JK. Analyses were conducted by DP.

Chapter 5

Research described in Chapter 5 was conceptualised by DP and developed in collaboration with SBH. Data collection and analyses were conducted by DP. Further significant contributions to the design of the study were made by Ian Apperly.

Author's Note: Throughout the thesis, 'we' is used as opposed to personal pronouns to reflect the collaborative nature of the research.

Conference Proceedings

Chapter 2

Pollard, D., Apperly, I.A., & Burnett Heyes, S. Navigating the teenage social network: does the capacity for social cognition develop during adolescence? In N. Lee (Chair), *Cognition in Context: Social Networks and Social Cognition in Adolescence*. Symposium conducted at the 2nd International Convention of Psychological Science. Vienna, 2017.

Chapter 3

Pollard, D., Apperly, I.A., & Burnett Heyes, S. Split or Steal? Adolescent Social Network Structures Predict Decision-Making in a Modified Prisoner's Dilemma. In B. Güroğlu (Chair), *Adolescent in a social world: Role of peer and parent relationships on social behavior and neural activation patterns across adolescence*. Symposium conducted at the 25th Biennial Meeting of the International Society for the Study of Behavioural Development**.** Gold Coast, 2018.

Chapter 5

Pollard, D., & Burnett Heyes, S. Peer Investment Decisions and Developing Social Inference in Adolescent Social Networks. In D. Pollard (Chair), *Navigating the Social Network in Late Childhood and Adolescence: Social and Economic Decision-Making in a Peer Context*. Symposium conducted at the 3rd International Convention of Psychological Science. Paris, 2019.

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Abbreviations

1pDG	1st Person Dictator Game
2pDG	2nd Person Dictator Game
2PP	2nd Person Perspective
3pDG	3rd Person Dictator Game
3PP	3rd Person Perspective
C	Competitor
dlPFC	Dorsolateral Prefrontal Cortex
E	Egoistic
EC	Empathic Concern
ECR-RC	Experienced in Close Relationships Scale-Revised
FAS-II	Family Affluence Scale II
fMRI	Functional Magnetic Resonance Imaging
IRI	Interpersonal Reactivity Index
KM	Kiddie Mach
LOTR	Life Orientation Test - Revised
mDG	Modified Dictator Game
MG-MRQAP	Multi-Group Multiple Regression with Quadratic Assignment Procedure
mPD	Modified Prisoner's Dilemma
MPFC	Medial Prefrontal Cortex
MRQAP	Multiple Regression with Quadratic Assignment Procedure
mTG	Modified Trust Game
P	Prosocial
PT	Perspective-taking

SNQ	Social Network Questionnaire
SVO	Social Value Orientation
TPJ	Temporoparietal Junction

Adolescence is a developmental period in which changes occur in both social cognition and the social environment (Pollard, Burnett Heyes & Apperly, 2010). While many past studies have attempted to track adolescent development in social cognition, a number of challenges have presented themselves. How does one measure developing social cognition in an authentic social context? How does one investigate the differing contributions of social environment and individual social cognition to task performance? And how does one disentangle distinct components of social cognition in order to determine their contribution to task performance?

Past research has given valuable insights into the development of adolescent social cognition using pure perspective-taking tasks (Dumontheil, Apperly & Blakemore, 2010; Symeonidou, Dumontheil, Chow & Breheny, 2016), and economic games (see Kilford, Garrett & Blakemore, 2016 for review). However, in order to control for the great variability in real-world social relationships, they have often done so in minimally social contexts. What this approach gives to the researcher in control, it loses in application to complex, authentic social environments. Social network analysis offers researchers the opportunity to investigate the development of decision-making within more authentic social contexts, which allows for the study of more complex and varied social relationships in a manner that better reflects participants' real social environment (van Atteveldt, van Kesteren, Braams & Krabbendam, 2018). Recently, researchers have increasingly combined social network analysis with game theory to investigate developing adolescent social cognition by using variables quantifying aspects of real-world social relationships and social network structures as predictors of behaviour in economic tasks (e.g. van den Bos, Crone, Meuwese & Güroğlu, 2018). Social tie variables, in particular, have the greatest applicability to the dyadic context of both relationships and strategic gameplay, and have been shown to predict decision-making in allocation games (Burnett Heyes et al., 2015; Harrison, Sciberras & James, 2011). Critically, these directed and dyadic social tie variables allow researchers to explore adolescent perspective-taking from differing adolescent perspectives, as depending on which member of the dyad serves as the reference point, these methods can be used to represent either the perspective of the participant (the ego) or their peer (the alter) on the relationship; when used in combination, dyadic variables can represent the shared perspective (mutual) of both dyad members. This element of the directed and dyadic social tie allows researchers to investigate the gap between how an individual's perception of the strength of their relationship contrasts with the actual strength of their relationship, as reported by both members of the dyad.

This thesis addresses three questions:

- [Q1] Do directed and dyadic social tie variables predict adolescent decision-making in economic games?
- [Q2] If so, does the strength of this prediction alter with age?
- [Q3] If so, what are the cognitive mechanisms driving this development?

In this thesis, I investigate trust, cooperation, giving, and reciprocation in economic games. Using versions of the Trust Game, Prisoner's Dilemma, and a set of Dictator Games, this thesis will explore whether social tie variables predict adolescent economic decision-making [Q1]. This framework has been employed in past studies using the Dictator Game as well as a physical effort task (Burnett Heyes et al., 2015; Harrison et al., 2011), and this thesis will investigate whether social tie variables are also robust predictors of decision-making in other economic games. Furthermore, this thesis will test whether these variables better predict late (vs. early) adolescent gameplay [Q2]. Prior work has found evidence that directed and dyadic social tie variables increasingly predict adolescent decision-making in the Dictator Game with increasing age (Burnett Heyes et al., 2015). This has been taken as cross-sectional evidence for the development of social decision-making during adolescence, potentially underpinned by the development of perspective-taking. However, it is still unclear whether this developmental trajectory will be observed in other games when using dyadic variables. Finally, using social network methods, I compare adolescent predictions of how their classmates view their shared relationship against how their classmates actually view their shared relationship, as well as predictions of how classmates allocate resources in a set of Dictator Games. These latter two studies will test whether late adolescents perceive the strength of their relationships, and the allocative strategies of their peers, more accurately than early adolescents (Q3). This will allow us to test whether the developing tendency of late adolescent social decision-making to be better predicted by social tie information is underpinned by a developing capacity to *infer* or *use* social information – two components of Theory of Mind, which have previously been delineated in the literature (Apperly, 2010).

1.1 The developing social adolescent

1.1.1 Brain

The development of the adolescent 'social brain' is well established in the literature. For example, seminal post-mortem research in the 1970s demonstrated that not all brain regions develop at the same rate or necessarily by early childhood (Huttenlocher, 1979; Huttenlocher, De Courten, Garey & Van Der Loos, 1983). The adolescent brain undergoes a significant reorganisation through changes in grey and white matter density, including in regions associated with social cognition (Mills et al., 2016; Tamnes et al., 2017). In addition, across a range of tasks asking adolescents to infer and judge communicative intentions, preferences, dispositions, and emotional responses to social situations, regions of the putative "social brain" are activated in an age-varying manner (for reviews see Burnett, Sebastian, Kadosh & Blakemore, 2011; Pollard, Burnett Heyes & Apperly, 2018; Will & Güroğlu, 2016).

1.1.2 Social environment

It is not only the adolescent brain that undergoes significant changes, but so too does the social environment. Teenagers inhabit a social space in which they navigate more complex, hierarchical networks inhabited by ever greater numbers of people with whom they share a great variety of relationships (Brown, 1990; Brown, Mory & Kinney, 1994; Pollard, Burnett Heyes & Apperly, 2018; Steinberg & Morris, 2001). Adolescents are active cultivators of their network as they strengthen or weaken their social ties according to a particular set of relationship features, including: friendship, reciprocity, intimacy, loyalty, commitment (Bigelow & La Gaipa, 1980; Youniss, 1982; Veenstra & Dijkstra, 2011; Wrzus, Hänel, Wagner & Neyer, 2012). Note that friendship is listed as a relationship feature as all friendships are relationships but not all relationships are friendships. This changing environment asks adolescents to solve more difficult social puzzles, store more social information, and use this social information more effectively (Pollard, Burnett Heyes & Apperly, 2018). Even adults with fully developed social capacities struggle to make accurate Theory of Mind inferences about people from different cultures, especially in unfamiliar contexts with unfamiliar social roles and relationships (Perez-Zapata, Slaughter & Henry, 2016). It therefore stands to reason that adolescents will continue to develop their ability to make inferences about others as they inevitably interact with unfamiliar social contexts, roles, and relationships.

1.1.3 Cognitive ability

Adolescent development is not confined to physical changes in the brain, or to changes in the social environment, but also to related changes in their cognitive capabilities. Executive function, which contributes significantly to social cognition in adults (McCleery, Surtees, Graham, Richards & Apperly, 2011;Samson, Apperly, Kathirgamanathan & Humphreys, 2005), undergoes a number of changes throughout adolescence, including: inhibitory control, strategic behaviour, working memory, processing speed, and decision-making (Anderson,

Anderson, Northam, Jacobs & Catroppa, 2001; Hooper, Luciana, Conklin & Yarger, 2004; Leon-Carrion, Garcia-Orza & Perez-Santamaria, 2004; Luciana, Conklin, Cooper & Yarger, 2005; Luna, Garver, Urban, Lazar & Sweeney, 2004). Furthermore, developmental research into Theory of Mind demonstrates that there is a detectable improvement in mindreading use through adolescence, which cannot solely be attributed to improvements in executive function. In one study, participants (*ages* = 7-27) played the director task, which requires participants to move items around an array according to the instructions of a director who cannot see all of the items (social condition), or according to the colours of the compartments (non-social) (Dumontheil, Apperly & Blakemore, 2010; Epley, Morewedge & Keysar, 2004). The results indicated that improvements in accuracy were present in both the social and non-social conditions during early adolescence. There was a significant difference in accuracy between middle-late adolescents (*ages* = 14-17) and adults in the social condition, but no significant difference in accuracy between middle-late adolescents and adults in the non-social condition. The authors suggest that the initial parallel improvement in accuracy in the social and non-social conditions for early adolescents represents the development of executive functions, such as inhibition and working memory (Anderson, Anderson, Northam, Jacobs & Catroppa, 2001; Casey et al., 1997; Romine & Reynolds, 2005; Tamm, Menon & Reiss, 2002). They further propose that the differences in accuracy between middle-late adolescents and adults that are particular to the social condition are attributable to a developing Theory of Mind capacity, which extends beyond executive function capacities. This finding was replicated in an eye-tracking study using the same paradigm (Symeonidou, Dumontheil, Chow & Breheny, 2016).

1.2 Economic games as measures of developing adolescent social cognition

Aside from these studies, few published experiments have shown evidence for the development of pure social perspective-taking in late childhood and adolescence (for another exception, see Devine & Hughes, 2013). Potentially this is because it is difficult to develop developmentally sensitive Theory of Mind tasks for which adolescents are not at ceiling, and which make minimal executive and linguistic demands or allow these to be matched across social and non-social conditions (Apperly, 2010; Pollard, Burnett Heyes & Apperly, 2018). However, there is an alternative approach, which studies the development of adolescent social cognition through the prism of game theory (Kilford, Garrett & Blakemore, 2016; Sutter, Zoller & Glätzle-Rützler, 2019). Game theory is the study of human interaction through the use of games. This field of study has a rich history that investigates every level of human interaction from dating to nuclear war by studying the principles that emerge from the rational and non-rational gameplay of carefully calibrated games (Binmore, 2007).

Many games have been used to investigate the development of social cognition in adolescents. This thesis will focus on the Trust Game (Berg, Dickhaut & McCabe, 1995), Prisoner's Dilemma (Poundstone, 1993), and Dictator Game (Kahneman, Knetsch & Thaler, 1986). These games were selected because they access key relationship features, which become more salient to adolescents: trust, reciprocity, cooperation, and altruism (Bagwell & Schmidt, 2011; Rilling & Sanfey, 2011). These games access these relationship features in distinct ways, but they also overlap in important aspects of their design. The Trust Game asks players to what extent they will trust and reciprocate trust within a sequential interaction. One player takes the role of the trustor and must decide how much to entrust to the trustee, which might be decided based on preferences, for example, return, equity and reciprocation, or individual and dyadic factors, including altruism, perceived trustworthiness and the strength of the prior relationship. From the perspective of the trustee, their choice to reciprocate is a type of Dictator Game as the original trustor has no option to reject or modify what is being returned to them (Camerer, 2003). Similarly, the Prisoner's Dilemma asks players to what extent they will cooperate or defect within a simultaneous interaction. Both players decide whether to share or steal an amount at the same time. Although the common terminology used to describe decisions made within the Prisoner's Dilemma refers to cooperation and defection, in principle, this game is structurally similar to a Trust Game as participants must decide whether to trust the other player to reciprocate their cooperation (Rilling & Sanfey, 2011). The key difference between the games for the purposes of the following studies is that, traditionally, the Trust Game takes place in a sequential context and the Prisoner's Dilemma takes place in a simultaneous context. Therefore, in the Trust Game, trustors know that the trustee will see the initial investment before making their decision and the trustees will know how much they have been entrusted with. This design may consequently make lesser demands on participants' perspective-taking when compared to a simultaneous game in which both participants have no information regarding the strategy of the other player. Subsequently, the Trust Game and Prisoner's Dilemma game were selected as games that test similar relationship features but in contexts that differently access perspective-taking, which has been linked to differences in adolescent decision-making (Kilford et al., 2016; Rilling & Sanfey, 2011; Sanfey 2007; van den Bos et al., 2010). Finally, the Dictator Game asks one player to what extent a participant will give to another player who has no power to influence or respond to their offer. This game has previously been used to demonstrate that directed and dyadic social tie variables predict allocation in adult and adolescent networks (Brañas-Garza et al., 2010; Burnett Heyes et al., 2015; Goeree, McConnell, Mitchell, Tromp & Yariv, 2010; Jones & Rachlin, 2006; Leider, Möbius, Rosenblat & Do, 2009). The Dictator Game is not designed to be an interaction in the same way as the Trust Game or Prisoner's Dilemma, but it is the only game in which decisions have been repeatedly been shown to be predicted by directed social tie and dyadic variables within whole-network contexts.

1.2.1 Trust Game

The Trust Game involves two players: the trustor, and the trustee. The trustor is given a stake, and they must choose how much of this stake to entrust to the trustee. The amount they entrust is multiplied (e.g. tripled) before being given to the trustee. The trustee must then decide how much of the tripled stake to return to the investor. Larger investment amounts offer greater opportunity for larger returns but require the trustor to trust that the trustee will not behave selfishly and retain all of the investment. Empirically, mature strategies tend towards cooperation, as late adolescent and adult trustors tend to entrust at least half of the original stake (Johnson & Mislin, 2011; Tzieropoulos, 2013; van den Bos et al., 2011). Late adolescent and adult trustees also tend to return slightly more than the original investment, resulting in a near-even split of resources (Buchan, Croson & Solnick, 2008; Sutter & Kocher, 2003).

Cross-sectional research suggests that trust does generally develop during adolescence, with trust increasing linearly from early childhood to early adulthood before plateauing through to late adulthood (Sutter & Kocher, 2007). Research points to individual- and social context-dependent changes in trust through adolescence. One past study highlights the potential role of perspective-taking to decision-making in the Trust Game (Fett et al., 2014). Combining the Trust Game and director task, the researchers found that adolescents (*ages* = 13-18) who more accurately acted upon the director's instructions in the director task adjusted their strategies more dramatically in response to unfair play in the Trust Game. Further research demonstrates the importance of social relationships and social information to decision-making, which increases with age. Late adolescents (*ages* = 15-17) and emerging adults (*ages* = 18-22) were more likely than early adolescents (*ages* = 12-14) to reciprocate trust from an anonymous trustor in circumstances where the trustor was taking a higher degree of risk (van den Bos et al., 2011). These decisions were also related to greater activation in the left TPJ and dorsolateral PFC (dlPFC), which the authors interpreted as evidence for the increasing recruitment of social cognition and cognitive control systems in late adolescence. Social information also predicts differential decision-making in the Trust Game between adolescent age groups. In an experiment where adolescents were given social information regarding whether their partner was a ‘good’ (trustworthy), ‘bad’ (untrustworthy) or ‘neutral’ partner, late adolescents (*ages* = 16-18) were more sensitive than early adolescents (*ages* = 12-13) to negative social information when they made their initial investment. Late adolescents were also more able than early adolescents to flexibly adjust their strategy in response to a partner acting out of type i.e. a ‘good’ partner pursuing an aggressive strategy (Lee, Jolles & Krabbendam, 2016). Therefore, prior findings from the Trust Game suggest that trust and reciprocity develop across adolescence, adolescents are increasingly able to flexibly adjust their strategies, and that their gameplay may vary according to who they are interacting with.

1.2.2 Prisoner’s Dilemma

In the standard Prisoner’s Dilemma (Poundstone, 1993), two players simultaneously decide whether to cooperate with each other, without knowledge of whether their partner is going to cooperate with them. If both partners cooperate, they both receive a modest payoff; if both defect, they both receive a small payoff; if one player cooperates while the other defects, then the player who cooperated receives the lowest payoff, while the player who defected receives the highest. The Nash equilibrium, or the balance of actions in which both players are following their best strategy in response to the other player, for the Prisoner’s Dilemma is mutual defection (Binmore, 2007; Rilling & Sanfey, 2011). However, in most versions of the game, participants cooperate at a higher rate than expected (Camerer, 2003); this is especially true of iterated versions, which better resemble real social interactions in the sense that players’ decisions cast a “shadow of the future” and have implications for reputation and future interactions (Axelrod & Hamilton, 1981; Cosmides & Tooby, 2000; Fehr & Gachter, 2002). Participants know that frequent defection has consequences; others will remember the player as a frequent defector and increase their own rates of defection, whether within the context of the game, or life more broadly.

Research using the Prisoner's Dilemma in adults highlights the importance of social relationships to decision-making (Rilling & Sanfey, 2011). Adults are more likely to cooperate with computers than humans, friends than strangers, and in-group members than out-group members (Dorrough, Glöckner, Hellmann & Ebert, 2015; Ames et al., 2006; Rilling, Sanfey, Aronson, Nystrom & Cohen, 2004; Rilling et al., 2004; Rilling et al., 2008). While there are fewer studies investigating the development of social cognition in adolescence with the Prisoner's Dilemma, there are a couple that support the utility of the game in relating developing strategic play to social cognition.

In one study, children and adolescents (*ages* = 6-18) played a game equivalent to a sequential, symmetric Prisoner's Dilemma (Brocas, Carrillo & Kodaverdian, 2017). Their findings indicated that cooperation increases with age in adolescence. When only considering participants, who had previously chosen to defect in a one-shot Prisoner's Dilemma, late adolescents were more likely to choose to cooperate in the first round of the sequential, symmetric Prisoner's Dilemma than early adolescents. This finding was interpreted as evidence that late adolescents are more cooperative, and better able to reason about future outcomes and the decisions of others. In another study where adult and adolescent participants played an iterated four-player Prisoner's Dilemma with three other players their own age through a computer interface, early adolescents were found to display reciprocal but volatile decision-making while late adolescents and adults employed more stable, cooperative strategies. The authors suggested that this result may reflect a developing Theory of Mind, which allows older participants to more flexibly adjust their strategies relative to early adolescents (Gutiérrez-Roig, Gracia-Lázaro, Perelló, Moreno, & Sánchez, 2014). In the case of this latter study, the conclusion that more volatile decision-making reflects a weaker

Theory of Mind stands on weak empirical ground. Therefore, highlighting the need for empirical research that directly investigates the bearing of social perspective-taking on gameplay in the Prisoner's Dilemma. These prior findings may be limited, but suggest that cooperation develops during adolescence, late adolescents are more strategic, and employ more stable, cooperative strategies, which may reflect improved Theory of Mind.

1.2.3 Dictator Game

The Dictator Game asks participants to decide how much of an endowment to allocate to a recipient, and the recipient has no choice but to accept the proposer's offer (Kahneman et al, 1986). In a one-shot Dictator Game, a purely self-interested proposer should not endow any amount to another subject, yet over 50% of subjects tend to allocate some amount to others; on average, between 10% and 25% of the original stake (Camerer, 2003; Forsythe, Horowitz, Savin & Sefton, 1994; Hoffman, McCabe, Shachat & Smith, 1994). The tendency of proposers to allocate some amount has been interpreted to reflect players' prosocial preferences and desires for fairness (Gummerum, Hanoch & Keller, 2008).

Research into adolescent decision-making in the Dictator Game is mixed, with some studies suggesting no change in altruistic giving in adolescence, and others suggesting a decrease in preferences for numeric equity, as well as an increase in preferences for social welfare efficiency and meritocratic rewards. For example, in one study, adolescent participants (*ages* = 8-17) played a version of the Dictator Game in which they could decide between egalitarian (other-regarding preference), spiteful (other-minimising preference), and efficient/altruistic (other-maximising preference) payoffs (Fehr, Glätzle-Rützler & Sutter, 2013). Late adolescents were found to be more efficiency-seeking than early adolescents with egalitarian preferences peaking at age 8. Prior to this study, researchers had employed a version of the Dictator Game with a novel modification where adolescent participants (*ages* = 11-19) had to divide a pot of money that had been generated through a previous task that required the dictator and recipient to expend real effort (Almås, Cappelen, Sørensen & Tungodden, 2010). The findings revealed that younger dictators do not modify their allocations based on effort expended by the recipient, but middle to late adolescent dictators took a meritocratic approach, giving less to players who have expended less effort. In general, altruism in the Dictator Game has been found to increase during childhood and decrease during adolescence (Brocas, Carrillo & Kodaverdian, 2017). Finally, late adolescents have been found to differentiate more between types of social relationships than early adolescents when making allocative decision in a prosocial game (Güroğlu, van den Bos & Crone, 2014).

Conversely, some past research suggests no change in allocation during adolescence. Fairness offers in a Dictator Game played with an anonymous peer were found to not differ during adolescence (Güroğlu, van den Bos & Crone, 2009), and individual allocations have been found to not differ by age (Gummerum, Keller, Takezawa & Mata, 2008). What this mixed pattern of findings may suggest is that adolescents do not differentiate between unknown others when playing the Dictator Game unless, but will do so if there is a salient social context. For instance, differentiating on the basis of the effort employed by the recipient (Almås et al., 2010), or the strength of their relationship with the recipient (Güroğlu, van den Bos & Crone, 2014).

1.3 Use of directed and dyadic social tie variables in economic games

While the above studies have demonstrated the importance of social variables to decision-making in economic games, they have predominantly done so in artificial, or limited social contexts. Although the use of confederates, and pre-programmed responses have given valuable insight into the developing relevance of social relationships to economic gameplay, a new wave of research has sought to take this further by testing the impact of real-world social network variables on economic decision-making (e.g. Güroğlu, van den Bos & Crone, 2014).

Social network research does not focus on the individual (or node) as the subject of interest, as psychological research does, but focuses instead on the connections (or edges) *between* individuals (Borgatti, Everett & Johnson, 2018; Robins, 2015). This is achieved by scoring and mapping connections between members of a network on a variable of interest, for example, geographic distance, trust, or relationship strength. The network scientist can then investigate these maps for network structures (e.g. three-cycles), processes (e.g. transitivity), properties describing particular nodes (e.g. centrality), or can examine individual relationships (dyads) of interest. This approach has the benefit of incorporating aspects of real social relationships existing within complex, authentic social systems, which are naturally occurring "arenas of cooperation, coordination, and conflict" (Robins, 2013).

1.3.1 Network- and individual-level predictors of economic decision-making

Network-level predictors refer to the structure of the network as a whole. For example, the overall density, cohesion, or number of smaller structures (e.g. 3-cycles) present within the network. Whereas individual-level predictors refer to the qualities of nodes within the structure, for instance, their centrality, or betweenness. Research using network- and individual- level variables has uncovered a number of predictors of economic decision-making. In adolescent classroom networks, high eigenvector centrality (highly connected node connected to other highly connected nodes) predicted higher levels of generalised trust in the Trust Game (van den Bos, Crone, Meuwese & Güroğlu, 2018). Adult participants with higher levels of social integration tend to give more in the Dictator Game (Brañas-Garza et al., 2010). Giving was also correlated with betweenness centrality (nodes that form a bridge to other parts of the network) and reciprocal degree (mutual friendships), suggesting that social integration and distance predict altruism in the Dictator Game. A few other studies have used social distance (the amount of connections between two nodes e.g. a friend has a social distance of 1, a friend of a friend has a social distance of 2) as the measure of interest and found that adults and adolescents give more in the Dictator Game when the social distance between themselves and the recipient is lower (Goeree, McConnell, Mitchell, Tromp & Yariv, 2010; Jones & Rachlin, 2006; Leider, Möbius, Rosenblat & Do, 2009). However, social distance and other binary network measures cannot capture all of the dimensions of a relationship. There are many kinds of friends and many kinds of acquaintances, which cannot be quantified by any one measure of network structure or node quality. That is why we advocate a social network approach to investigating the role of social variables in economic decision-making, using a network measure that quantifies the nature of a relationship between two individuals.

1.3.2 Directed and dyadic social tie predictors of economic decision-making

At its core, the fundamental unit of a social network is the dyad (Robins, 2015). The connections between pairs of network members can be combined to create a full map of the whole network, but its lowest constituent will always be the dyad. Recent studies show that directed and dyadic social tie variables are highly informative determinants of prosocial behaviour in both adults and adolescents. In one study, children and adolescents played three distribution games and the Trust Game with different interaction partners: friends, antagonists, neutral classmates, and anonymous peers. The results indicated that with increasing age, adolescents increasingly differentiated prosocial behaviour depending on the nature of their relationship with their peers (Güroğlu, van den Bos & Crone, 2014). This study suggests that when late adolescents play economic games, they not only consider how they are playing, but who they are playing.

In another study, members of a research laboratory completed a social network questionnaire that assessed participants' levels of friendship, perceived mutual trust, previous collaboration, and the number of strong or negative interactions they had shared (Harrison, Sciberras & James, 2011). Participants then earnt money for themselves and other network members in a physically strenuous task that required them to hold a squat pose against a wall for as long as possible. Ego-rated social tie strength (how strong the participant perceived their relationship to be with the other network member) predicted the amount of physically costly money participants were prepared to earn for their peers. The direction and degree of reciprocation was also found to be an important predictor of voluntary physical effort, as participants invested more in those who reported a stronger relationship with the participant than the participant reported to with them.

Similar results were found in adolescent classroom networks (Burnett Heyes et al., 2015). Participants completed a social network questionnaire (adapted from Harrison et al., 2011), which mapped a social tie strength network that incorporated different dimensions of their relationships, for example, trust, friendship, and whether they spent time with each other outside of school. Participants then played a modified Dictator Game where they allocated money to their classmates from an initial pot. Ego-rated social tie strength and relationship reciprocation were again found to predict giving in the Dictator Game. Similarly to the previous study, participants gave more to classmates with whom they reported a stronger relationship, and additionally to classmates who reported a stronger relationship with the participant than the participant reported with them. An interaction between these directed and dyadic social tie variables and year group was also found, indicating that both directed and dyadic variables predicted Dictator Game giving more strongly in late vs. mid or early adolescents. These findings support the utility of taking a directed and dyadic social tie approach to studying economic decision-making, including developmentally.

In these two studies, social tie strength and reciprocation were both predictors of allocative decision-making, and the latter study suggests these variables can track the developing incorporation of social relationship information into gameplay decisions. Importantly, they do so in a bounded network context where a broad and varied set of relationships can be studied and compared against one another, including negative relationships, acquaintances, and friendships of varying strengths. Therefore, by taking a network approach, the researcher need not rely on the participant to select representative relationships from within their class, which can be a problematic issue within social network data collection (Robins, 2015).

Theoretically, because non-social network forms of data collection rely on the participants' interpretation of their relationships, they may be more limited in terms of the types of relationship they can effectively analyse. For example, should a researcher want to investigate the effect of friendship on decision-making within an economic game, they might ask participants to bring friends to the experiment and assume that participant-defined friendships are similar. This may lead to a dilution of the effects whereby the analysis cannot effectively distinguish between the influence of stronger and weaker relationships on decision-making. In the case of reciprocity, it may be the case that a participant brings a friend, but that their pre-defined 'friend' may feel that the participant is more of an acquaintance. The consequences for interpretation in this case may be that the researchers find an inconsistent relation between their chosen relationship variable and their dependent variable as they are assuming that their relationship variable captures the same kind of relationship for each dyad, whereas the relationships could differ in important ways. Even if the overall result is not so affected by this issue, researchers may still miss richer explanations for their data that might be to some extent explained by the reciprocity contained within the relationship. None of this is to say that social network methods are superior in their capacity to reveal information about the nature of friendships, but to argue that this approach is complementary to traditional research methods, which can elicit similar information. We merely observe that social network methods assume the utility of taking the perspectives of both members of a dyad, while traditional research methods do not. Moreover, following the research this thesis is modelled on, we assume the utility and greater ecological validity of characterising a relationship in a continuous (relationship strength) rather than binary (e.g. friendship/no friendship) way.

Additionally, whole-classroom sampling has certain pragmatic advantages over participant-led sampling of individual dyads, as the latter does not optimally allow for the collection of large datasets within often narrow, school-set time constraints. Given that school students are already naturally arranged into classroom networks, it is perhaps surprising that psychology researchers do not adopt this whole-network approach, especially as this is standard procedure for social network researchers. A whole-network approach might be considered advantageous both for reasons of practicality, and as an effective method for comparing relationships within each network (Ushakov & Kukso, 2016).

The next step is to address how generalisable this effect is, and whether directed and dyadic social tie variables predict decision-making in other economic games with other relationship features being accessed by these games. Past research indicates that social tie variables are robust predictors of behaviour in the Dictator Game, and there are indications that decision-making in the Trust Game and Prisoner's Dilemma is predicted by relationship variables (Trust Game: Binzel & Fehr, 2013; Glaeser, Laibson, Scheinkman & Soutter, 2000; van den Bos, Crone, Meuwese & Güroğlu, 2018; Prisoner's Dilemma: Ames et al., 2006; Mienaltowski & Wichman, 2020). However, to our knowledge, no past study has investigated the impact of social tie strength on decision-making within the Trust and Prisoner's Dilemma games.

Therefore, **Chapter 2** will investigate the social tie determinants of trust and expected reciprocity in a modified Trust Game, and whether they better predict late adolescent (vs. early adolescent) decision-making. **Chapter 3** will investigate the social tie determinants of cooperation in a modified Prisoner's Dilemma, and whether they better predict late adolescent (vs. early adolescent) decision-making. **Chapter 5** will investigate the social tie determinants of altruistic giving in a set of modified Dictator Games, and whether they better predict late adolescent (vs. early adolescent) decision-making.

1.4 What drives adolescent development in economic decision-making?

Not only do social network methods allow one to investigate network-, individual-, and dyadic-level determinants of behaviour alongside each other, but they offer researchers the opportunity to disentangle the effects of the different components of social cognition they track. Particularly in the case of social tie data, both the input of the participant (ego) and other network members (alter), are recorded and can be compared with one another to investigate egocentric and altercentric determinants of economic decision-making. While any participant may have a good idea of how their peers perceive them, they cannot know precisely how they are perceived, they can only approximate based on their own inferences. Social network methods allow for the probing of this gap between perception and reality.

As described previously, there is evidence to suspect that developing adolescent strategic gameplay is in part driven by developing social cognition (Will & Güroğlu, 2016). Assuming this is true, there are two possibilities. First, mental state *inference* ability may develop. Second, the tendency to *use* the outcome from mental state inference may develop. The inference-storage-use model posits that perspective-taking can be divided into three distinct components: inference, storage, and use (Apperly, 2010). This thesis will use this framework in combination with a social network approach to investigate these two competing hypotheses for adolescent development in social cognition. That is, whether late adolescents do more accurately infer the perspectives of others, and therefore, whether trends reflecting developments in social and economic decision-making could reflect developments in the ability to *infer* or *use* directed and dyadic social tie information.

1.4.1 Inference or use?

In order to carry out an action based on social information, first, one must infer another person's mental state. Past research suggests this may require the use of abductive reasoning, which is the process of finding the most likely explanation of an observation based on a hypothesis that may be true or untrue. fMRI research into the neural correlates of abductive belief reasoning asked participants to indicate where a character would look for a prize based on the character's belief about the location of the prize, the prize's actual location, and the character's facial expression showing their desire for the prize (positive/negative/ambiguous). Participants were slower to adjudicate when presented with an ambiguous facial expression, suggesting an inferential processing cost (Hartwright, Apperly & Hansen, 2014). fMRI data revealed activity in the rostral medial prefrontal cortex (rmPFC) was modulated by the level of abductive reasoning required, suggesting a role for the rmPFC in the inference of ambiguous desires. Past research also suggests the recruitment of the rmPFC in tasks that demand richer inferences, or the comprehension of ambiguous stories (Jenkins and Mitchell, 2009; Van Overwalle, 2009).

Second, in order to make a decision based on social information, one must use inferred mental state information. Research using the director task demonstrates that even in tasks that minimally require the inference or storage of mental state information, adults and adolescents still make egocentric errors (Dumontheil, Apperly & Blakemore, 2010). While participants are required to infer the perspective of the director, in this case, how the array appears to the director, this is a minimal inference constraint as compared to classical Theory of Mind tasks. Therefore, suggesting the principle source of egocentric error is the participant's own capacity to use the information they have.

It stands to reason that if the developing role of social cognition in economic decision-making is driven by a developing capacity to *infer*, then in tests of inferential accuracy, early adolescents and late adolescents should differ. If this effect is driven by the developing capacity to *use* information, then in tests of inferential accuracy, early adolescents and late adolescents should be equally capable. This thesis investigates the two potential inferences an adolescent may be making when playing these economic games: they may be inferring the nature of the relationship, the strategy of the other player, or both.

Chapter 4 will investigate whether late adolescents predict the relationship strength ratings of their classmates more accurately than early adolescents. **Chapter 5** will describe a novel implementation of the Dictator Game, which asks participants to decide how much money they will allocate to classmates, predict how much classmates will give to them, and predict how much classmates will allocate to each other. This final study will test not only the importance of social tie variables as determinants of decision-making at different levels of perspective-taking in the Dictator Game, but it will also test whether late adolescents also perceive the allocative strategies of their classmates more accurately than early adolescents.

1.5 Design of the games

1.5.1 Modified Trust Game

In **Chapter 2**, late adolescent participants (*N* = 169, *Nnetworks* = 11, *range* = 16-19) played a modified Trust Game that asked players to take the role of the trustor and decide how much to give to each classmate and predict how much each classmate will return to them. The modified Trust Game was designed to measure the amount of hypothetical money that participants would entrust to classmates and expect to be reciprocated by classmates. This was done within the context of practical time and logistical constraints that did not allow us to run a traditional Trust Game in which participants could entrust an amount to a classmate and then see the amount their classmate would actually return. Consequently, a modified version was designed which asked participants to imagine out of an original stake of £5, how much they would give to each classmate, and then knowing that this endowment would be tripled, predict how much would be returned by each classmate. This allowed us to investigate both trust and expected reciprocity, thus testing both elements of the Trust Game. This is therefore a one-shot repeated Trust Game with multiple partners and no feedback.

1.5.2 Modified Prisoner's Dilemma

In **Chapter 3**, adolescent participants (*N* = 156, *nNetworks* = 9, *age range* = 13 - 18) played a modified Prisoner's Dilemma that asked players to decide whether to 'split' (cooperate) or 'steal' (defect) a pot of money (1, 2, 3, 4, or 5 coins) with or from each classmate. The modified Prisoner's Dilemma was designed to measure to what extent participants would cooperate with other classmates. This was done in the context of practical and logistical constraints that did not allow us to run a traditional Prisoner's Dilemma in which participants would receive instant feedback on the decision their classmate made, allowing them to adjust their strategy accordingly. Consequently, a modified version was designed which asked participants to imagine that for each pot of money (1, 2, 3, 4, or 5 coins) they had to decide whether to split (cooperate) or steal (defect) that pot. This is therefore a one-shot repeated Prisoner's Dilemma with multiple peers and no feedback, which allows us to investigate levels of cooperation within the context of a traditional Prisoner's Dilemma.

1.5.3 Ego-perceived vs. Alter-rated Relationship

In **Chapter 4**, adolescent participants (*n* = 918, *nNetworks* = 58, *age range* = 12-18) indicated on a social network questionnaire what relationship strength rating they predict each classmate will give to their relationship. This score was compared against their classmates' actual relationship strength ratings. This method allowed us to directly test how accurately adolescents predicted classmates' perceptions of their shared relationship.

1.5.4 1st, 2nd, and 3rd Person modified Dictator Game

In **Chapter 5**, adolescent participants (N = 292; Nnetworks = 24; age range = 12 – 18) played three versions of the Dictator Game. In the 1st person Dictator Game, participants decided how much of an original hypothetical £100 pot to allocate to each classmate. In the 2nd person Dictator Game, participants predicted how much each classmate would allocate to them in the 1st person Dictator Game. In the 3rd person Dictator Game, participants predicted how much classmates would allocate to each other in the 1st person Dictator Game. The modified Dictator Games were designed to measure how much participants would allocate to their classmates, how much they expected their classmates to allocate to them, and how accurately they could predict allocation to both themselves and others.

1.6 Thesis Outline and Hypotheses

This thesis seeks to answer three questions:

- [Q1] Do directed and dyadic social tie variables predict adolescent decision-making in economic games?
- [Q2] If so, does the strength of this prediction alter with age?
- [Q3] If so, what are the cognitive mechanisms driving this development?

Chapters 2, **3** and **5** investigate adolescent decision-making in a modified Trust Game, Prisoner's Dilemma, and set of Dictator Games. **[H1]** We hypothesise that late adolescent decision-making in the Trust Game, Prisoner's Dilemma, and Dictator Games will be predicted by egocentric, altercentric, and mutual directed and dyadic social tie variables (Burnett Heyes et al., 2015; Harrison, Sciberras & James, 2011). **[H2]** We also predict that late (vs. early) adolescent decision-making will be better predicted by these social tie variables in the Prisoner's Dilemma and Dictator Games (Burnett Heyes et al., 2015; Gutiérrez-Roig, Gracia-Lázaro, Perelló, Moreno, & Sánchez, 2014; van den Bos et al., 2011).

Chapters 4 and **5** investigate whether late adolescents are better at *inferring* or *using* social and strategic information than early adolescents. **[H3]** We hypothesise that late adolescents will perceive the strength of their relationships more accurately than early adolescents. **[H4]** We also predict that late adolescents will predict the allocative decisions of their classmates more accurately than early adolescents *(*van den Bos et al., 2011; Lee, Jolles & Krabbendam, 2016).

Trust works both ways: social tie predictors of trust and expected reciprocity in late adolescent social networks

2.1 Abstract

While there is plenty of evidence to suggest that adolescents are more sensitive to trust and reciprocity, relative to early adolescents, it remains less clear to what extent this sensitivity is determined by individual versus interpersonal mechanisms. In this study, we investigate whether directed and dyadic social tie and individual difference variables predict late adolescent economic decision-making in a modified Trust Game in an authentic social context. Results show evidence that both egocentric and mutual directed and dyadic social tie variables predict late adolescent (*N* = 169, *Nnetworks* = 11, *range* = 16-19) decision-making in the Trust Game. Participants gave more to, and expected more from, classmates with whom they reported a stronger relationship, and with classmates that reported a stronger relationship with the participant than the participant reported with the classmate. These findings highlight the value of considering social network variables in research on adolescent social decision-making.

2.2.1 Adolescent sensitivity to trust

Adolescence is the period of life between childhood and adulthood characterised by alterations in social cognition and motivation, and changes in the social environment (Crone and Dahl, 2012). During adolescence, individuals orient socially towards peers and integrate within increasingly complex social environments (Brown & Larson, 2009; Nelson, Leibenluft, McClure & Pine, 2005). Quality trumps quantity; as the adolescent's overall social network expands and diversifies, so too does their sensitivity to relationship features like trust and reciprocity (Bigelow & La Gaipa, 1980; Güroğlu, van den Bos & Crone, 2009; Lee, Jolles & Krabbendam, 2016; Urberg, Değirmencioğlu, Tolson & Halliday-Scher, 1995; Wrzus, Hänel, Wagner & Neyer, 2012).

While there is plenty of evidence to suggest that late adolescents are more sensitive to trust and reciprocity, relative to early adolescents, it remains less clear to what extent this sensitivity is determined by individual versus interpersonal mechanisms. Are late adolescents more likely to trust due to their more developed individual capacities? Or are late adolescents more sensitive to the interpersonal mechanisms at play between multiple actors? If so, which interpersonal mechanisms are they sensitive to? The current study was conducted to investigate individual and interpersonal (social tie) determinants of trust and reciprocation in late adolescents, using a Trust Game played hypothetically with real-world peers. For the purposes of this study, interpersonal determinants are conceptualised as variables that represent a connection between two participants (either a behavioural game decision or a relationship variable), whereas individual determinants represent variables that represent information about an individual participant (e.g. age, empathic concern). This terminology fits well with the social network analysis framework, which maps the connections (edges) between individuals (nodes) and computes their unique contributions to behaviour (Robins, 2015). Here, interpersonal variables conceptually correspond to edge descriptors and individual variables to descriptors of nodes.

2.2.2 Trust Game

The Trust Game has been used extensively to investigate behavioural sensitivity to trust and reciprocity, both in adults *(*Rilling & Sanfey, 2011; Sanfey, 2007) and adolescents *(*Kilford, Garrett & Blakemore, 2016; King-Casas, Tomlin, Anen, Camerer, Quartz & Montague, 2005; Güroğlu, van den Bos & Crone, 2009a, 2009b; Lemmers-Jansen, Fett, Hanssen, Veltman & Krabbendam, 2018; van den Bos, Westenberg, van Dijk & Crone, 2010). The Trust Game involves two players: the trustor, and the trustee. The trustor is given a stake, and they must choose how much of this stake to entrust to the trustee. The amount they entrust is multiplied (e.g. tripled) before being given to the trustee. The trustee must then decide how much of the tripled stake to return to the trustor. Larger investment amounts offer greater opportunity for larger returns but require the trustor to trust that the trustee will not behave selfishly and retain all of the investment. Empirically, mature strategies tend towards cooperation, as late adolescent and adult trustors tend to entrust at least half of the original stake (Johnson & Mislin, 2011; Tzieropoulos, 2013; van den Bos et al., 2011). Late adolescent and adult trustees also tend to return slightly more than the original investment, resulting in a near-even split of resources (Buchan, Croson & Solnick, 2008; Sutter & Kocher, 2003).

2.2.3 Adolescent differentiation based on social information and individual differences

Studies employing the Trust Game suggest the importance of intention, social information, and the interpersonal context in the strategies of late adolescent participants. Specifically, late adolescents are likely to return higher amounts of money if they have been trusted with larger investments, suggesting that they are sensitive to the intentions of the investor (van den Bos et al., 2010). Adolescents are also influenced by the social information they receive about

Trust Game partners and will invest more in a partner previously described as ‘good’ than one described as ‘bad’. Additionally, late (vs. early) adolescents demonstrate greater adaptability in circumstances in which they must weigh their prior social knowledge against current gameplay circumstances. Should the ‘good’ partner adopt an aggressive strategy, late adolescents are quick to adapt their investment strategies according to the observed behaviour of the other player, over-riding the social information previously received (Lee, Jolles & Krabbendam, 2016).

Not only are interpersonal variables important determinants of decision-making in economic games, but so too are individual differences between adolescents. Past research suggests that self-reported perspective-taking and empathic concern predict cooperation in the Dictator and Ultimatum game (Artinger, Exadaktylos, Koppel & Sääksvuori, 2014; Burnett Heyes et al., 2015). Machivellianism predicts low levels of trust in the Trust Game (Bereczkei, Deak, Papp, Perlaki & Orsi, 2013). Affluence is associated with cooperation and greater investment in the Dictator Game (Nettle, Colléony & Cockerill, 2011). Parental attachment has been related to social-decision making in the Ultimatum Game (Almakias & Weiss, 2012), and male and female participants demonstrate different levels of trust and trustworthy behaviour in the Trust Game, though the direction of these differences is mixed in the literature (Buchan, Croson & Solnick, 2008; Innocenti & Pazienza, 2006; Lemmers-Jansen, Krabbendam, Veltman & Fett, 2017).

In sum, prior studies indicate that late adolescents show differential patterns of Trust Game behaviour based on both interpersonal (social tie) and individual characteristics, including prior social information, the observed behaviour of their opposite player, and their own individual cognitive characteristics. However, to date these variables have not been systematically combined within a study that tests real-world peer relationships.

2.2.4 The social network

Social network methods can be used for this purpose to test hypotheses relating authentic interpersonal information to economic decision-making. Within this framework, social network data that quantifies interpersonal variables, including the dyadic connections between pairs of individuals and the overall structure of a network can be measured. Subsequently, a social network analysis of these network variables alongside the individual attributes more traditionally used in psychological research can be conducted to provide greater explanatory power to predict decision-making in the Trust Game. This approach allows for the study of exchange decisions in the context of established peer relationships at a number of different levels. For example, at the network-level, recent studies show evidence that greater social cohesion predicts greater overall levels of trust (van den Bos, Crone, Meuwese & Güroğlu, 2018). But in order to understand the determinants of late adolescent trust and reciprocity, it is arguably advantageous to take a social tie-level approach. Fundamentally, the Trust Game involves decisions to trust and reciprocate in a social tie context and it therefore has face validity that social tie variables should be robust predictors of decision-making in the Trust Game. Furthermore, past research finds that social distance does predict levels of trust and trustworthiness in adults (Binzel & Fehr, 2013; Glaeser, Laibson, Scheinkman & Soutter, 2000), suggesting both face and empirical validity for such a design.

2.2.5 Egocentric, altercentric, and mutual effects

A further aspect of social relationship variables worth taking into consideration is whether they are from the perspective of the ego (the sender), the alter (their partner), or both (mutual). For example, I (ego) can indicate that I have a strong relationship with you (alter), and consequently I may invest more money in you in a Trust Game. Thus, the egocentric variable exerts an impact on Trust Game behaviour. However, you may not reciprocate this relationship strength - you may not like me as much as I like you. Whether or not altercentric variables impact ego Trust Game behaviour will depend on whether or not the ego is sensitive to 'both sides' of the mutual dyadic context. Given that prior research indicates late adolescent participants differentiate their trust and reciprocation strategies based on what they perceive the intentions of their partners to be, we can predict that egocentric, altercentric, and mutual dyadic relationship variables may have an impact on Trust Game behaviour. Specifically, because the derivation of dyadic network variables involves a score for the ego (the focal participant) and alter (their fellow network member), it is possible to investigate social perspective-taking by using both known social information (how the ego perceives their relationship with the alter) and inferred social information (how the alter perceives their relationship with the ego) as predictors of economic decision-making. Probing this gap can provide valuable insight into how important social inference is for late adolescent economic decision-making.

In one social network-level paradigm, egocentric measures of relationship strength were mapped within adolescent networks and used as predictors of giving in a modified Dictator Game (Burnett Heyes et al., 2015). Additionally, a mutual relationship reciprocation measure was derived, which combines egocentric and altercentric social tie strength information to indicate the direction in which a relationship may be unbalanced. That is, whether a participant (ego) feels they have a stronger relationship with a classmate (alter) than the classmate feels towards them, or vice versa. Late adolescent versus early adolescent giving was found to be predicted positively by ego-rated social tie strength, and negatively by relationship reciprocation. Late adolescents would give more to those they reported a stronger relationship with, and to classmates who reported a weaker relationship with the participant than the participant reported with them. This finding was interpreted as evidence for late adolescent sensitivity to real-world social relationship strength in the context of economic games. This effect of relationship reciprocation is not well understood and has only been demonstrated in three prior studies (Burnett Heyes et al., 2015; Harrison et al., 2011). In the following study, we test whether this effect is also present in adolescent decision-making within the Trust Game.

2.2.6 The study

In this study, we investigate whether interpersonal social tie and individual difference variables predict late adolescent economic decision-making in a modified Trust Game. We mapped the strength of social ties within eleven late adolescent social networks (*N* = 169; *age range* = 16-18). Analysis used the participants' ratings of ego-rated social tie strength (egocentric variable) and the extent to which this was reciprocated (mutual variable) to predict the amounts of hypothetical money that participants would entrust to other classmates, and how much they would expect to be returned. This age range was selected on the basis that late adolescents are behaviourally sensitive to others' intentions and altercentric social information in both network and non- network contexts (Burnett Heyes et al., 2015; Dumontheil, Apperly & Blakemore, 2010; Lee, Jolles & Krabbendam, 2016).

2.2.7 Hypotheses

We predicted that late adolescent Trust Game behaviour would be based on ego and mutual social information and individual characteristics. [H1] We hypothesised that participants would entrust more money to, and expect greater returns from, classmates with whom they reported a stronger relationship (i.e. stronger ego-rated social tie strength; Burnett Heyes et al., 2015; Güroğlu, van den Bos & Crone, 2014*).* [H2] We predicted that participants would entrust more to and expect higher returns from classmates for whom *alter-rated social tie strength* exceeded *ego-rated social tie strength*, i.e. based on both ego and altercentric variables. This hypothesis was based on past research indicating late adolescents are sensitive to the behaviour and intentions of others when playing economic games (Burnett Heyes et al., 2015; Fett et al., 2014; Lee, Jolles & Krabbendam, 2016; van den Bos et al., 2010). [H3] In addition, we hypothesised that the following individual characteristics would predict Trust Game behaviour as they have in previous studies: Machiavellianism (Bereczkei, Deak, Papp, Perlaki & Orsi, 2013; Spitzer, Fischbacher, Herrnberger, Grön & Fehr, 2007), family affluence (Nettle, Colléony & Cockerill, 2011), self-reported empathic concern and perspective-taking (Artinger, Exadaktylos, Koppel & Sääksvuori, 2014; Burnett Heyes et al., 2015), attachment anxiety and attachment avoidance (Almakias & Weiss, 2012), and gender (Buchan, Croson & Solnick, 2008; Innocenti & Pazienza, 2006).

2.3 Method

2.3.1 Participants

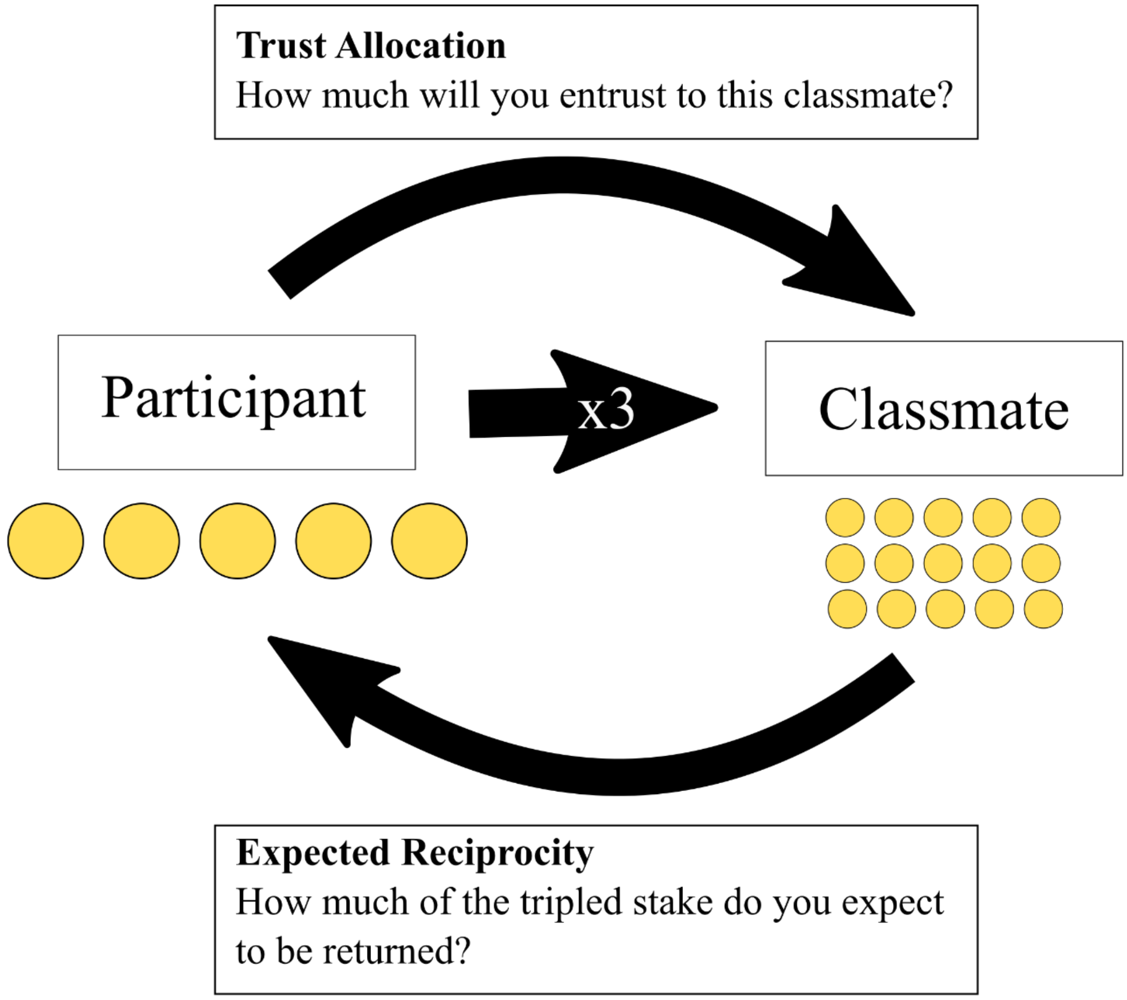
169 participants in 11 classroom networks (see Appendix A1) were recruited from 2 schools (*female* = 112, *Mage(SD)* = 16.99(.47), *range* = 16-19). Consent was obtained from participants prior to the experiment as well as assent for each questionnaire. The study was approved by the University of Birmingham Science, Technology, Engineering and Mathematics Ethical Review Committee.

2.4 Measures

2.4.1 Modified Trust Game (mTG)

Trust Allocation and Expected Reciprocity were measured using a modified Trust Game (mTG). The mTG was composed of two phases: trust allocation and expected reciprocity. An initial Trust phase resembling a standard one-shot Trust Game played as the trustor, repeated across multiple trustees. For each trustee, participants were asked to record how much of their 5-coin stake they would give to each trustee (classmate). Participants were explicitly prompted to consider their return on investment when making their allocation. A subsequent Expected Reciprocity phase asked participants to indicate how much of their tripled stake they would expect in return from each classmate. An intervening comprehension question asked participants how much money each classmate would receive following the tripling of the stake. Consequently, participants played the Trust Game in both phases: as the trustor using an egocentric perspective, and as the trustee using an altercentric perspective (Figure 2.1.).

a)



b)

Classmates	Amount to Trust (0-5 coins)		How much have they got?	How much will they give back?
Anna	3	x3	9	4
Simran	5	x3	15	12

Figure 2.1. a) A depiction of both phases of the mTG. b) A representation of the task.

2.4.2 Social Network Questionnaire

Social network variables were generated using a seven-item social network questionnaire (SNQ) designed for adolescents (Burnett Heyes et al., 2015; Harrison et al., 2011). Three binary response items (yes = 1, no = 0) assessed whether participants had a familial tie to any network members, spent time outside of school with network members, and had chosen to work academically with each network member. Three ordinal response items assessed the perceived strength of the relationship with each network member (‘What kind of relationship do you have with *X*?’; 4 = *best friend*, 3 = *good friend*, 2 = *friend*, 1 = *acquaintance*, 0 = *no relationship*, -1 = *negative relationship*), importance of resolving conflicts with each network member (‘How important is it to you to resolve conflicts with *X?’* ; 1 = *try really hard to resolve*, 0 = *make a small effort to resolve*, -1 = *wouldn’t care*), and how much participants trusted each network member compared to a stranger (‘How much do you trust *X?’;* 1 = *more than*, 0 = *the same as*, -1 = *less than).* Finally, a continuous measure of relationship duration was included.

2.4.3 Gender

Gender was self-reported on the SNQ. Participants could indicate male, female, or a self-identified gender identity term. Past research indicates that males and females exhibit differing levels of trusting and trustworthy behaviour in the Trust Game. However, these findings have been mixed with some research suggesting that males trust more than females, other research suggesting that females trust more than males, and others only finding gender differences in unfair contexts (Buchan, Croson & Solnick, 2008; Innocenti & Pazienza, 2006; Lemmers-Jansen, Krabbendam, Veltman & Fett, 2017). Female gender was coded as 1 and male gender was coded as 0.

2.4.4 Interpersonal Reactivity Index (IRI-EC/PT)

The IRI is a 28-item self-report measure of dispositional empathy (Davis, 1980). The perspective-taking (PT) (e.g. “I try to look at everybody’s side of a disagreement before I make a decision”) and empathic concern (EC) subscales (e.g. “I am often touched by things that I see happen”) were used for this study. Responses are scored on a 5-point scale of ‘1 = Does not describe me very well’ to ‘5 = Describes me very well’. Good internal reliability and construct validity have been demonstrated in adolescent groups (Hawk et al., 2012). In past research, PT and EC subscales have been found to be weak predictors for cooperation in economic games (Artinger, Exadaktylos, Koppel & Sääksvuori, 2014; Burnett Heyes et al., 2015).

2.4.5 Kiddie Mach (KM)

The Kiddie Mach assesses Machiavellianism in adolescents, adapted from the Machiavellianism Scale-IV (Christie & Geis, 1970). The 20-item self-report questionnaire yields a composite score of Machiavellian orientation (Andreou, 2004; Sutton & Keogh, 2001). Responses are scored on a 5-point Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree). This measure has good internal reliability in adolescent samples (Peeters, Cillessen & Scholte, 2010; Sutton & Keogh, 2001). Past research suggests higher Machivellianism scores are associated with selfish resource allocation (Spitzer et al., 2007), and lower levels of trust in the Trust Game (Bereczkei, Deak, Papp, Perlaki & Orsi, 2013).

2.4.6 Family Affluence II (FAS-II)

The FAS-II measures socioeconomic status and is appropriate for adolescent participants (Currie et al., 2004). The four items on the questionnaire are: “Does your family own a car or van?”, “Do you have your own bedroom for yourself?”, “How many times did you travel away on holiday with your family during the past 12 months?”, and “How many computers and laptops does your family own?”. Scoring is different for each item; a high total score (maximum = 9) indicates high family SES, while a low score (minimum = 0) indicates low family SES. The FAS-II is a valid measure of adolescents’ socioeconomic status (Hobza, Hamrik, Bucksch & De Clercq, 2017), and there is a high concordance between children’s and parents' responses to the FAS-II (Andersen et al., 2008). Past research indicates participants from wealthier areas tend to be more cooperative and make greater investments in the Dictator Game (Nettle, Colléony & Cockerill, 2011).

2.4.7 Experiences in Close Relationships Scale-Revised (ECR-RC)

The ECR-RC is a 12-item questionnaire that presents child and adolescent participants with statements which assess whether they demonstrate anxious and/or avoidant attachment with their primary and secondary caregivers (Brenning, Soenens, Braet & Bosmans, 2011). The attachment anxiety (e.g. "I'm worried that my caregiver might want to leave me") and attachment avoidance (e.g. "I prefer not to get too close to my caregiver") subscales both consist of six items, and responses are recorded on a 7-point Likert scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree). The scale has excellent reliability and validity (Brenning, Van Petegem, Vanhalst & Soenens, 2014). Previous research suggests parental attachment is related to social decision-making in the Ultimatum Game with anxiously attached individuals tending to offer higher shares, and avoidant individuals tending to offer lower shares (Almakias & Weiss, 2012).

2.5 Experimental Procedure

Measures were completed using pen and paper in a large room that afforded privacy to each participant. The experiment lasted approximately 40-60 minutes. At the beginning of the testing session, the mTG was explained to participants. Participants were instructed that the goal of the game was to earn as much money as possible and that the researchers would calculate who earnt the most hypothetical money based on the responses of the entire class. In fact, scores were not analysed in this way, and all participants were informed of this at the end of the testing session. This minor deception was approved by the University of Birmingham Science, Technology, Engineering and Mathematics Ethical Review Committee.

The instructions given to participants explicitly stated that participants should think carefully about the responses of their classmates, and that classmates may choose a cooperative or uncooperative strategy to maximise their payoff. This was done to ensure that participants were engaging with the game in a realistic way where they should consider the intentions of their fellow classmates.

2.6 Statistical Procedures

2.6.1 Modified Trust Game (mTG) Variables

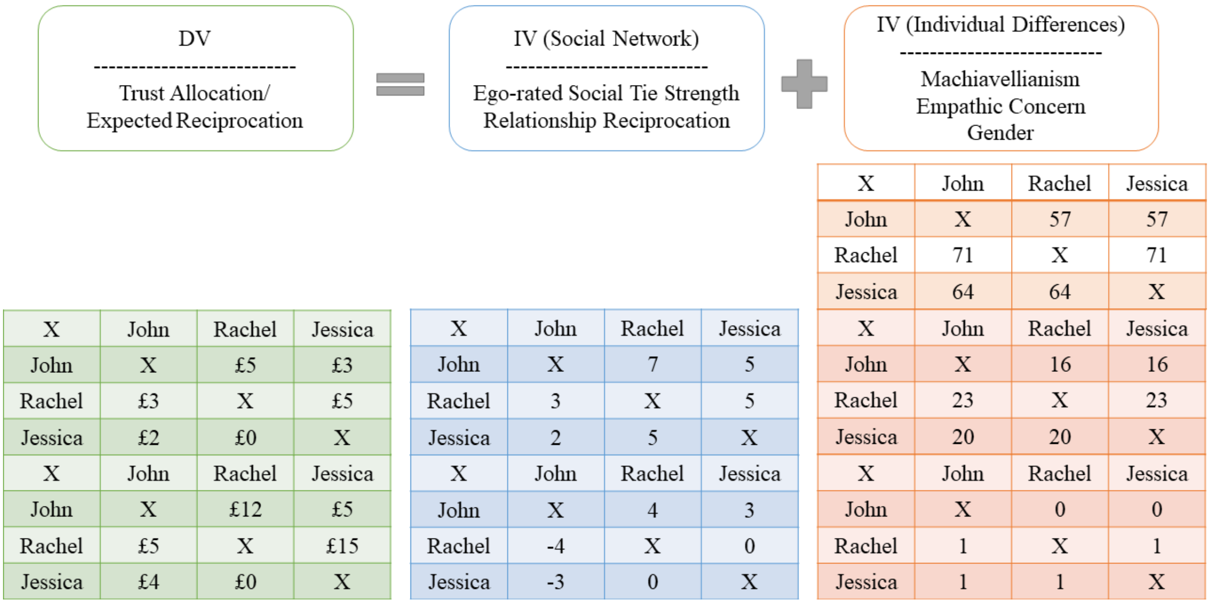
A Trust matrix was created for each classroom network representing the amount each participant (rows) entrusted to each classmate (columns). An Expected Reciprocity matrix was created for each classroom network representing the amount each participant (rows) expected in return from each classmate (columns).

2.6.2 Social Network Questionnaire (SNQ) Variables

Four social network variable matrices were derived from items on the SNQ for each classroom network. *Duration* indicated how long the participant (ego; rows) had known each network member (alter; columns). Similarly, *familial ties* indicated whether each ego reported a familial tie to each alter. *Ego-rated social tie strength* was calculated by summing across the remaining SNQ items. *Ego-rated social tie strength* represented directed relationship strength as perceived by the participant or ego; as such, this variable takes into account egocentric social information. *Relationship reciprocation* was calculated as *ego-rated social tie strength* minus transposed *ego-rated social tie strength* (i.e. *alter-rated social tie strength)*. Thus, *Relationship reciprocation* represents the discrepancy between relationship strength perceived by ego versus alter; as such, this variable takes into account both egocentric and altercentric (mutual) social information.

2.6.3 Individual Difference Variables

Egocentric and altercentric individual difference predictor matrices were generated for individual difference variables (*IRI-EC*, *IRI-PT*, *KM*, *FAS-II*, *Gender*, *ECR-RC Anxious*, and *ECR-RC Avoidant*). Egocentric individual difference predictor matrices were created by repeating the participants' individual difference scores across columns. That is, while each row in a matrix would represent a unique score to each participant, each column would be a repeat of the previous column. Analytically, this allows for egocentric individual difference scores to be used as a predictor of each unique cell within dependent variable matrices (Figure 2.2.). Altercentric individual difference predictor matrices were created by transposing the egocentric individual difference predictor matrices. This allows for altercentric individual difference scores to be used as predictors; while each column in a matrix would represent a unique score to each participant, each row would be a repeat of the previous column.



X	John	Rachel	Jessica
John	X	£5	£3
Rachel	£3	X	£5
Jessica	£2	£0	X

X	John	Rachel	Jessica
John	X	£12	£5
Rachel	£5	X	£15
Jessica	£4	£0	X

X	John	Rachel	Jessica
John	X	7	5
Rachel	3	X	5
Jessica	2	5	X

X	John	Rachel	Jessica
John	X	4	3
Rachel	-4	X	0
Jessica	-3	0	X

X	John	Rachel	Jessica
John	X	57	57
Rachel	71	X	71
Jessica	64	64	X

X	John	Rachel	Jessica
John	X	16	16
Rachel	23	X	23
Jessica	20	20	X

X	John	Rachel	Jessica
John	X	0	0
Rachel	1	X	1
Jessica	1	1	X

Figure 2.2. A depiction of the data preparation and analysis.

2.7 Statistical Analyses

The statistical analyses were comprised of two parts. 1) A within-network analysis of network and non-network variables as predictors of decision-making in the mTG.(see Appendix A4-A7) 2) A pooled-network analysis of network and non-network variables as predictors of decision-making in the mTG.

2.7.1 Sample Descriptives

Means and standard errors were calculated for non-network variables (see Appendix A2), including: *age*, *family affluence* (FAS-II), *empathic concern* (IRI-EC), *perspective-taking* (IRI-PT), *anxious attachment* (ECR-RC Anxious), *avoidant attachment* (ECR-RC Avoidant), and *Machiavellianism* (KM). Bootstrapped mean densities and standard errors were calculated for network variables: *trust*, *expected reciprocity*, *ego-rated social tie strength*, and *relationship reciprocation* (see Appendix A3; Table 2.1; Table 2.2).

2.7.2 Model Selection

In order to generate a parsimonious set of predictors for the multi-group multiple regression with quadratic assignment procedure (MG-MRQAP) model, we initially created single-network multiple regression with quadratic assignment procedure (MRQAP; Dekker, Krackhardt & Snijders, 2007; Krackhardt, 1988) models (see Appendix A4-A7). MRQAP models were used to test for a relationship between explanatory interpersonal and individual independent variables and the decision-making in the mTG within each network. Predictors that did not survive in the final MRQAP model for any network were not included in the final MG-MRQAP. The initial Trust MG-MRQAP model included all social tie and individual-level predictors except for *familial ties* and *avoidant attachment (alter)*. The initial Expected Reciprocity MG-MRQAP model included all social tie and individual-level predictors except for *familial ties*, and *duration*.

2.7.3 Multiple Regression Predicting Resource Allocation Across all Networks

Multi-group multiple regression with quadratic assignment procedure (MG-MRQAP) was used to test for a relationship between explanatory interpersonal, and individual difference variables and decision-making in the mTG across networks. Two models were tested, one for Trust and one for Expected Reciprocity. In MG-MRQAP, regression parameters are estimated by regressing the pooled dependent variable matrices on to the pooled explanatory variable matrices. These regression coefficients were compared to a distribution of coefficients under the null hypothesis generated via Y-permutation of row and column positions of the data. To account for network nesting, permutation was allowed only within networks, and the intercepts for different networks were allowed to vary independently (i.e. a fixed effects approach by class). This analysis was conducted in R (R Development Core Team, 2011). Statistical significance was set at $p < .05$, two-tailed for non-directional, and one-tailed for directional hypotheses. No directional hypotheses were postulated for the relationship between *duration* and *trust allocation* or *expected reciprocity*; hypotheses relating to all other predictors were directional. Nonsignificant variables were dropped from the analysis in a stepwise manner, beginning with the variable for which the two-tailed p value was closest to 1. Note that MRQAP and MG-MRQAP models were also run including *alter-rated social tie strength*. *Relationship reciprocation* and *alter-rated social tie strength* cannot be run in the same model as *relationship reciprocation* is a combination of *ego-rated* and *alter-rated social tie strength*. Both models were run to investigate whether *relationship reciprocation* and *alter-rated social tie strength* predicted different behaviour. For this study, the analysis including *alter-rated social tie strength* was not included (see Appendix A8-A9).

2.8 Results

2.8.1 Sample Descriptives

Non-network variables	*M*(*SD*)	Range	*N*

Age (Years)	16.99(0.47)	16 – 19	169
FAS-II	7.71(1.47)	2 – 9	144
ECR-RC Avoidant	5.5(2.3)	1 – 32	151
ECR-RC Anxious	14.62(3.6)	1 – 32	151
IRI-EC	25.87(4.84)	10 – 35	160
IRI-PT	23.59(5.33)	9 – 35	160
KM	55.05(7.33)	37 – 84	154

Table 2.1. Non-network sample descriptives.

Network variables	*M*(*SEM*) density	Range	*N*
Trust Allocation	2.33(0.28)	0 – 5	3912
Expected Reciprocity	4.62(0.68)	0 – 15	3912
Ego-rated Social Tie Strength	0.81(0.17)	-3 – 7	3912
Relationship Reciprocation	1.06(0.14)	0 – 7	3912

Table 2.2. Network sample descriptives.

2.8.2 Trust Game Comprehension Question

Across the entire sample (see Appendix A10), participants correctly calculated how much money each classmate would receive following the tripling of the stake on 97% of occasions on average (*range* = 89% - 100%).

2.8.3 Trust MG-MRQAP Model

Social network and individual difference variables (see Methods) were included in a MG-MRQAP model as predictors for Trust in the mTG across the entire sample (N = 169). In the final Trust model (R^2_{adj} = .46, p < .001), *ego-rated social tie strength* significantly predicted greater allocation during the Trust phase of the mTG (Table 2.3). This can be interpreted as follows: All else being equal, participants (ego) indicated they would entrust more hypothetical money to classmates (alters) with whom they reported a stronger relationship. *Relationship reciprocation* negatively predicted trust. All else being equal, participants (ego) invested more in classmates (alters) who reported stronger relationship strength toward them than the participant reported with the classmate. Finally, *IRI-EC (Alter)* predicted Trust Allocation such that participants who scored more highly on the *empathic concern* subscale of the IRI received slightly larger hypothetical investment sums from their classmates.

Independent Variable	Unstandardised Regression Coefficient	*p* value
MG-MRQAP model		
$R^2_{adj} = .46$, $p < .001$		
Ego-rated social tie strength	3.12	< .001
Relationship Reciprocation	-0.10	< .05
IRI-EC (Alter)	0.02	.02

Table 2.3. Trust MG-MRQAP model. Class intercepts for the model were: Year 12A (*b* = 1.32, *p* <.001), 12B (*b* = -0.27, *p* = .25), 12C (*b* = 0.51, *p* = .55), 13A (*b* = 0.41, *p* = .92), 13B (*b* = -0.03, *p* = .95), 13C (*b* = 0.54, *p* = .63), 13D (*b* = 0.26, *p* = .79), 13E (*b* = 0.31, *p* = .86), 13F (*b* = -0.41, *p* = .73), 13G (*b* = 0.57, *p* = .59), 13H (*b* = -0.19, *p* = .70). Independent variables eliminated due to non-significance were Gender (Ego) (*b* = 0.01, *p* = 0.47), Empathic Concern (Ego) (*b* = 0.01, *p* = 0.47), Perspective-taking (Alter) (*b* = 0.01, *p* = 0.46), Anxious Attachment (Alter) (*b* = -0.02, *p* = 0.40), Family Affluence (Alter) (*b* = -0.01, *p* = 0.40), Machiavellianism (Ego) (*b* = -0.01, *p* = 0.41), Avoidant Attachment (Ego) (*b* = -0.02, *p* = 0.40), Anxious Attachment (Ego) (*b* = 0.08, *p* = 0.36), Gender (Alter) (*b* = -0.06, *p* = 0.32),

Machiavellianism (Alter) (b = -0.01, p = 0.19), Family Affluence (Ego) (b = 0.05, p = 0.23), Duration (b = 0.02, p = 0.18), and Perspective-taking (Ego) (b = 0.02, p = 0.10).

2.8.4 Expected Reciprocity Model

Social network and individual difference variables were included in a MG-MRQAP model as predictors for Expected Reciprocity in the mTG across the entire sample (N = 169). In the final Expected Reciprocity model (R^2_{adj} = .39, p < .001), *ego-rated social tie strength* predicted greater expected returns during the *Expected Reciprocity* phase of the Trust Game. *Relationship reciprocation* had a significant negative relation with Expected Reciprocity. *IRI-EC (Alter)* positively predicted Expected Reciprocity. *Gender (Ego)* and *Gender (Alter) negatively* predicted Expected Reciprocity (Table 2.4). All else being equal, participants (ego) expected more hypothetical money to be returned by classmates (alters) with whom they reported a stronger relationship, and by classmates who reported greater relationship strength toward the participant than the participant reported towards the classmate. In addition, participants predicted that classmates with higher *empathic concern* scores would produce higher investment returns. Female participants expected higher proportions of the stake to be returned by their classmates than did male participants. Participants also expected higher returns from female than from male classmates.

Independent Variable	Unstandardised Regression Coefficient	p value
MG-MRQAP model		
R^2_{adj} = .39, p < .001		
Ego-rated social tie strength	6.84	< .001
Reciprocation	-0.34	.02
IRI-EC (Alter)	0.05	.03

Gender (Ego)	1.17	.02
Gender (Alter)	0.57	.03

Table 2.4. Expected Reciprocity MG-MRQAP model. Class intercepts for the model were: Year 12A (b = 1.4, $p < .001$), 12B (b = -1.02, p = .25), 12C (b = 0.51, p = .93), 13A (b = 1.39, p = .98), 13B (b = 1.88, p = .93), 13C (b = 3.75, p = .87), 13D (b = 3.84, p = .91), 13E (b = 1.03, p = .79), 13F (b = 2.51, p = .74), 13G (b = 2.86, p = .84), 13H (b = 2.54, p = .82). Independent variables eliminated due to non-significance were: Machiavellianism (Ego) (b = 0.01, p = 0.50), Empathic Concern (Ego) (b = -0.01, p = 0.49), Family Affluence (Alter) (b = 0.02, p = 0.37), Avoidant Attachment (Alter) (b = -0.03, p = 0.37), Perspective-taking (Alter) (b = -0.01, p = 0.37), Anxious Attachment (Ego) (b = -0.25, p = 0.35), Avoidant Attachment (Ego) (b = 0.07, p = 0.33), Anxious Attachment (Alter) (b = 0.19, p = 0.18), Perspective-taking (Ego) (b = 0.06, p = 0.13), Family Affluence (Ego) (b = 0.19, p = 0.13), and Machiavellianism (Alter) (b = -0.02, p = 0.19).

2.9 Discussion

This study investigated the contribution of interpersonal and individual variables to decision-making in the Trust Game in late adolescence. We tested whether the directed and dyadic social tie variables, *ego-rated social tie strength* [H1], *relationship reciprocation* [H2], and individual difference variables [H3] predicted Trust and Expected Reciprocation in late adolescents playing a Trust Game with real-world peers. Results showed evidence that both egocentric and mutual directed and dyadic social tie variables as well as a number of individual difference variables predicted late adolescent decision-making in the Trust Game.

2.9.1 Social tie predictors of trust and expected reciprocity

In the initial Trust phase of our modified Trust Game, single classroom (MRQAP) and group-level (MG-MRQAP) network models revealed that Trust was predicted positively by *ego-rated social tie strength*, and *IRI-EC (alter)*, as well as negatively by *relationship reciprocation*. Participants, or egos, entrusted higher amounts of hypothetical money to classmates, or alters, with whom they reported a stronger relationship. The *ego-rated social tie strength* variable was derived from a social network questionnaire assessing multiple dimensions of relationships including: how the ego perceives the strength of their relationship with the alter, whether the ego spends time outside of school with the alter, and whether the ego trusts the alter. In addition, participants reported that they would entrust more to classmates who reported a stronger relationship with the participant than the participant reported with the classmate. Therefore, the effects of these variables on trust reflect a composite of relationship strength (comprising companionship, trust, time spent together, among others) as perceived by the participant and in interaction with the perspective of another network member. Otherwise, most individual difference predictors did not survive the backward elimination procedure in the final model. Participants with higher levels of empathic concern received more hypothetical money during the Trust phase of the experiment relative to those with lower levels of empathic concern, but the effect size was small.

In the Expected Reciprocity phase of the modified Trust Game, single-classroom and group-level network models demonstrated that Expected Reciprocity was predicted positively by *ego-rated social tie strength* and *IRI-EC (alter)*, and negatively by *relationship reciprocation*, *gender (ego)*, and *gender (alter)*. Participants expected greater amounts to be returned to them by classmates with whom they reported a stronger relationship, and by classmates who reported a stronger relationship with the participant than the participant reported with the classmate. Participants also expected those with higher empathic concern to return larger amounts of hypothetical money. Finally, female participants expected higher amounts to be returned to them, and participants expected that their female classmates would return higher proportions of the entrusted stake.

These findings indicate that late adolescents' Trust Game behaviour reflects mutual as well as egocentric relationship variables. In other words, late adolescents' trusting behavior takes into account both their own and another person's evaluation of each dyadic relationship. This finding demonstrates that not only are social tie variables powerful predictors of physical exertion and giving in the Dictator Game (Burnett Heyes et al., 2011; Harrison, Sciberras & Jams, 2011), but also of Trust and Expected Reciprocity in the Trust Game. Furthermore, unlike these two prior studies, it is the first example of directed and dyadic social tie variables as strong predictors of decision-making in a truly dyadic context where a participant must carefully consider the reciprocal actions of a fellow player.

In both phases of the mTG, participants' trust and expected reciprocation decisions reflected how strongly they reported their relationship to be with classmates, and on how strongly classmates reported their relationships to be with the participant. That is, late adolescent participants showed behavioural sensitivity to both egocentric and altercentric relationship variables when deciding how much to invest and when predicting returns. We would expect *ego-rated social tie strength* and *relationship reciprocation* to predict decision-making in both phases of the game as participants should consider what they think the other player will do in response to their initial investment. The final results bear this out and point towards the importance of incorporating directed and dyadic social tie variables into our conception of essentially dyadic economic games. This complements recent work which suggests that forms of second-person information, such as reciprocity, may be vital to developing the foundations of social understanding (de Bruin, van Elk & Newen, 2012; Moore & Barresi, 2017). The ability of a late adolescent to effectively construct their gameplay strategy and respond effectively to the strategies of others depends on their capacity to recognise and respond to a sequence of mutually relevant actions. The individual capacities of two players alone, which are relatively stable, are unlikely to be the dominant predictors of responses to another player operating within the context of mutually relevant decision-making and subsequent actions.

It is important to note that the *ego-rated relationship strength* is an example of 'known' social information, while *relationship reciprocation* represents the combination of 'known' and 'inferred' social information. The participant will know how strong they consider their relationship to be with a peer but must infer how strong that peer considers their relationship to be with the participant. Late adolescent decision-making reflected both known and inferred social information in both phases of the mTG. Based on past research, we expect that early adolescent decision-making may not be predicted by inferred social information as represented by *relationship reciprocation*, as their capacities for inference may not be fully developed (Dumontheil, Apperly & Blakemore, 2010; Güroğlu, van den Bos & Crone, 2009; Lee, Jolles & Krabbendam, 2016). However, the reasons for the effect of relationship reciprocation in this particular direction are not well understood. It is not clear why participants tend to entrust more to classmates who report a stronger relationship with the participant than the participant reported with them. It may represent a predictive bias where participants, inferring that a classmate believes they have a strong relationship with the participant, entrust more to the classmate assuming that a greater sum will be returned (e.g. Güroğlu, van den Bos & Crone, 2009). However, this explanation would not translate neatly to previous studies using the Dictator Game, which does not contain a reciprocation dynamic. Alternatively, it may represent a difference in status, whereby the classmate is assumed by the participant to be trustworthy as they would attempt to ingratiate themselves with the participant. However, this interpretation would contradict past findings demonstrating that high- and low-status peers rarely invest in prosocial relations with each other (Rijsewijk, Dijkstra, Pattiselanno, Steglich & Veenstra, 2016).

It is also worth noticing that participants entrusted on average 2.3 coins to classmates in line with past work suggesting that trustors tend to entrust about half of the stake to the trustee (Buchan, Croson & Solnick, 2008; Sutter & Kocher, 2003). However, participants also expected a generous return of 4.6 coins, or two thirds of the tripled stake, which would leave the participant with 7.3 coins on average, and the peer with 2.3 coins on average. This result could build on previous findings that although adolescents are about as risk-averse as adults when making economic decisions in contexts where the risks were known, their risk-taking increases when the likelihood of winning or losing was more ambiguous (Tymula et al., 2012). In this circumstance, the level of expected return is ambiguous, and adolescents may be generally more optimistic about how much will be returned following their initial investment.

2.9.2 Individual difference predictors of trust and expected reciprocity

IRI-EC (Alter) was a significant, albeit weak, individual difference predictor in both phases of the mTG. Network members who scored more highly on *IRI-EC* received higher hypothetical amounts during the Trust phase and were also expected to return more money in the Expected Reciprocity phase of the game. In a previous study that used a modified Dictator Game in an adolescent social network setting, *ego* (not *alter*) empathic concern predicted investment. The nature of the Trust Game, and in particular our version of the game, is such that participants are prompted to think about the return on their investment. This could encourage greater use of alter characteristics in investment decisions. Past studies have shown that high levels of empathic concern are associated with increased intentions to give money and time, increased actual giving of money and time, and even costly altruistic giving (Bekkers, 2010; Einolf, 2008; Feldman-Hall, Dalgleish, Evans & Mobbs, 2015).

Gender was a significant predictor of decision-making in the Expected Reciprocity phase of the mTG. Female participants were expected to return higher amounts, and female participants expected higher amounts to be returned to them. These results support past findings that female participants feel more obligated to trust and reciprocate in the Investment Game than male participants, and will return higher amounts of money to those that trust them (Buchan, Croson & Solnick, 2008; Croson & Buchan, 1999). However, it should be noted that, relative to the social network predictors, the effects of all individual difference predictors were weak.

2.9.3 Limitations

A limitation of this study is that it does not contain younger or older comparison age groups, meaning that it was not possible to track any improving propensity for adolescents to take the perspectives of their peers when making economic decisions. In future, this design could be employed to investigate whether children or early adolescents are less likely than late adolescents to take into account altercentric social information in their trusting decisions, as has previously been shown using a Dictator Game. The structure of the mTG also allows for the systematic testing of the use of social information, as the Expected Reciprocity phase explicitly requires the participant to use relevant social information to make a decision, while the Trust phase only does so implicitly. Therefore, future studies could investigate the differences between adolescent age groups when making decisions that explicitly or implicitly require the use of relevant social information (see Apperly, 2010; Pollard, Burnett Heyes & Apperly, 2018).

A final conceptual limitation of this study worth considering is that it may not be accurate to discuss interpersonal and individual variables as if they have such a sharp dividing line between them. Certainly, in the case of directed social tie strength variables (e.g. ego-rated social tie strength), it is true that these variables represent the perception of a relationship from the perspective of one participant, and not a shared relationship as represented by a true dyadic variable (e.g. relationship reciprocation). In this study and later chapters, interpersonal and individual determinants are discussed with this separation in mind as the social network analysis framework delineates between variables that represent connections between members of a network (either directed or undirected edges) and variables that represent individual traits of members within a network (nodes). In this analysis, directed social tie strength variables represent connections between network members. Furthermore, these connections share variance in a way that individual difference variables do not as participants record multiple observations in reference to other participants within the analysis, hence the need for social network analysis. However, while this might be an analytically useful framework as it allows us to quantify and compare relationships within social groups, we emphasise that this conceptually does not mean that directed social tie strength variables represent anything ‘more’ than each participant’s individual perspective of their relationship.

2.9.4 Future studies

Future studies should investigate whether adolescents gain greater access to the minds of peers as they develop, or whether they develop a greater proficiency for using information inferred from the mental states of others (Keysar, Lin & Barr, 2003; Symeonidou, Dumontheil, Chow & Breheny, 2015). The generalisability of the social network measures' effects on economic decision-making should also be tested in other game theoretical paradigms. Based on evidence from this study, we would hypothesise that egocentric and mutual dyadic variables would, for example, predict cooperation in the Prisoner's Dilemma (Poundstone, 1993), and fair splits in the Ultimatum Game (Güth, Schmittberger & Schwarze, 1982). Future research should also be conducted to try and understand the effect of relationship reciprocation and its direction. For example, by investigating the potential co-evolution of prosocial behaviour and evolving relationship strength within a longitudinal social network design. Finally, further research could use this method to test other individual difference measures that may have an impact on economic decision-making. The benefit of the social network approach being that one can investigate whether others may perceive the individual difference attributes of network members.

2.10 Conclusion

This study combined game theory and social network analysis to investigate the social network-level and individual-level determinants of trust and expected reciprocity in a modified Trust Game played sequentially with all members of a real-world network. Our results demonstrated that social network-level variables were robust and consistent predictors of decision-making in both phases of the Trust Game. Specifically, trust and expected reciprocity were predicted by both ego-rated relationship strength and the extent to which the alter reciprocated relationship strength. These findings highlight the value of considering social tie variables in research on social decisions made within real-world social contexts. Additionally, we found effects of individual variables which were broadly consistent with prior literature. Further research using this approach could seek to examine the relative contributions of social network- and individual-level variables to decision-making within other economic games and other adolescent groups. Such research may shed greater light on how both our individual characteristics and our perceptions of our relationships impact our decision-making.

Split or steal? Stronger relationships predict adolescent defection in the Prisoner's Dilemma.

3.1 Abstract

The Prisoner's Dilemma has been used extensively in the social decision-making literature to distinctly investigate the predictors of simultaneous cooperation and defection in adults, but not in adolescents. In this study, we combine social network methods with a novel version of the Prisoner's Dilemma to test whether directed and dyadic social tie variables predict adolescent cooperation in a simultaneous context, and whether these variables better predict late (vs. early) adolescent decision-making (*N* = 157, *nNetworks* = 9, *age range* = 13 - 18). Participants across all adolescent networks chose to defect from classmates with whom they reported a stronger relationship, and from classmates who reported stronger relationships with them. Conversely, participants chose to cooperate with classmates with whom they reported a stronger relationship than the classmate reported with them. Finally, early adolescent decision-making was better predicted by egocentric variables, suggesting that early adolescents were the most inclined to defect from friends. Our findings demonstrate that directed and dyadic social tie relationship variables made some contribution to predicting decision-making in the mPD, however, the variance explained was small.

3.2.1 Decision-making in a simultaneous context

A number of game theory paradigms have been employed to explore the developing sensitivity of adolescents to social features in economic games (see Kilford, Garrett & Blakemore, 2016 for review), including the Trust Game (Berg et al., 1985; e.g. van den Bos, Westenberg, van Dijk & Crone, 2010), Ultimatum Game (Güth et al., 1982; e.g. Güroğlu, van den Bos & Crone, 2009), and Dictator Game (e.g. Burnett Heyes et al., 2015; Kahneman et al., 1986). However, very little research has been conducted on adolescents using the Prisoner's Dilemma (Poundstone, 1993), despite this game being used extensively in the adult social decision-making literature to distinctly investigate the predictors of cooperation and defection in a simultaneous context (Rilling & Sanfey, 2011). Furthermore, while past research using other economic games indicates that adolescents are generally sensitive to relationship features, it is still not clear what the individual, interpersonal, and cognitive determinants of this sensitivity are and how these combine to influence economic decision-making. Subsequently, this study was designed to investigate the individual and interpersonal determinants of cooperation and defection decisions in real-world adolescent peer relationships using a novel version of the Prisoner's Dilemma game.

3.2.2 Prisoner's Dilemma

In the standard version of the Prisoner's Dilemma (Poundstone, 1993), two players simultaneously decide whether to cooperate with a partner, without knowledge of whether their partner is going to cooperate with them. If both partners cooperate, they both receive a modest payoff; if both defect, they both receive a small payoff; if one player cooperates while the other defects, then the player who cooperated receives the lowest payoff, while the player who defected receives the highest. The Nash equilibrium, or the balance of actions in which both players are following their best strategy in response to the other player, for the

Prisoner's Dilemma is mutual defection (Binmore, 2007; Rilling & Sanfey, 2011). However, in most versions of the game, participants cooperate at a higher rate than expected (Camerer, 2003); this is especially true of iterated versions, which better approximate real social interactions due to their greater temporality. Players must calculate not only the decision they are making in the present moment, but what repercussions their decision may have for their reputation, and what consequences they may face from their fellow player in future iterations (Axelrod, 1984; Axelrod & Hamilton, 1981). Similarly, social relationships are founded on repeated interactions, which give each member of the relationship more information and context for how they should perceive their relationship in the present and for how they should approach it in the future. Consequently, the Prisoner's Dilemma has always provided some of the most fascinating insights into human interactions through the prism of economic decision-making in social contexts (Cosmides & Tooby, 2000; Fehr & Gachter, 2002).

3.2.3 Social and individual difference predictors of decision-making in the Prisoner's Dilemma

Past research has repeatedly demonstrated the importance of social relationship features to decisions made within the Prisoner's Dilemma by adults (see Rilling & Sanfey, 2011 for review; Yamagishi, Kanazawa, Mashima & Terai, 2005). For example, participants are more likely to cooperate with a human than a computer, which was hypothesised to be because participants felt that the computer was less likely to punish defection, therefore allowing them to maximise earnings (Rilling, Sanfey, Aronson, Nystrom & Cohen, 2004). Not only are participants more likely to cooperate with humans over computers, but with friends over strangers, suggesting the importance of the presence of a social relationship to cooperative behaviour (Ames et al., 2006; Mienaltowski & Wichman, 2020). Supporting findings from the fMRI literature show that gameplay feedback from the partner to the player elicits activation in brain regions associated with Theory of Mind, for example, the dorsomedial prefrontal cortex (DMPFC), posterior cingulate, and the temporo-parietal junction (TPJ) (Rilling, Sanfey, Aronson, Nystrom & Cohen, 2004). Once again, suggesting a role for social perspective-taking in decision-making. Finally, players also tend to cooperate more with designated in-group members than out-group members when playing the game (Rilling, King-Casas & Sanfey, 2008). Past research also notes the dynamism of sensitivity to in-group membership, as one study found that in-group members were not more likely to cooperate with in-group members and defect from outgroup members until several rounds had passed in an iterated Prisoner's Dilemma (Dorrough, Glöckner, Hellmann & Ebert, 2015). Therefore, not only do social affiliations play an important role in predicting cooperation in the Prisoner's Dilemma, but the importance of these affiliations can evolve over time with repeated interactions – a mechanism which may be an effective analogy for general cooperation in social relationships in itself.

Unfortunately, very little research has been conducted with the Prisoner's Dilemma in adolescent populations. This is surprising as although the Prisoner's Dilemma does share features with the Trust Game, which has repeatedly been used (e.g. Lee, Jolles & Krabbendam, 2016; van den Bos, Crone, Meuwese & Güroğlu, 2018; van den Bos et al., 2010), it differs significantly in that it requires players to simultaneously choose whether to cooperate with each other (Rilling & Sanfey, 2011). In the Trust Game, the trustee has the option to reciprocate trust based on information they already have on a decision their partner has already made, and the trustor is aware that the trustee will know the decision of the trustor before making their decision. Whereas in the Prisoner's Dilemma, greater demands are made on the player to infer the strategy of their partner as neither player knows what decision the other will make, therefore, placing greater demands on players' perspective-taking abilities.

To our knowledge, only a couple of studies have specifically investigated adolescent decision-making in the Prisoner's Dilemma. In one study, children and adolescents (*ages* = 6-18) played a game equivalent to a sequential, symmetric Prisoner's Dilemma (Brocas, Carrillo & Kodaverdian, 2017). Their findings indicated that cooperation increases with age in adolescence. When only considering participants, who had previously chosen to defect in a one-shot Prisoner's Dilemma, late adolescents were more likely to choose to cooperate in the first round of the sequential, symmetric Prisoner's Dilemma than early adolescents. This finding was interpreted as evidence that late adolescents are more cooperative, and better able to reason about future outcomes and the decisions of others. In another study, adult and adolescent participants played an iterated four-player Prisoner's Dilemma within their own age groups with three other real players through a computer interface. Early adolescents were found to display reciprocal but volatile decision-making while late adolescents and adults pursued more stable, cooperative strategies. The authors suggested that this result may reflect a developing Theory of Mind, which allows older participants to more accurately adjust their strategies to the decisions of other players (Gutiérrez-Roig, Gracia-Lázaro, Perelló, Moreno, & Sánchez, 2014).

While past research has also pointed towards the increasing role of intentionality and social features in adolescent economic decision-making, there are also studies which have related strategic differences in economic gameplay to individual differences between players. Participants with prosocial social value orientations tend to be more cooperative, while participants with egoistic social value orientations tend to be more likely to defect in a one-shot Prisoner's Dilemma (Balliet, Parks & Joireman, 2009; Lambert, Declerck, Emonds & Boone, 2017; Simpson, 2004). Machiavellianism has been shown to predict defection (Deutchman & Sullivan, 2018), while socioeconomic status has been shown to predict cooperation in the Dictator Game (Nettle, Colléony & Cockerill, 2011). Finally, gender has been found to predict differing gameplay; females cooperate more than males in early rounds of the Prisoner's Dilemma (Ortmann & Tichy, 1999), but males have been found to cooperate more than females overall (Rapoport & Chammah, 1965).

3.2.4 The social network

This past research demonstrates that general relationship features, intentionality, and individual differences are clearly important to decision-making in the Prisoner's Dilemma, however, no prior research has attempted to investigate the predictive power of directed and dyadic social tie variables. This is especially surprising considering that the Prisoner's Dilemma is played within an explicitly dyadic context in which one must consider the reputation and predict the actions of another player. If we are concerned with the importance of social relationships to decision-making within the Prisoner's Dilemma, then we should not only investigate general and artificial relationships between players, but also real, authentic, established social relationships.

Social network methods can be used to this effect by measuring the impact of social tie variables as predictors of decision-making, alongside the effects of other individual difference variables. This approach allows for the disentangling of egocentric, altercentric, and mutual dyadic variables and their contributions to variance in gameplay. Dyadic variables demand a score for the participant (ego) and all the other network members (alters), and therefore, allow the researcher to test the contribution of egocentric social information the participant knows (how the participant perceives their relationship with a fellow network member), altercentric inferred social information (how the participant perceives their relationship with a fellow network member), and mutual social information (the shared perception of the relationship) to decision-making. A dyadic approach allows for the testing of the predictive power of egocentric, altercentric, and mutual variables.

Burnett Heyes et al. (2015) used this approach to combine game theory with social network analysis to investigate the extent to which social tie strength and reciprocity modulated prosocial resource allocation in a modified Dictator Game. Adolescent (*age range* = 13-16 years) classroom networks were mapped using a social network questionnaire (adapted from Harrison et al., 2011), and participants were asked to privately distribute money between themselves and other members of their class. Analyses revealed that both ego-rated social tie strength and relationship reciprocity predicted prosocial giving in the modified Dictator Game and both variables explained more variance than individual difference variables. Further significant interactions with year group indicated that relationship reciprocity predicted prosocial resource allocation better for late adolescent than for early adolescent groups. This pattern of findings was interpreted as evidence for the importance of directed and dyadic social tie variables as determinants of decision-making in economic games, and their ability to reveal the development of the adolescent's capacity to infer the mental states of others as it applies to economic decision-making.

3.2.5 The study

In this study, we pair this research paradigm with a novel version of the Prisoner's Dilemma to test whether directed and dyadic social tie variables predict adolescent cooperation in a simultaneous context. We mapped nine social networks (*N* = 157; *age range* = 13 - 18) across five year groups using a social network questionnaire (Burnett Heyes et al., 2015; adapted from Harrison et al., 2011). This measure produced scores denoting the strength of the relationships between individuals within the classroom network. Participants also completed the Family Affluence Scale II, Kiddie Mach, and Social Value Orientation questionnaire (Currie et al., 2004; Davis, 1980; Nachamie, 1970; Van Lange, 1999). Respectively, these questionnaires produced quantitative measures for family affluence, Machiavellianism, and social value orientation. Both directed and dyadic social tie and individual difference variables were used as predictors for cooperation in a modified version of the Prisoner's Dilemma. In this modified version of the game, participants would decide whether to split (cooperate) or steal (defect) differing amounts of money with different classmates. These decisions were recorded on a paper questionnaire in a hypothetical context without feedback.

3.2.6 Hypotheses

[H1] We hypothesised that participants would tend to cooperate more with classmates with whom they reported stronger social ties, with classmates that reported stronger relationships with them, and with classmates who reported a stronger relationship with the participant than the participant reported with the classmate (Burnett Heyes et al., 2015). Therefore, *cooperation* would be predicted by the egocentric variable: *ego-rated social tie strength*; the altercentric variable: *alter-rated social tie strength*, and the mutual dyadic variable: *relationship reciprocation*. [H2] We also predicted an interaction between egocentric, altercentric, and mutual dyadic variables, and year group, following past research suggesting that late adolescents better incorporate social perspectives than early adolescents when playing economic games (Burnett Heyes et al., 2015, Güroğlu, van den Bos & Crone, 2009, 2014). [H3] Additionally, we hypothesised that family affluence would predict greater cooperation (Nettle, Colléony & Cockerill, 2011); Machiavellianism would predict greater defection (Spitzer et al., 2007); prosocial value orientations would predict greater cooperation, while egoistic value orientations would predict defection (Balliet, Parks & Joireman, 2009; Lambert, Declerck, Emonds & Boone, 2017; Simpson, 2004); and that males would cooperate more than females overall (Rapoport & Chammah, 1965).

3.3 Method

3.3.1 Participants

We recruited 157 participants in nine networks from five schools (see Appendix B1). Data was obtained from nine classes within year groups: 9 (*n* = 49, *nNetworks* = 2, *female* = 49, *Mage*(*SD*) = 13.32 (0.48) years, *range* = 13 - 14 years), 10 (*n* = 41, *nNetworks* = 2, *female* = 41, *Mage*(*SD*) = 14.3(0.47) years, *range* = 14 - 15 years), 11 (*n* = 17, *nNetworks* = 1, *female* = 12, *Mage*(*SD*) = 15.2(0.39) years, *range* = 15 - 16 years), 12 (*n* = 35, *nNetworks* = 3, *female* = 26, *Mage*(*SD*) = 16.23(0.31) years, *range* = 16 - 17 years), and 13 (*n* = 15, *nNetworks* = 1, *female* = 15, *Mage*(*SD*) = 17.10(0.36) years, *range* = 17 - 18 years). Consent was gained from the parents or guardians of all participants, and assent was obtained from the participants themselves. The study was approved by the University of Birmingham Science, Technology, Engineering and Mathematics Ethical Review Committee.

3.4 Measures

3.4.1 Modified Prisoner's Dilemma (mPD)

Cooperation was measured using a modified questionnaire version of the Prisoner's Dilemma game (mPD). The mPD questionnaire listed each member of the participant's class alongside five pots of hypothetical money that would purportedly be divided between the participant and each classmate. The hypothetical money pots were worth one, two, three, four and five coins; for each classmate and pot of money, participants chose whether to split (cooperate) or steal (defect) with or from each classmate. The rules of the game followed a standard Prisoner's Dilemma formula with a minor modification. Participants were told that if both the participant and the classmate chose to split, then they would both share the stake; if both the participant and the classmate chose to steal, then they would both get nothing; if one of the players chose to split, while the other chose to steal, then the player who chose to steal would keep the entire stake, and the player who chose to split would keep nothing (Figure 3.1.). Note that the minor modification in this design is that the lowest payoff is not associated solely with the [cooperate x defect] cell of the payoff matrix, meaning that the participant does not have recourse to minimise their loss if they believe their opponent would defect in the game. While this was taken into consideration, it was decided that this design was more comprehensible to an adolescent sample, particularly in younger year groups. Participants did not believe they would receive money, but that the researchers would calculate who the best players of the game were. All participants were informed at the end of the study that the purpose of the research was not to determine the best players of the mPD.

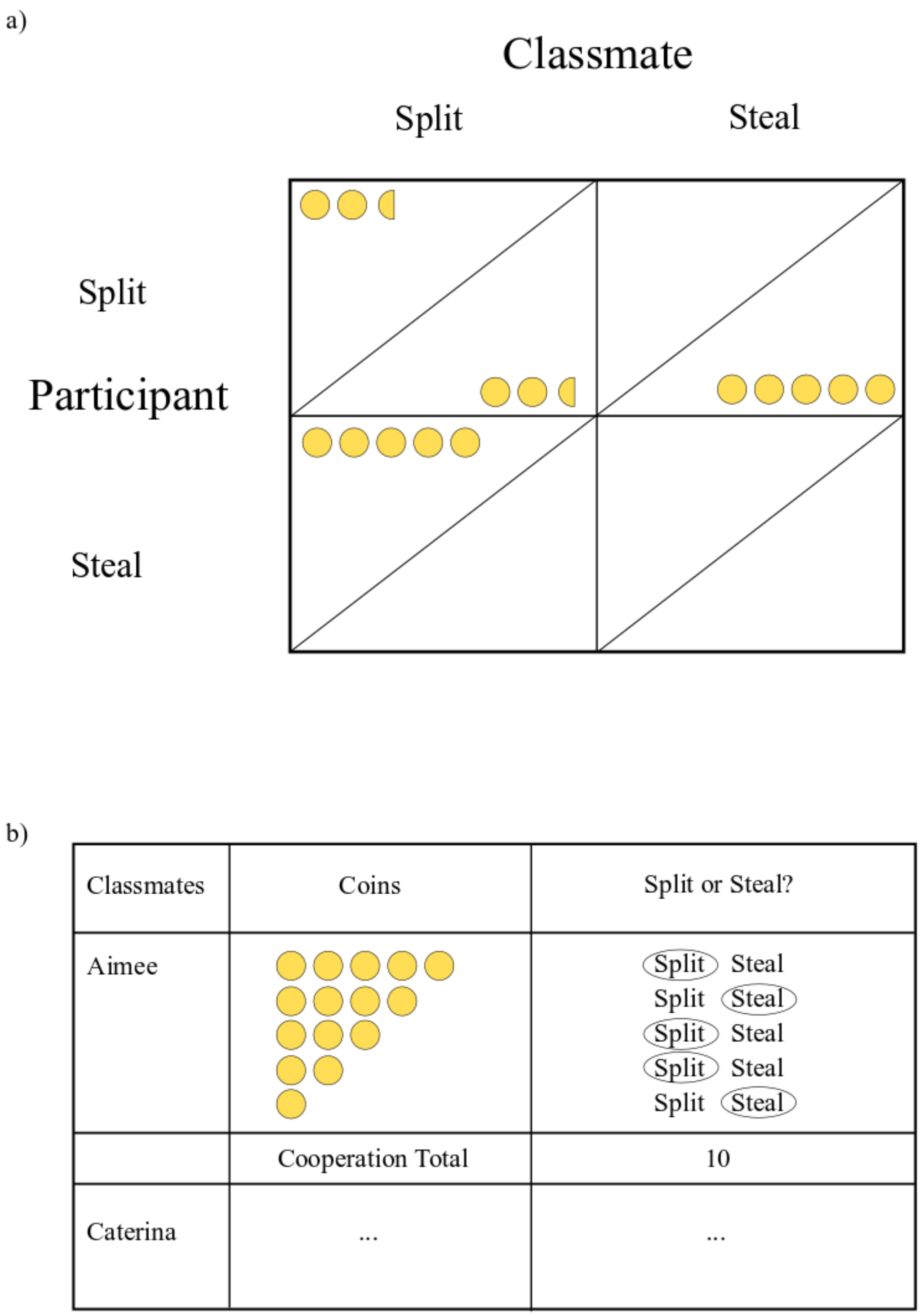


Figure 3.1. a) Example payoff matrix for a stake of 5 coins in the modified Prisoner's Dilemma. Upper-left quadrant: Split-Split; participant and classmate share stake equally. Upper-right quadrant: Split-Steal; participant gets nothing, classmate gets entire stake. Lower-left quadrant: Steal-Split; participant gets entire stake, classmate gets nothing. Lower-

right quadrant: Steal-Steal; participant and classmate both get nothing. Note that in the traditional Prisoner's Dilemma, if players think their partners are going to defect, then they have the option to also defect and retain a small payoff (e.g. 5,1), whereas if they chose to cooperate then they would not retain any payoff (e.g. 5,0). In the mPD, if their partner defects, participants have no recourse to mitigate the loss. The game was formulated this way to decrease the chances that early adolescent participants would be more confused by the rules of the game than late adolescents. b) Depiction of mPD measure.

3.4.2 Social Network Questionnaire (SNQ)

A seven-item version of the SNQ (Burnett Heyes et al., 2015; Harrison et al., 2011) adapted for adolescents was used to assess the strength of the social ties between participants. The SNQ was identical to that used in Chapter 2. Five social network variables were created from this questionnaire. *Ego-rated social tie strength* represented the strength of the relationship between the participant (ego) and classmate (alter), as assessed by the participant. *Alter-rated social tie strength* represented the strength of the relationship between the participant and classmate, as assessed by the classmate. *Relationship reciprocation* represented the difference between the participant's and the classmate's assessment of relationship strength, referenced to *ego-rated social tie strength*. These three measures were conceptualised as three measurements of social tie strength that represented different levels of social inference: egocentric, altercentric, and mutual (Selman, 1980). If cooperation in the mPD was predicted by *ego-rated social tie strength* that would suggest participant decision-making was in part determined by an egocentric variable i.e. how the participant perceives the relationship. If cooperation in the mPD was predicted by *alter-rated social tie strength* that would suggest decision-making was partly determined by an altercentric variable i.e. how another network member perceives the relationship as inferred by the participant. Finally, if cooperation was predicted by *relationship reciprocation* that would suggest that decision-making was in part determined by a mutual dyadic variable i.e. the shared representation of the relationship as perceived by the participant. Control variables were also derived from the SNQ: *duration* represented how long the participant had known each classmate, and *familial ties* represented whether the participant was related to any classmates.

3.4.3 Gender

Gender was recorded on the SNQ. Participants could indicate male, female, or a self-identified gender identity term. Past research suggests potential gender differences in decision-making on the Prisoner's Dilemma, although findings have been inconsistent. There is evidence that females cooperate more than males in early rounds of the Prisoner's Dilemma (Ortmann & Tichy, 1999), but that males cooperate more than females overall (Rapoport & Chammah, 1965). Other research suggests that there are no global gender differences in decision-making in the Prisoner's Dilemma, but that social context may be a moderator for some small gender differences (Balliet, Li, Macfarlan & Van Vugt, 2011; Eckel & Grossman, 2008; Simpson, 2003). In the current study, female gender was coded as 1 and male gender was coded as 0.

3.4.4 Social Value Orientation (SVO)

The SVO is a nine-item measure of stable distributional preferences between oneself and others (Van Lange, 1999). Each item is a table signifying three potential distributions between the responder and an abstract other. One of the distributions represents an egoistic decision, where the responder wants maximal gain for themselves; another distribution represents the prosocial decision, whereby the responder maximises the payoff for both themselves and the other; the final distribution represents the competitor decision, where the responder maximises their own payoff relative to the other. This measure has been shown to have good test-retest reliability and validity (Murphy, Ackermann & Handgraaf, 2011). Past research suggests that prosocial participants tend to cooperate more in one-shot Prisoner's Dilemma games, and bias towards cooperative exchanges in the iterated versions, while egoistic participants show the opposite behavioural pattern. (Balliet, Parks & Joireman, 2009; Lambert, Declerck, Emonds & Boone, 2017; Simpson, 2004). SVO has also been found to moderate the relationship between mentalising and trust in the Trust Game (Derks, Van Scheppingen, Lee & Krabbendam, 2015).

3.4.5 Kiddie Mach (KM)

The Kiddie Mach was administered as in Chapter 2 as a measure of Machiavellianism appropriate for adolescents (Nachamie, 1970). Machiavellianism has been shown to predict defection in the Prisoner's Dilemma (Deutchman & Sullivan, 2018).

3.4.6 Family Affluence II (FAS-II)

The FAS-II was administered as in Chapter 2 as an adolescent-appropriate measure of socioeconomic status (Currie et al., 2004). It has previously been found that participants from wealthier areas were more likely to demonstrate cooperative behaviour and make larger investments when playing the Dictator Game (Nettle, Colléony & Cockerill, 2011). Therefore, it was hypothesised that higher socioeconomic status would predict cooperation in the Prisoner's Dilemma.

3.5 Experimental Procedure

Participants completed all the measures with pen and paper in a large testing room that allowed privacy for each individual. The experiment took approximately 40-60 minutes to complete. The mPD was adapted from the British television programme Goldenballs (see Appendix B2). Rules for the mPD were given to participants at the beginning of the session and examples of all three outcomes (both split; both steal; split and steal) were shown to participants via clips from Goldenballs. Participants were told they would be playing a paper version of the game but that they should imagine themselves playing with each classmate in the questionnaire. Participants were also told that the goal was to make as much money as possible and that the researchers would calculate who earnt the most hypothetical money based on the responses of the entire class. Consequently, they should think carefully about the decisions they make with each classmate to ensure that they maximise their payoffs, as opponents can defect. However, participant scores would not be compared in this way. All participants were informed of this at the end of the session. This minor deception was approved by the University of Birmingham Science, Technology, Engineering and Mathematics Ethical Review Committee. All measures were presented in a questionnaire pack that contained measures in the following order: mPD, SNQ, individual difference measures (KM, FAS-II, SVO).

3.6 Statistical Procedures

3.6.1 Modified Prisoner's Dilemma

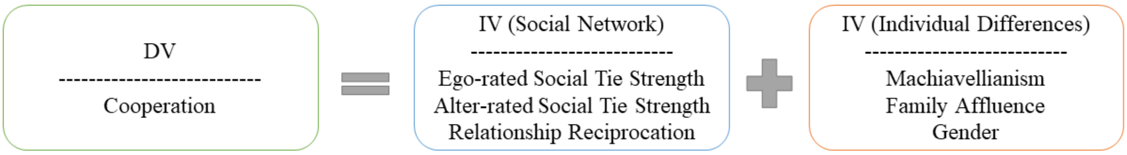
For each participant (ego)-classmate (alter) dyad, responses across the five stakes of the mPD were summed to create a single cooperation value. This value represented cooperation by summing the products of the binary decision responses (split = 1, steal = 0), and the corresponding stakes (1-5 coins) relating to each classmate within a participant's network. For each dyad, this value was included in a n x n cooperation matrix representing how many coins each ego (rows) chose to split with each alter (columns) in their network (Figure 3.2.).

3.6.2 Social Network Questionnaire

Five variable matrices were derived from the SNQ for each classroom. *Duration* indicated how long the participant (ego; rows) had known each network member (alter; columns). Similarly, *familial ties* indicated whether each ego reported a familial tie to each alter. *Ego-rated social tie strength* was calculated by summing across the remaining SNQ items. Thus, *ego-rated social tie strength* represented directed relationship strength as perceived by the participant or ego; as such, this variable encodes egocentric social information. *Alter-rated social tie strength* was derived by transposing the *ego-rated social tie strength* matrices, meaning that the rows represent social tie strength as perceived by alters. Thus, *alter-rated social tie strength* represents directed relationship strength as perceived by the alter, and therefore encodes altercentric social information. Finally, *relationship reciprocation* was calculated by subtracting the *alter-rated social tie strength* matrices from the *ego-rated social tie strength* matrices as in Chapter 2 and prior studies (Burnett Heyes et al., 2015; Harrison et al., 2011). Therefore, *relationship reciprocation* represents the discrepancy between relationship strength perceived by ego versus alter as referenced to the ego (i.e. a positive value corresponds to egocentric > altercentric social tie strength); as such, this variable takes into account both egocentric and altercentric (i.e., mutual) dyadic social information.

3.6.3 Individual Difference Variables

Scores for the KM, and FASII were calculated for each participant. These values were input into a matrix by repeating the participant's score across every cell in the row relating to the participant. This procedure was repeated for each member of the network, resulting in a matrix with unique row values corresponding to each participant, repeated across every column. The SVO measure results in three categorical outputs. Consequently, three separate SVO variable matrices were created representing prosocial, egoistic, and competitor scores. The input process was the same as for the other individual difference variables, except that instead of a continuous value being repeated across each row, there was a binary value (1 = Presence of SVO, 0 = Absence of SVO). Gender was also a categorical binary variable, and thus matrices were created in the same way (0 = Male, 1 = Female). For each variable, ego and alter matrices were created. Ego matrices represent how the participant's individual difference variable score predicted the amount the participant chose to split (cooperate). Alter matrices represent how the classmate's individual difference variable score predicted the amount the participant would split (cooperate) with the classmate.



X	John	Rachel	Jessica
John	X	£9	£15
Rachel	£5	X	£15
Jessica	£2	£0	X

X	John	Rachel	Jessica
John	X	7	5
Rachel	3	X	5
Jessica	2	5	X

X	John	Rachel	Jessica
John	X	3	2
Rachel	7	X	5
Jessica	5	5	X

X	John	Rachel	Jessica
John	X	4	3
Rachel	-4	X	0
Jessica	-3	0	X

X	John	Rachel	Jessica
John	X	57	57
Rachel	71	X	71
Jessica	64	64	X

X	John	Rachel	Jessica
John	X	3	3
Rachel	10	X	10
Jessica	6	6	X

X	John	Rachel	Jessica
John	X	0	0
Rachel	1	X	1
Jessica	1	1	X

Figure 3.2. A depiction of the data preparation and analysis.

3.7 Statistical Analyses

The statistical analyses were comprised of three parts. 1) An analysis of the descriptive differences of network and non-network variables between year groups (see Appendix B2-B3; Table 3.1; Table 3.2). 2) A within-network analysis of network and non-network variables as predictors of cooperation in the mPD (see Appendix B4-B5). 3) A pooled-network analysis of network and non-network variables as predictors of cooperation in the mPD. Note that in the third phase, two distinct models had to be created separately: one including *alter-rated social tie strength* as a predictor, and one including *relationship reciprocation*. This is because *relationship reciprocation* is a linear combination of *ego-rated social tie strength* and *alter-rated social tie strength*, so any model including all three variables would produce incalculable coefficients for *relationship reciprocation*.

3.7.1 Sample Descriptives

Means and standard errors were calculated and compared using ANOVAs for the non-network variables: *family affluence* (FAS-II), and *Machiavellianism* (KM). Chi-square tests were used to compare *gender* and *social value orientation* (SVO: *competitor*, *egoistic*, *prosocial*) frequencies between year groups. Bootstrapped mean densities and standard errors were calculated for network variables: *cooperation*, *ego-rated social tie strength*, *relationship reciprocation* and *duration*.

3.7.2 Model Selection

Similarly to Chapter 2, the variables entered into the initial MG-MRQAP model were selected if they had a) differed significantly between year groups in the descriptives, or b) predicted cooperation in any of the single-group multiple regression with quadratic assignment procedure (MRQAP; Dekker, Krackhardt & Snijders, 2007; Krackhardt, 1988) models. Additionally, terms were entered into the model, which accounted for remaining explanatory variable interactions with year group. Included in both the initial Cooperation MG-MRQAP model including Relationship Reciprocation and the initial Cooperation MG-MRQAP model including Alter-Rated Social Tie Strength were all significant predictors at the single-group level, which included all social network- and individual-level predictors except for *familial ties* and *SVO-Egoistic*.

3.7.3 Multiple Regression Predicting Resource Allocation Across all Networks

As in Chapter 2, a multi-group multiple regression with quadratic assignment procedure (MG-MRQAP) was used to analyse the relationship between explanatory variables and cooperation in the mPD across all networks. Dependent variable matrices were regressed on to explanatory variable matrices within networks in order to obtain regression coefficients. Year group was coded using a dummy variable and then multiplied by all the explanatory matrix values, allowing for the examination of network-level (year group) variable interactions with explanatory variables. Analysis was conducted in R (R Development Core Team, 2011). Statistical significance was set at $p < .05$, two-tailed for non-directional, and one-tailed for directional hypotheses. No directional hypotheses were postulated for the relationship between cooperation in the mPD and *duration*; hypotheses relating to all other predictors were directional. Nonsignificant variables were dropped from the analysis in a stepwise manner, beginning with the variable for which the two-tailed *p* value was closest to 1. An exception to this order of predictor elimination was made for cases where the main effect p-value was larger than its corresponding interaction term; in this case the main effect for a significant interaction was retained in the model.

3.8 Results

3.8.1 Sample Descriptives

There was no significant difference between age groups in either Kiddie Mach ($F(4,143) = 0.83$, $p = .47$) or Family Affluence ($F(4,1423) = 1.91$, $p = .11$) scores. Chi-square tests revealed a significant difference between age groups in gender distribution $X^2(4, N = 104) = 31.22$, $p < .001$). Post-hoc tests revealed a significant difference between Year 9 and Years 11, and 12; and Year 10 and Years 11 and 12. Years 9, 10, and 13 did not have any male participants, whereas Years 11 and 12 did. Chi-square tests also revealed a significant difference between age groups in SVO-P frequencies $X^2(4, N = 104) = 10.92$, $p < .05$). Post-hoc tests revealed a significant difference between Year 9 and Years 10, and 13; as well as Year 12 and Year 13. Relative to group size, Years 10 and 13 had more prosocial participants than Year 10, and Year 13 had significantly more than Year 12. Chi-square tests showed a significant difference between age groups in SVO-C frequencies $X^2(4, N = 104) = 11.12$, $p < .05$). Post-hoc tests revealed a significant difference between Year 9 and Years 10; as well as

Year 10 and Year 12. Year 9 had a higher number of competitors than 10, and Year 12 had a higher number than 10. Finally, chi-square tests revealed no significant difference between age groups in SVO-E frequencies $X^2(4, N = 104) = 3.06, p > .05$).

Non-network variables	Year 9 *N*	Year 9 *M(SD)*	Year 9 *Range*	Year 10 *N*	Year 10 *M(SD)*	Year 10 *Range*	Year 11 *N*	Year 11 *M(SD)*	Year 11 *Range*
Family Affluence	49	9.75(2.36)	8 - 13	41	9.88(2.31)	7 - 13	17	9.64(1.50)	6 - 12
Machiavellianism	49	57.26(12.95)	46 - 83	41	57.68(11.05)	47 - 78	17	56.35(7.16)	47 - 72
Gender (female)	49			41			12		
SVO-E	4			4			0		
SVO-P	16			23			9		
SVO-C	11			2			4		

	Year 12 *N*	Year 12 *M(SD)*	Year 12 *Range*	Year 13 *N*	Year 13 *M(SD)*	Year 13 *Range*
Family Affluence	35	10.21(1.63)	6 - 13	15	11.46(1.96)	7 - 13
Machiavellianism	35	54.66(8.33)	47 - 67	15	55.2(7.88)	41 - 72
Gender (female	26			15		
SVO-E	5			1		
SVO-P	11			10		
SVO-C	11			1		

Table 3.1. Non-network descriptives.

Network variables	Year 9 *N*	Year 9 *Density M (SEM)*	Year 9 *Range*	Year 10 *N*	Year 10 *Density M (SEM)*	Year 10 *Range*	Year 11 *N*	Year 11 *Density M (SEM)*	Year 11 *Range*	Year 12 *N*	Year 12 *Density M (SEM)*	Year 12 *Range*	Year 13 *N*	Year 13 *Density M (SEM)*	Year 13 *Range*
Cooperation	1465	5.78(0.81)	0 – 9	841	8.08(0.63)	0 – 14	289	6.11(0.78)	1 – 15	417	5.05(0.87)	0 – 13	225	5.46(0.70)	0 – 7
SNQ-O	1465	1.54(0.22)	-3 – 7	841	1.98(0.21)	-3 – 7	289	2.22(0.22)	-1 – 7	417	2.05(0.21)	-1 – 7	225	1.89(0.19)	0 – 6
SNQ-R	1465	0.87(0.14)	0 – 7	841	1.84(0.27)	0 – 7	289	1.31(0.09)	0 – 5	417	0.94(0.14)	0 – 5	225	1.05(0.12)	0 – 4
Duration	1465	1.58(0.20)	0 – 9	841	3.25(0.17)	0 – 14	289	3.76(0.41)	1 – 15	417	1.94(0.44)	0 – 13	225	1.17(0.29)	0 – 7

Table 3.2. Network descriptives.

3.8.2 Cooperation MG-MRQAP Model including Relationship Reciprocation

Social network and individual difference variables (see Methods) were included in a MG-MRQAP model as predictors for *cooperation* in a one-shot mPD across all classes in all year groups (N = 157). In the final Cooperation MG-MRQAP model (R^2_{adj} = .08, p < .001), including Relationship Reciprocation, higher *ego-rated social tie strength* significantly predicted less *cooperation*, whereas, *relationship reciprocation*, and *gender* (ego) (1 = Female) positively predicted *cooperation*. There was also a negative interaction between *ego-rated social tie strength* and year group (Table 3.3). All else being equal, participants chose to defect more from classmates with whom they reported a stronger relationship. However, when participants reported a stronger relationship with the classmate than classmate reported with the participant, then the participant would choose to cooperate more in the mPD. The interaction indicates that early adolescent participants were more likely to choose to steal from those they reported a stronger relationship with than late adolescents. Additionally, female participants tended to cooperate more than male participants.

Independent Variable	Unstandardised Regression Coefficient	p value
MG-MRQAP model R^2_{adj} = .08, p < .001		
Ego-rated social tie strength	-5.89	< .001
Relationship Reciprocation	0.15	.02
Gender (Ego)	2.78	.01
Ego-rated social tie strength x Year Group	-0.56	< .001

Table 3.3. MG-MRQAP model with relationship reciprocation predicting PD cooperation. Class intercepts for the model were: Year 9A (*b* = 11.37, *p* = 1.00), Year 9B (*b* = -1.09, *p* = .14), Year 10A (*b* = 1.57, *p* < .001), Year 10B (*b* = 1.01, *p* < .001), Year 11A (*b* = -0.23, *p* = .003), Year 12A (*b* = -0.30, *p* = .99), Year 12B (*b* = -1.98, *p* < .001), Year 12C (*b* = 0.27, *p* < .001), Year 13A (*b* = 2.15, *p* = 0.42). Independent variables eliminated due to non-significance were Duration x Year Group (*b* = -0.01, *p* = .49), Gender (Alter) x Year Group (*b* = 0.33, *p* = .39), SVO-C (Ego) x Year Group (*b* = 0.36, *p* = .34), Reciprocation x Year Group (*b* = 0.01, *p* = .44), Gender (Ego) x Year Group (*b* = 1.25, *p* = .31), SVO-C (Ego) (*b* = 0.41, *p* = .38), KM (Ego) x Year Group (*b* = -0.01, *p* = .29), KM (Ego) (*b* = -0.01, *p* = .49), Duration (*b* = -0.03, *p* = .49), SVO-P (Ego) x Year Group (*b* = -0.14, *p* = .39), SVO-C (Alter) x Year Group (*b* = -0.13, *p* = .27), SVO-P (Alter) x Year Group (*b* = -0.09, *p* = .38), SVO-P (Alter) (*b* = -0.09, *p* = .38), FAS-II (Ego) x Year Group (*b* = -0.09 *p* = .17), FAS-II (Ego) (*b* = 0.03, *p* = .40), FAS-II (Alter) x Year Group (*b* = 0.09, *p* = .002), KM (Alter) x Year Group (*b* = -0.01, *p* = .40), KM (Alter) (*b* = 0.01, *p* = .40), SVO-C (Alter) (*b* = 0.25, *p* = .17), FAS-II (Alter) (*b* = 0.06, *p* = .12), SVO-P (Ego) (*b* = -1.10, *p* = .09), Gender (Alter) (*b* = 0.74, *p* = .06).

3.8.3 Cooperation MG-MRQAP Model including alter-rated social tie strength

Social network and individual difference variables (see Methods) were included in a MG-MRQAP model as predictors for *cooperation* in a one-shot mPD across all classes in all year groups (*N* = 157). In the final Cooperation MG-MRQAP model (R^2_{adj} = .08, *p* < .001), including Alter-rated Social Tie Strength, higher *ego-rated social tie strength* significantly predicted less *cooperation*, as did *alter-rated social tie strength*. Conversely*, gender (ego)* predicted *cooperation*. There was also a negative interaction between *ego-rated social tie* *strength* and year group (Table 3.4). All else being equal, participants chose to defect more from network members with whom they reported a stronger relationship, and from network members who reported a stronger relationship with the participant. The interaction indicates that early adolescent participants were more likely to choose to steal from those they reported a stronger relationship with than late adolescents. Similarly to the previous model, female participants tended to cooperate more than male network members.

Independent Variable	Unstandardised Regression Coefficient	*p* value
MG-MRQAP model $R^2_{adj} = .08$, $p < .001$		
Ego-rated social tie strength	-4.35	< .001
Alter-rated social tie strength	-1.54	.02
Gender (Ego)	2.78	.01
Ego-rated social tie strength x Year Group	-0.56	.002

Table 3.4. MG-MRQAP model with alter-rated social tie strength predicting PD cooperation. Class intercepts for the model were: Year 9A (*b* = 11.37, *p* = 1.00), Year 9B (*b* = -1.09, *p* = .13), Year 10A (*b* = 1.57, *p* = < .001), Year 10B (*b* = 1.01, *p* = < .001), Year 11A (*b* = -0.23, *p* = .003), Year 12A (*b* = -0.30, *p* = .99), Year 12B (*b* = -1.98, *p* = .002), Year 12C (*b* = 0.27, *p* = < .001), Year 13A (*b* = 2.15, *p* = .39). Independent variables eliminated due to non-significance were: Duration x Year Group (*b* = -0.01, *p* = .48), SVO-C (Ego) x Year Group (*b* = 0.35, *p* = .34), Gender (Alter) x Year Group (*b* = 0.33, *p* = .40), Alter-rated social tie strength x Year Group (*b* = 0.01, *p* = .44), Gender (Ego) x Year Group (*b* = 1.25, *p* = .43), KM (Ego) x Year Group (*b* = -0.01, *p* = .28), KM (Ego) (*b* = -0.01, *p* = .49), SVO-C (Ego) (*b*

= 0.42, p = .37), Duration (b = -0.03, p = .36), SVO-P (Ego) x Year Group (b = -0.14, p = .40), FAS (Ego) x Year Group (b = -0.08, p = .21), FAS (Ego) (b = 0.03, p = .45), SVO-C (Alter) (b = -0.14, p = .23), SVO-P (Alter) (b = -0.19, p = .13), SVO-P (Alter) (b = -0.04, p = .44), FAS (Alter) x Year Group (b = 0.09, p = .08), KM (Alter) x Year Group (b = -0.01, p = .39), KM (Alter) (b = 0.02, p = .41), SVO-C (Alter) (b = 0.25, p = .15), FAS (Alter) (b = 0.06, p = .11), SVO-P (Ego) (b = -1.10, p = .09), Gender (Alter) (b = 0.74, p = .06).

3.9 Discussion

This study tested three distinct hypotheses: [H1] directed and dyadic social tie variables (*ego-rated social tie strength*, *alter-rated social tie strength*, and *relationship reciprocation*) would predict cooperation in the mPD, [H2] there would be an interaction between egocentric, altercentric, and mutual social network variables, and year group, and [H3] individual difference variables would also predict cooperation in the mPD.

Single classroom (MRQAP) and group-level (MG-MRQAP) network models showed that participants across all adolescent networks would choose to defect from classmates with whom they reported a stronger relationship, and from classmates who reported stronger relationships with them. Conversely, participants would cooperate with classmates who they reported a stronger relationship with than the classmate reported with them. Single (MRQAP) and group-level (MG-MRQAP) network models also revealed that, across all year groups, female participants cooperated more than male participants. Finally, early adolescents were more likely than late adolescents to steal from classmates with whom they reported a stronger relationship.

3.9.1 Social tie predictors of cooperation

Our findings demonstrate that directed and dyadic social tie relationship variables made some contribution to predicting decision-making in the mPD, although the direction of effects ran counter to our predictions. Relationship strength variables were derived from a social network questionnaire, which scored relationships on multifarious dimensions, including: how the participant perceives the strength of their relationship with each network member, whether the participant spends time outside of school with each network member, and whether the participant believes it is important to resolve conflicts with each network member. This pattern of results demonstrates that egocentric, altercentric and mutual dyadic variables account for variance in models predicting adolescent decision-making in the mPD. Adolescents show evidence of taking into account their own evaluation of the other player, and the other player's evaluation of them. This result supports the findings of Chapter 2, as well as past research, which suggests the importance of social network relationship variables as predictors of adults' expenditure of physical effort to earn money for a colleague (Harrison, Sciberras & James, 2011) and adolescents' financial investment in classmates in a Dictator Game (Burnett Heyes et al., 2015). However, interpretation of these results must be treated with caution as the total variance explained was low (R^2_{adj} = .08). This was a surprise given that the models in Chapter 2 (Trust Allocation R^2_{adj} = .46; Expected Reciprocity R^2_{adj} = .39) and in past research explained a much higher proportion of variance (Burnett Heyes et al., 2015: Study 1 R^2_{adj} = .25; Study 2 R^2_{adj} = .43).

Across both MG-MRQAP models, adolescent participants cooperated more with network members with whom they reported a *weaker* relationship, as indexed by the positive coefficient of the significant *ego-rated social tie strength* predictor. In model 1, participants cooperated more with classmates with whom they reported greater outgoing relationship strength than the classmate reported towards them, as indexed by the positive coefficient of the significant *relationship reciprocation* predictor (i.e. *ego-rated social tie strength* minus *alter-rated social tie strength*). Thus, participants were more inclined to defect from classmates whom they reported liking *less* than the classmate reported liking them. In model 2, participants cooperated more with classmates who reported weak (as opposed to strong) social tie strength with the participant, indexed by the negative coefficient of the *alter-rated social strength* predictor. While we hypothesised that these social tie variables would significantly predict cooperation, the direction of these significant relationships runs contrary to our expectations in every single case.

In the case of *ego-rated social tie strength*, participants tended to cooperate more with those they reported a weaker relationship, and therefore defected more from classmates with whom they reported a stronger relationship. We had hypothesised that participants would cooperate more with those they shared a stronger relationship, as past research using the Prisoner's Dilemma with adults *(*Dorrough, Glöckner, Hellmann & Ebert, 2015; Gutiérrez-Roig, Gracia-Lázaro, Perelló, Moreno, & Sánchez, 2014), and other economic games with adolescents had suggested (Chapter 2; Dictator Game: Burnett Heyes et al., 2015; Ultimatum Game and Trust Game: Güroğlu, van den Bos & Crone, 2009; Trust Game: van den Bos, Westenberg, van Dijk & Crone, 2010). Participant tendency to defect from those they shared a closer relationship with may reflect that the potential consequences of defecting from a friend were not salient to them, because the money used was hypothetical, and so there was a low social cost to defection. However, past research suggests that whether the money is real, or hypothetical should not influence decision-making (Burnett Heyes et al., 2015; Miyapuram, Tobler, Gregorios-Pippas, & Schultz, 2012). It may also be that because the game was a repeated one-shot mPD with no feedback that defection was the superior strategy, and therefore adolescents pursued it (Binmore, 2007). An iterated version of the game may have produced more cooperation as in previous research (see Camerer, 2003). However, it still would not explain why participants defected from those they shared strong relationships in particular, as compared to with those whom they shared weak relationships. If all adolescents were solely pursuing the most profitable strategy, then we would expect them to choose defection in every interaction. It might be that participants felt that there was in fact lower social risk to defecting from those they shared a strong relationship with, as the relationship would be robust enough to withstand defection, akin to teasing within friendships (Spear, 2000). Further research suggests that early adolescents are more likely to interpret teasing between friends (vs classmates) as benevolent, and that early adolescents are slightly more likely than children to report lower negative affect from teasing on some subjects (Jones, Newman & Bautista, 2005). This might partially explain why early adolescents were more likely than late adolescents to steal from friends, however, no conclusions can be drawn as the cited study did not compare late and early adolescents.

In the case of *alter-rated social tie strength*, participants tended to cooperate and 'split' more with those who reported a weaker relationship to them, and therefore defected more from classmates who reported a stronger relationship to the participant. We had hypothesised that participants would cooperate more with those who reported a stronger relationship to them in line with findings in Chapter 2. This result may have similar explanations to the finding regarding *ego-rated social tie strength*. Participants may have felt more comfortable defecting from close peers in a game with hypothetical rewards, pursued the most profitable strategy according to the structure of the game, or engaged in a playfully hostile interaction due to the strength of their perceived relationship (Binmore, 2007; Burnett Heyes et al., 2015; Camerer, 2003; Spear, 2000). Note that while this result may reflect similar conclusions to those drawn from the significance of *ego-rated social tie strength*, it is important to keep in mind the crucial difference between *ego*- and *alter-rated social tie strength*. *Ego-rated social tie strength* reflects the participant's *known* perspective, while *alter-rated social tie strength* reflects the classmate's *inferred* perspective. That these two are consistent is not necessarily surprising, but they are distinct.

In the case of *relationship reciprocation*, participants tended to cooperate and 'split' more with classmates who reported a weaker relationship to the participant than the participant reported with the classmate. We had hypothesised that participants would cooperate more with those who reported a stronger relationship to the participant than the participant reported with them. However, we find a significant relationship in the opposite direction predicted for this study and found in past research (Burnett Heyes et al., 2015; Chapter 2). The main difference between the present study and those before is the game itself. This study used a modified Prisoner's Dilemma, while the most comparable studies used the Dictator Game and Trust Game. The simultaneous nature of the mPD may place the participant in a position where they feel more pressure to cooperate when they do not know how their partner will play, in this case, against a classmate they share an unbalanced relationship with. This contrasts the Trust Game, in which trustees can see what decision the trustor made, and the Dictator Game, in which the participant's partner has no power to influence the participant's decision (Rilling & Sanfey, 2011). This finding could also be indicative of a developing relationship where participants are trying to ingratiate themselves to network members with whom they hope to share a stronger relationship in the future. One longitudinal study of popularity and adolescent friendship networks found that lower status adolescents would strive to enhance their status by developing closer relationships with higher status adolescents (Dijkstra, Cillessen & Borch, 2013). While similarity of status and popularity did partially account for similarity of friendship networks, influence processes accounted for increasing similarity in popularity over time, as low status peers increased their popularity having become more similar to their higher status friends. It may be that the effect found in the *relationship reciprocation* group-level model may refer to the same effect, as adolescent participants choose to act more cooperatively with network members they hope to grow closer with. Finally, it may even be unsurprising that participants chose to cooperate more with classmates they liked more than the classmate liked them. There is plenty of precedent for adolescents cooperating more with peers they like (e.g. Güroğlu, van den Bos & Crone, 2014), but these studies do not measure the imbalance within unreciprocated relationships. However, all suggestions must be treated as speculative due to the low explanatory power of the model, and the fact that the result is not supported by the most directly comparable research. Further research is required to identify the cause of the discrepancy in the predictive direction of relationship reciprocation as it applies to different economic games.

This study finds that social tie variables at least partially determine decision-making in the mPD at every level: egocentric (*ego-rated social tie strength*), altercentric (*alter-rated social tie strength*), and mutual (*relationship reciprocation*) (Selman, 1980). In this study, adolescents took into account the strength of their relationship at three distinct levels, while nearly all of the individual difference variables did not survive the final model.

3.9.2 Individual difference predictors of cooperation

Finally, it is worth noting the individual difference variable that yielded a significant result in both models: female participants cooperated more than male participants. This finding has little support in the wider literature as a meta-analysis of 272 effect sizes drawn from 50 years of research found no global gender differences in decision-making (Balliet, Li, Macfarlan & Van Vugt, 2011). However, limited support can be found in past work describing females as being more cooperative than males in the Prisoner's Dilemma when being observed (Charness & Rustichini, 2011), and generally during early rounds of the game (Ortmann & Tichy, 1999).

3.9.3 Limitations

The decision to use a one-shot Prisoner's Dilemma for this design was based on the practicality of mapping decisions made across an entire classroom network. While this allows for the mapping of a more varied set of relationships, it does not allow for the testing of social tie variables as predictors of cooperation in an iterated-Prisoner's Dilemma with feedback. Past studies have shown that participants tend to cooperate more in iterated versions of the game than in one-shot versions (Camerer, 2003), and it would be useful to investigate the evolution of adolescent decision-making as predicted by social relationship variables. It may be that participants are less willing to defect from classmates in an iterated game where they can observe the responses and infer the strategic and social consequences. Finally, it might be that giving participants explicit instructions to accrue as much money as possible during the task biased them towards defection. The instruction was given to ensure that participants were pursuing the same goal, meaning that the interpretation of the results could be restricted to a smaller number of hypothesised strategies that participants may pursue. However, it is possible that had participants been given more freedom to play the game according to their own goals, there may have been greater cooperation within dyads with high relationship strength. While there is no evidence that we know of to support this intuitive hypothesis, it warrants testing in future studies.

3.9.4 Future studies

Future studies should seek to further investigate the power of directed and dyadic social tie variables as determinants of behaviour in other economic games, for example, as a predictor of fair splits in the Ultimatum Game (Güth et al., 1982). Our results hint at the opportunity social tie variables offer to those interested in the development of teasing behaviours and their layered, complex, developing nature. Future work should apply other games to this design that offer the participant an opportunity to cooperate with or betray a partner with whom they share a real-world, authentic social tie. Further individual difference variables could also be used as determinants of economic decision-making within this paradigm. Finally, the Prisoner's Dilemma has a rich fMRI literature, which supports the game as reliably eliciting cooperation behaviourally, and 'social brain' activation neurally. Future experiments should investigate the power of social network variables as predictors of neural activity (Rilling & Sanfey, 2011).

3.10 Conclusion

This study used directed and dyadic social network variables as predictors of cooperation in the Prisoner's Dilemma. The analysis revealed that egocentric *ego-rated social tie strength* and altercentric *alter-rated social tie strength* variables predicted defection, whereas mutual *relationship reciprocation* predicted cooperation. These results tentatively highlight the importance of including social tie variables, which reflect authentic social relationships, as predictors of cooperation in the Prisoner's Dilemma. Future research should seek to investigate the predictive power of these variables in different versions of the Prisoner's Dilemma, as well as disentangle the effects of the different altercentric variables within these models, the different kinds of relationships these reflect, and the different strategies they provoke.

Reading the adolescent social network: late adolescents predict the strength of their social relationships more accurately than early adolescents.

4.1 Abstract

As the adolescent 'social brain' develops, so too do the demands on it as adolescents are asked to navigate more complex, hierarchical social networks inhabited by ever greater numbers of people that they do not know well. While studies have found adolescents develop the ability to infer the perspectives and intentions of unknown dictators and economic competitors, it is not clear whether adolescents' direct inferences of their own social environment improves. In this study, we tested whether late adolescents assess their dyadic relationships more accurately than early adolescents (*n* = 918, *nNetworks* = 58, *age range* = 12-18). Two items were used from a social network questionnaire to assess participants' (ego) beliefs about the strength of their relationship with each classmate (alter), and the participants' predictions of how strong the classmate perceives their relationship to be. Late adolescents did predict their classmates' ratings of their dyadic relationship more accurately than middle and early adolescents. This finding supports past evidence suggesting that the ability to *infer* how others view our shared relationships is still developing through adolescence and shows that this can be observed directly.

4.2.1 Developing adolescent capacities for social inference

Adolescence is a period of great social change, both at the level of the individual and the network. As the adolescent 'social brain' develops (Mills et al., 2016), so too do the demands on it as adolescents are asked to navigate more complex, hierarchical social networks inhabited by ever greater numbers of people that they do not know (Brown, 1990; Brown, Mory & Kinney, 1994; Pollard, Burnett Heyes & Apperly, 2018; Steinberg & Morris, 2001). Friendship, intimacy, reciprocity, loyalty, commitment and trust become more important as children grow into adolescents. Critically, the acquisition of these relationship features requires inferences about the perspectives of others (Bigelow & La Gaipa, 1980; Youniss, 1982). This is an environment that asks teenagers to solve harder social conundrums, hold greater stores of social information, and use this information in an increasingly nuanced way (Apperly, 2010; Pollard, Burnett Heyes & Apperly, 2018). These changes to the social environment have a particular bearing on the ability of adolescents to make the kinds of "best guess" abductive inferences that are often demanded of them. For example, one might try to infer the strength of one's relationship with a peer, but must do so in a fluid social environment where all of the relevant social information may not be available, meaning that they can only make a best guess. In adults, this ability depends on familiarity with people, and roles, as well as the broader social and relationship context. Past evidence shows that even for adults it is relatively challenging to make mental state inferences about others from different cultures (Perez-Zapata, Slaughter & Henry, 2016). If adults struggle to make abductive inferences in unfamiliar contexts, then we might expect adolescents to struggle within their own socially fluid contexts.

It is not clear what the developmental trajectory of adolescent Theory of Mind may be and what bearing this may have on their ability to make mental state inferences within their social environment. While classical accounts may attribute adolescents with a fully developed

Theory of Mind, it is likely that the classical tests are not sufficiently challenging or incisive enough to elicit error and delineate different capacities for mindreading (Pollard, Burnett Heyes & Apperly, 2018). Only a limited amount of research has been done investigating the development of Theory of Mind in adolescence. One notable study asked a range of participants from late childhood to adulthood (*ages* = 7-27) to complete the director task, finding that perspective-taking accuracy improved throughout adolescence and that this improvement, particularly in late adolescence could not be attributed to improvements in executive function (Dumontheil, Apperly & Blakemore, 2010). This finding was replicated in later research (Symeonideau, 2015).

Further corroborating evidence for the developing mental state inferential abilities of adolescents can be found in the adolescent economic decision-making literature. Late adolescents are increasingly sensitive to being trusted with larger stakes relative to early adolescents, and more likely to reciprocate trusting behaviours from a partner (van den Bos, Westenberg, van Dijk & Crone, 2010). Late adolescents are more likely than early adolescents to identify that unfair offers are less likely to be accepted than fair offers, suggesting a developing ability to incorporate intentionality into their strategies *(*Güroğlu, van den Bos & Crone, 2009). Late adolescents are also more adept at differentiating between playing partners in their prosocial decision-making, giving the most to ‘friends’ and less to ‘antagonist’ or ‘neutral’ classmates (Güroğlu et al., 2014). Given that adolescents must navigate these fluid social environments, while still developing the ability to infer the perspectives and intentions of abstract dictators and economic competitors, we might ask: do adolescents’ inferences of their own social environment improve?

4.2.2 Inference as a component of perspective-taking

While a number of studies discuss adolescent improvement in various tasks as being related to improvements in perspective-taking, it is less discussed which particular component of perspective-taking is improving. The inference-storage-use model of Theory of Mind suggests that one's Theory of Mind can be compartmentalised into three distinct components: inference, storage, and use (Apperly, 2010; Pollard, Burnett Heyes & Apperly, 2018). *Inference*: The ability to infer the mental state of another agent (e.g. Hartwright, Apperly & Hansen, 2014). *Storage*: The ability to store the inferred mental state of another agent (e.g. Hartwright, Apperly & Hansen, 2012). *Use*: The ability to use the inferred and stored mental state of another agent (e.g. Keysar, Barr, Balin & Brauner, 2000). In adolescents, to our knowledge, the only component that has been investigated developmentally is *use* (Devine & Hughes, 2012; Dumontheil et al., 2010; Symeonideau, 2015). This study seeks to investigate the development of *inference* in adolescence using predictions of peer-rated relationship strength as a proxy.

4.2.3 The social network

To do so, this study uses a social network paradigm to compare adolescents' predictions of peer-rated relationship strength against reported relationship strength within authentic, bounded networks. The social network variables of interest in this study comprise the egocentric and altercentric nature of a relationship between two individuals, or dyad, the fundamental unit of the social network (Robins, 2015). The participant (ego) may give a score indicating how strong they feel their relationship is with another network member (alter). Therefore, this allows for an analysis of a relationship from the perspective of the ego, the perspective of the alter, and the interaction of the two perspectives. This approach sits well with the embodied cognition literature, which views interaction as key to developing theories of social understanding (de Bruin, van Elk & Newen, 2012; Moore & Barresi, 2017).

Social tie variables derived from a social network questionnaire have been used as predictors of the prosocial allocation of physical effort (Harrison et al., 2011), giving in a modified Dictator Game (Burnett Heyes et al., 2015), trust and expected reciprocity in a modified Trust Game (Chapter 2), and cooperation in a modified Prisoner's Dilemma (Chapter 3). While these studies used social tie variables as a means of relating decision-making to the strength of authentic social relationships, they did so indirectly. It is also possible to simply ask adolescents how they would describe their relationship with a classmate, and how they predict their classmate would describe their relationship with the participant.

4.2.4 The study and hypothesis

In this study, we will directly test whether late adolescents more accurately predict their classmates' ratings of their shared dyadic relationships than early adolescents. Two items were used from a social network questionnaire to assess: 1) participants' (ego) beliefs about the strength of their relationship with each classmate (alter), and 2) participants' (ego) predictions of how strong the classmate perceives their relationship to be with the participant. Using these scores, participants' predictions (2) were compared with classmates' evaluations (1) to create ego-predicted vs alter-rated relationship difference scores. These difference scores were compared between early, middle, and late adolescent groups. In line with past research (Dumontheil, Apperly & Blakemore, 2010; Güroğlu et al., 2014; Güroğlu, van den Bos & Crone, 2009), [H1] we hypothesise that late adolescents will more accurately predict their classmates' ratings of their shared dyadic relationships than early adolescents.

4.3 Method

4.3.1 Participants

We recruited 918 participants in 58 networks from 14 schools (see Appendix C1). Data were obtained from 58 classes within year groups 7 to 13: early adolescent (*n* = 178, *nNetworks* =

12, *female* = 87, *Mage*(*SD*)= 12.46(0.50) years, *range* = 12 - 13 years), mid adolescent (*n* = 227, *nNetworks* = 14, *female* = 82, *Mage*(*SD*) = 14.23(0.86) years, *range* = 13 - 16 years), and late adolescent (*n* = 513, *nNetworks* = 32, *female* = 223, *Mage*(*SD*) = 16.85(0.61) years, *range* = 16 - 19 years). Consent was gained from the parents or guardians of all participants, and assent was obtained from the participants themselves. This study was approved by the University of Birmingham Science, Technology, Engineering and Mathematics Ethical Review Committee.

4.4 Measures

4.4.1 Social Network Questionnaire

A seven-item version of the SNQ adapted for adolescents (Burnett Heyes et al., 2015; Harrison et al., 2011) was used to assess the strength of the social ties between participants. The SNQ retained all the questions from the measure specified in chapters 2, 3, and in previously published research (Burnett Heyes et al., 2015). The only addition made was a prediction item that asked participants to predict how they believed each classmate would characterise their relationship with the participant. Only two ordinal items were used for the analysis: a) the strength of the relationship between the participant (ego) and each network member (alter) ('What kind of relationship do you have with *X?';* 4 = *best friend*, 3 = *good friend*, 2 = *friend*, 1 = *acquaintance,* 0 = *no relationship*, -1 = *negative relationship*), b) and the strength of the relationship that the participant predicts that each network member (alter) would assign ('What kind of relationship would *X* say they have with you?'; 4 = *best friend*, 3 = *good friend*, 2 = *friend*, 1 = *acquaintance*, 0 = *no relationship*, -1 = *negative relationship*).

4.5 Experimental Procedure

Participants completed the social network questionnaire as part of a battery of measures across different studies. Measures were completed with pen and paper in large testing rooms that allowed privacy for each individual. Each testing session lasted 15-60 minutes.

4.6 Statistical Procedures

Ego-predicted vs alter-rated error scores were calculated for each participant by subtracting ego-predicted social tie strength score matrices from alter-rated social tie strength score matrices. The resulting matrix contained cells that indicated to what extent participants (ego) overestimated (positive scores), underestimated (negative scores), or accurately estimated their classmates' (alter) characterisation of the relationship. These ego-predicted vs alter-rated relationship difference scores were transformed into absolute values and then averaged across each row, giving a single score for each participant representing their mean relationship perception accuracy across all classmates.

Participant year groups were then grouped into three broader adolescent age groups: early adolescent (*n* = 178, *nNetworks* = 12, *female* = 87, *Mage*(*SD*)= 12.46(0.50) years, *range* = 12 - 13 years), mid adolescent (*n* = 227, *nNetworks* = 14, *female* = 82, *Mage*(*SD*) = 14.23(0.86) years, *range* = 13 - 16 years), and late adolescent (*n* = 513, *nNetworks* = 32, *female* = 223, *Mage*(*SD*) = 16.85(0.61) years, *range* = 16 - 19 years). This was done to reduce the impact of variability in the number of networks and participants within each year group. Importantly, the results were the same whether using age or year groups (see Appendix C2).

4.7 Statistical Analyses

4.7.1 Sample Descriptives

Means and standard deviations were computed for the absolute error score in each age group. Bootstrapped mean densities and standard errors were computed for alter-rated social tie strength networks within each age group (Table 4.1; Table 4.2). Finally, a chi-square test was conducted to test for differences in gender distributions between age groups.

4.7.2 Analysis of variance (ANOVA)

A one-way analysis of variance (ANOVA) was calculated on the ego-predicted vs alter-rated difference scores with age group as a between-subjects factor.

4.8 Results

4.8.1 Sample Descriptives

The Chi square test revealed no significant difference in gender frequencies between age groups (X^2 (4, N = 918) = 6, p = .19).

Non-network variables	*M*(*SD*)	Range	*N*
Early Adolescent			
Age (Years)	12.46(0.50)	12 - 13	178
Absolute Error	0.63(0.29)	0 – 1.54	178
Gender			87
Mid Adolescent			
Age (Years)	14.23(0.86)	13 - 16	227
Absolute Error	0.59(0.27)	0 - 2	227
Gender			82
Late Adolescent			
Age (Years)	16.85(0.61)	16 - 19	513
Absolute Error	0.34(0.21)	0 – 1.22	513
Gender			223

Table 4.1. Non-network descriptives.

Network variables	*M*(*SEM*) density	Range	*N*
Young Adolescent	1.20(0.19)	-1 – 3	3522
Mid Adolescent	1.68(0.20)	-1 – 3	4373
Late Adolescent	1.17(0.13)	-1 – 3	9031

Table 4.2. Network descriptives.

4.8.2 Ego-perceived vs alter-rated error

The ANOVA revealed significant differences between age groups in the accuracy of participants in assessing how classmates perceived the relationship they shared, $F(718) = 105.5$, $p < .001$, $\eta 2 = 0.22$ (Figure 4.1). A Tukey post-hoc test revealed that late adolescents were significantly more accurate than middle (*MDiff* = -0.25, $p < .001$) and early (*MDiff* = -0.28, $p < .001$) adolescent participants. There was no significant difference in accuracy scores between early and middle adolescents (*MDiff* = -0.03, $p = 0.43$).

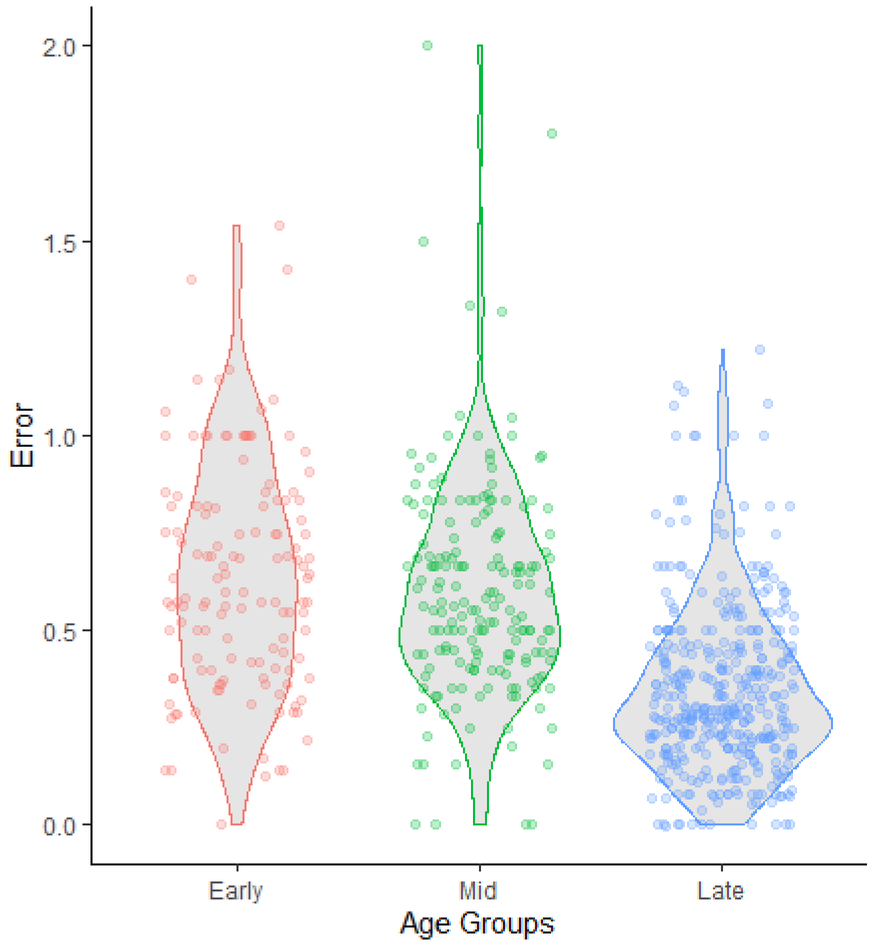


Figure 4.1. Plot of the distribution of ego-predicted vs alter-rated relationship difference scores in early, mid, and late-adolescent age groups. A jitter was applied to each group to improve clarity.

4.9 Discussion

In this study, two items from a social network questionnaire were compared scoring the participants' perception of the strength of their relationships, and their predictions for their classmates' perceptions of the strength of their shared relationship. An ANOVA revealed that there was a significant difference in accuracy scores between late, middle, and early adolescent participants. Post-hoc tests revealed that late adolescents were significantly more accurate than middle and early adolescent participants. There was no significant difference in accuracy scores between early and middle adolescents.

4.9.1 Evidence for improving inferential performance in direct, socially authentic contexts

Late adolescents did infer their classmates' perspective of their relationship more accurately than middle and early adolescents. Not only was there a significant difference between group accuracy scores, but the effect size was large (Cohen, 2013). Although the mean accuracy difference appears small, it may be qualitatively significant. The difference between thinking someone is a 'good friend' or a 'best friend', a 'friend' or an 'acquaintance' could be a consequential difference. This finding is consistent with past research that finds late adolescents (vs. early adolescents) use the perspectives of other agents more accurately (Dumontheil, Apperly & Blakemore, 2010; Symeonidaeu, 2015), incorporate inference into their economic decision-making (Lee, Jolles & Krabbendam, 2016; Güroğlu et al., 2014; Güroğlu, van den Bos & Crone, 2009), and that social tie variables are predictors of this developmental trajectory (Burnett Heyes et al., 2015). Critically, this study extends past research by incorporating direct measures of developing adolescent inferential performance in the context of authentic social relationships.

4.9.2 The root of perspective-taking improvements

This finding may also give further information regarding the foundations of developmental differences in performance between adolescents in tasks that indirectly test their inferential capabilities. The inference-storage-use model of Theory of Mind suggests that one's Theory of Mind can be compartmentalised into three distinct components: inference, storage, and use (Apperly, 2010; Pollard, Burnett Heyes & Apperly, 2018). In adolescents, the only component that has been investigated developmentally is *use* with studies suggesting that late adolescents (vs early adolescents) are better able to *use* the perspectives of others in contexts where there are minimal requirements to *infer* or *store* mental state information (Dumontheil et al., 2010; Symeonideau, 2015). Our findings further suggest that mental state *inference* may also be developing throughout adolescence as minimal requirements were made of participants regarding *storage* or *use*. This raises the question of whether adolescent social cognitive development involves development in ToM *inference*, *use*, or both. For instance, in economic games that relate economic decision-making to ToM (Sanfey, 2007).

4.9.3 Limitations and future studies

The potential limitations of this study centre around interpretation. It may be argued that predictions of peer ratings are not a good proxy for mentalising, or indeed, that this study does not test perspective-taking in any sense. It may be that participants were not engaging Theory of Mind to infer the beliefs of classmates, but instead they predict peer ratings based on observed behaviour within the context of the relationship. There is a vibrant debate about the operationalisation of Theory of Mind and whether paradigms that purport to test Theory of Mind actually do so (Quesque & Rossetti, 2020). It may be that age group differences in predictive accuracy in the current study signify improvements in social reasoning or some other form of submentalising (Heyes, 2014). Our interpretation of this study is based on the assumption that in order to accurately predict how a peer would rate a shared relationship, some inference of their mental state or beliefs is required. However, it is also conceivable that a participant could predict a peers' rating based merely on observed behaviour within the context of the relationship, for example, a participant may think that a peer is typically nice towards them and that such actions are characteristic of friendship, and therefore, the peer must see the participant as a friend. Furthermore, a third possibility is that these mechanisms interact, and participants infer the beliefs of their peers based in part on the actions of their peers within the context of the relationship (social reasoning), moderated by their capacity to infer the beliefs of their peers (ToM), linking their behaviour to their mental state (social reasoning*ToM) (Ermer, Guerin, Cosmides, Tooby & Miller, 2006). This is a difficult problem to disentangle, requiring urther discussion and task innovation to probe the boundaries of Theory of Mind and its interactions with other aspects of cognition (Lockwood, Apps & Chang, 2020; Schaafsma, Pfaff, Spunt & Adolphs, 2015).

A final interpretative issue is the lack of clarity regarding whether early adolescent participants made less accurate inferences because they genuinely struggled to infer the mental states of their classmates, or because they have less convergent definitions of relationship strength. It may be that an early adolescent's definition of a best friend may be another early adolescent's definition of a good friend. Late adolescents, however, may have a greater shared understanding of what features define a friendship category. Future work should seek to investigate whether early adolescent friendship concepts overlap and blur more than late adolescent friendship concepts. This study also only investigated a single social tie variable, which scores a broad definition of relationship strength. The SNQ has many items (e.g. trust, conflict resolution), which would be suitable objects for a similar study. For example, one could use a multivariate cluster analysis to investigate how these different dimensions of relationship strength cluster, and whether they cluster differently for late and early adolescents. Qualitative focus group interviews could also be used to investigate these possible differences. Future studies could also seek to use this design as a complement to classical game theory paradigms, and test whether developmental changes in gameplay are likely to be founded by improving *inferential* or *use* capacities. If late adolescent decision-making makes better use of mental state inference than that of early adolescents, then through the use of social tie variables as predictors, researchers can test the following distinct hypotheses: 1) whether early adolescents seem to be fully aware of their peers' mental states, but do not use them effectively, or 2) whether they are simply not as aware of their peers' mental states.

4.10 Conclusion

Two items were analysed from a social network questionnaire scoring participants' perception of the strength of their relationships with each classmate, and their predictions of their classmates' perceptions of the strength of their shared relationship. These scores were compared to investigate whether late adolescents predicted their classmates' perspective of the relationship more accurately than did early adolescents. This hypothesis was confirmed: late adolescents did predict their classmates' perspective of their relationship more accurately than did middle and early adolescents. This finding supports past research that finds late adolescents (vs. early adolescents) use the perspectives of other agents more accurately (Dumontheil, Apperly & Blakemore, 2010; Symeonidaeu, 2015), and may suggest that the adolescent *inference* of perspectives is also developing alongside the *use* of perspectives (Apperly, 2010). Future studies could use this design as a complement to classical game theory paradigms, and test whether developmental changes in gameplay are likely to be founded by improving mental state *inferential* or *use* capacities.

Taking a 1^{st}, 2^{nd}, and 3^{rd} person perspective: social tie variables predict giving in a novel Dictator Game.

5.1 Abstract

Research into adolescent social decision-making using economic games suggests the importance of social cognition in the evolving strategies of adolescents, and the increasing incorporation of other perspectives into their allocative decisions. However, what is not clear is whether the adolescent's increasing incorporation of other perspectives is underwritten by a developing capacity to *infer* or to *use* social information as delineated by the inference-storage-use model. This study investigates whether adolescents (N = 292; *Nnetworks* = 24; *age range* = 12 – 18) increasingly differentiate their allocative decision-making with increasing age and whether this could be driven by developing capacities to *infer* allocation decisions. Participant allocation decisions in 1^{st} and 2^{nd} person Dictator Games were compared against the strength of their social ties, and allocation prediction accuracy was compared between year groups in a 2^{nd} person and 3^{rd} person Dictator Game. Analyses revealed that directed and dyadic social tie variables predicted economic decision-making across all adolescent year groups, and that early adolescent decision-making was better predicted by mutual dyadic variables than was late adolescent decision-making. Finally, there was no significant difference between year groups in how accurately participants inferred the allocative decisions of classmates. These findings demonstrate the importance of social tie variables as predictors of allocation and predicted allocation in the Dictator Game. Negative interactions with year group and the lack of evidence for developing improving accuracy in allocation predictions may have been caused by the non-costly design of the game, and the sensitivity of the Dictator Game to minor changes.

5.2.1 Decision-making in an allocative context

As discussed in chapters 2 and 3, there has been much research into adolescent social decision-making using a variety of economic games that produce behavioural measures of trust, reciprocity, cooperation, equity preferences, and more (Meuwese, Zanolie, Güroğlu & Crone, 2020; Fett et al., 2014; Güroğlu, van den Bos & Crone, 2009; Lee, Jolles & Krabbendam, 2016; van den Bos et al., 2010). These studies demonstrate the importance of social cognition in the evolving strategies of adolescents, and the increasing incorporation of perspective-taking into their decision-making. Allocative games have been used in this context but differ from, for example, the Trust Game and Prisoner's Dilemma, as the coordination required is heavily biased in favour of a proposer. This proposer may have ultimate control over an allocation decision, or they may operate within the boundaries set by a player that accepts or rejects a proposed allocation. Even in this case, only one player has the power to adjust an allocation. While the literature is mixed in terms of determining whether these allocative games track the general development of fairness strategies in adolescence (e.g. Gummerum, Keller, Takezawa & Mata, 2008), there are indications that adolescent and adult decision-making does change dependent on the nature of the relationship shared between proposer and recipient (Burnett Heyes et al., 2015; Güroğlu, van den Bos & Crone, 2014; Schreuders, Klapwijk, Will & Güroğlu, 2018). However, while these studies might suggest that adolescents increasingly differentiate their allocation decisions with age based on the nature of the relationships they share with recipients, it is unclear whether this age difference is underpinned by differing capacities to *infer* social information, *use* social information, or both. This study seeks to investigate whether late adolescents, relative to early adolescents, differentiate their allocative decision-making based on their dyadic relationships (e.g. Güroğlu, van den Bos & Crone, 2014). We will also investigate whether this effect is driven by age differences in the capacities to *infer* or to *use* inferred allocation decisions by using a novel version of the Dictator Game, which asks participants to consider allocation in the 1st, 2nd, and 3rd person.

5.2.2 The Dictator Game

The Dictator Game is one of the simplest economic games; it asks participants to decide how much of an endowment to allocate to a recipient, and the recipient has no choice but to accept the proposer's offer (Kahneman, Knetsch & Thaler, 1986). In a one-shot Dictator Game, a purely self-interested proposer should not endow any amount to another subject, yet over 50% of subjects tend to allocate some amount to others; on average, between 10% and 25% of the total (Camerer, 2003; Forsythe, Horowitz, Savin & Sefton, 1994; Hoffman, McCabe, Shachat & Smith, 1994). The tendency of proposers to allocate some amount has been interpreted to reflect the players' prosocial preferences and desires for fairness (Gummerum, Hanoch & Keller, 2008). Research on adolescent decision-making in the Dictator Game suggests a decrease in preferences for numeric equity, as well as an increase in preferences for social welfare efficiency and meritocratic rewards with increasing age. Late adolescents, relative to early adolescents, prefer not to share equally, but to increase the overall amount available to all players, and to give greater amounts to those who deserve it (Almås et al., 2010; Fehr et al., 2013; Martinsson, Nordblom, Rützler & Sutter, 2011; Meuwese, de Rooij & Güroğlu, 2015; Sutter et al., 2010; Sutter, Zoller & Glätzle-Rützler, 2019).

5.2.3 The social network

Increasingly, social network methods have been used to investigate network structure variables as determinants of decision-making in the Dictator Game. At the network-level, betweenness centrality (measured as a participant's centrality as a bridge between members of a network and the number of mutual friendships they hold) and social distance (the number of connections between the participant and another network member) have been found to predict giving in the Dictator Game *(*Brañas-Garza et al., 2010; Goeree, McConnell, Mitchell, Tromp & Yariv, 2010; Jones & Rachlin, 2006; Leider, Möbius, Rosenblat & Do, 2009). The dyadic level is potentially the most informative level in an analysis of the development of social cognition as reflected in Dictator Games. Especially as the Dictator Game (among other games) takes place within an explicitly dyadic context, where one player must consider another. It therefore has face validity that when a participant is asked to make an economic decision within the context of a pre-existing relationship, they might consider the nature of that relationship when making the decision. Past research supports the claim that directed and dyadic social tie variables are robust predictors of decision-making in allocative contexts. Ego-rated social tie strength (how strong a participant reports their relationship to be with another network member) and relationship reciprocation (the level of reciprocation in the relationship shared between a participant and a network member) have been found to predict costly physical exertion to the benefit of another network member in adults (Harrison, Sciberras & James, 2011). In adolescents, ego-rated social tie strength and relationship reciprocation have been found to predict costly giving in a modified Dictator Game, and late adolescent (vs. early-adolescent) decision-making has been found to be better predicted by these dyadic determinants (Burnett Heyes et al., 2015). Similarly, in Chapter 2, trust and expected reciprocity in a Trust Game was predicted by ego-rated social tie strength and relationship reciprocation. In Chapter 3, defection in a Prisoner's Dilemma was predicted by ego-rated social tie strength and alter-rated social tie strength (how strong a network member reports their relationship to be with the participant), whereas cooperation was predicted by relationship reciprocation.

One benefit of the dyadic approach is it allows for the probing of the gap between what participants know about their relationships (how strong they feel the relationship to be), and what they infer about their relationships (how strong they predict other network members will feel their relationship to be). Across all of these studies, adolescent economic decision-making was predicted by egocentric (ego-rated social tie strength; how I perceive another network member), altercentric (alter-rated social tie strength; how another network member perceives me), and mutual (relationship reciprocation; my shared perception with another) dimensions of a relationship (see Selman, 1980). In Burnett Heyes et al. (2015), late adolescent decision-making in the Dictator Game was better predicted by egocentric and mutual variables than was early adolescent decision-making. This was interpreted to broadly represent evidence for the protracted development of social cognitive perspective-taking in adolescence. Yet it is unclear which aspect of developing perspective-taking this difference represents. Is it the case that late (vs. early) adolescent decision-making is better predicted by mutual dyadic variables because late adolescents are more aware of the relationship dynamics at play within their networks? Or could it be that early adolescents are as aware of their relationship dynamics as late adolescents, but they do not use this information in the context of economic games?

5.2.4 Inference or use?

In past research, Theory of Mind has been proposed as an underlying cognitive mechanism that is utilised to assist decision-making within economic games both in studies of behaviour and its neural correlates (Sanfey, 2007; van den Bos et al., 2010). However, no past research has attempted to disentangle how different components of Theory of Mind contribute to this decision-making. The inference-storage-use model of Theory of Mind suggests that Theory of Mind can be compartmentalised into three distinct components: inference, storage, and use (Apperly, 2010). Since they are separate components of Theory of Mind, these can be manipulated orthogonally to produce differential effects in Theory of Mind tasks particular to the manipulated component. Adult participants are slower to locate an item in a false-belief task when an avatar’s desire for that object is ambiguous vs. explicit (inference: Hartwright, Apperly & Hansen, 2014). They are also slower when statements explicitly indicate an avatar's false belief about the object's location, or the desire to avoid the object, as participants must store both the true location and false belief of the avatar (storage: Hartwright, Apperly & Hansen, 2012). Finally, participants are more error prone when locating items according to instruction in a social (vs. non-social) context even when minimal inferential or storage demands are made, suggesting that using specifically social information incurs a cost of its own (use: Keysar, Barr, Balin & Brauner, 2000). This model provides a framework for investigating whether developing adolescent economic decision-making is best explained by improving capacities to infer or use social information.

5.2.5 Inference at different levels

There are important distinctions within these compartments as well – especially within inference. The embodied cognition literature distinguishes between second-person modes of interaction, which are reciprocal in nature, and third-person modes of interaction, which are not (Reddy, 2018). There is a fundamental difference between inferring the mental state of an abstract agent (3rd person perspective) versus an agent with whom you must interact (2nd person perspective) to achieve a goal (de Bruin, van Elk & Newen, 2012). For example, although classic studies using false-belief tasks suggest that children younger than four are not able to infer the mental states of other agents, when the task is performed in a reciprocal interactive context, even infants as young as 18 months can infer the agent's mental state (Buttelmann, Carpenter & Tomasello, 2009). This approach marries well with work from Selman (1980), whose open-ended interviews with adolescents distinguish different levels of perspective-taking at, among others, levels: 2 (simple reciprocal perspective-taking i.e. take self *or* other's perspective), and 3 (mutual perspective-taking i.e. take self *and* other's perspective). According to Selman's research, there is a trend towards higher level perspective-taking through adolescence with a greater proportion of late (vs. early) adolescents at Level 3. Consequently, in addition to investigating any differences in the development of adolescent social inference and use, it is important to investigate whether there are any differences between reciprocal (2PP) and non-reciprocal (3PP) modes of inference.

5.2.6 The framework

This study will implement a novel framework for testing whether the behaviour of late adolescents (vs early adolescents) in the Dictator Game might be better explained by improving capacities to *infer* or to *use* social information (Apperly, 2010; Burnett Heyes et al., 2015; Chapter 4). Firstly, we will investigate whether late adolescent (vs early adolescent) decision-making is better predicted by social tie variables, replicating past research (Burnett Heyes et al., 2015). Additionally, an analysis will be conducted investigating whether late adolescent (vs early adolescent) predictions for amounts received in the Dictator Game are predicted by social tie variables. Secondly, we will attempt to answer the question of whether this developmental difference is better explained by early adolescents inaccurately predicting how much hypothetical money would be allocated to them in the same circumstances or whether early adolescents accurately predict how much their peers will allocate to them but do not *use* this information effectively (Dumontheil, Apperly & Blakemore, 2010). As in Chapter 4, prediction accuracy will be used as a proxy for inference. However, in this case, allocation prediction accuracy will be investigated since past studies show that adolescents modify their economic decision-making according to their perceptions of how generous other players are or will be (Lee, Jolles & Krabbendam, 2016; van den Bos et al., 2010). Thirdly, we will investigate whether early (vs. late) adolescents make similarly accurate inferences in both reciprocal and non-reciprocal contexts (Selman, 1980). If the same age trend is observed as in previous research (Burnett Heyes et al., 2015) and early adolescents make less accurate allocation predictions than late adolescents then this will be considered as tentative evidence for the improving *inference* hypothesis. If the same age trend is observed as in past research and early adolescents make similarly accurate allocation predictions as late adolescents, then this will be considered tentative evidence for the *use* hypothesis. If no age trend is found, then it will not be possible to investigate potential *inference* or *use* hypotheses.

5.2.7 The study and hypotheses

Based on the above considerations, a novel implementation of the Dictator Game was created comprising of three games, which would investigate: [1] whether adolescent giving and the amount adolescents expected to receive was predicted by directed and dyadic social tie variables (2PP) (e.g. Chapter 2; Chapter 3); [2] whether late adolescents made more accurate predictions than early adolescents about the exchange of hypothetical money in both reciprocal and non-reciprocal contexts (2PP and 3PP) (e.g. Apperly, 2010; de Bruin, van Elk & Newen, 2012); and [3] whether late adolescent giving and the amounts late adolescents expected to receive were better predicted by social network dyadic variables relative to early adolescents (e.g. Burnett Heyes et al., 2015). If all three are found to be true, this would suggest that late adolescent superior performance was driven by greater inferential capacity. If [1] and [3] were supported, but [2] was not, then that would suggest that late adolescent superior performance was driven by a greater capacity for use but not inference (Figure 5.1.).

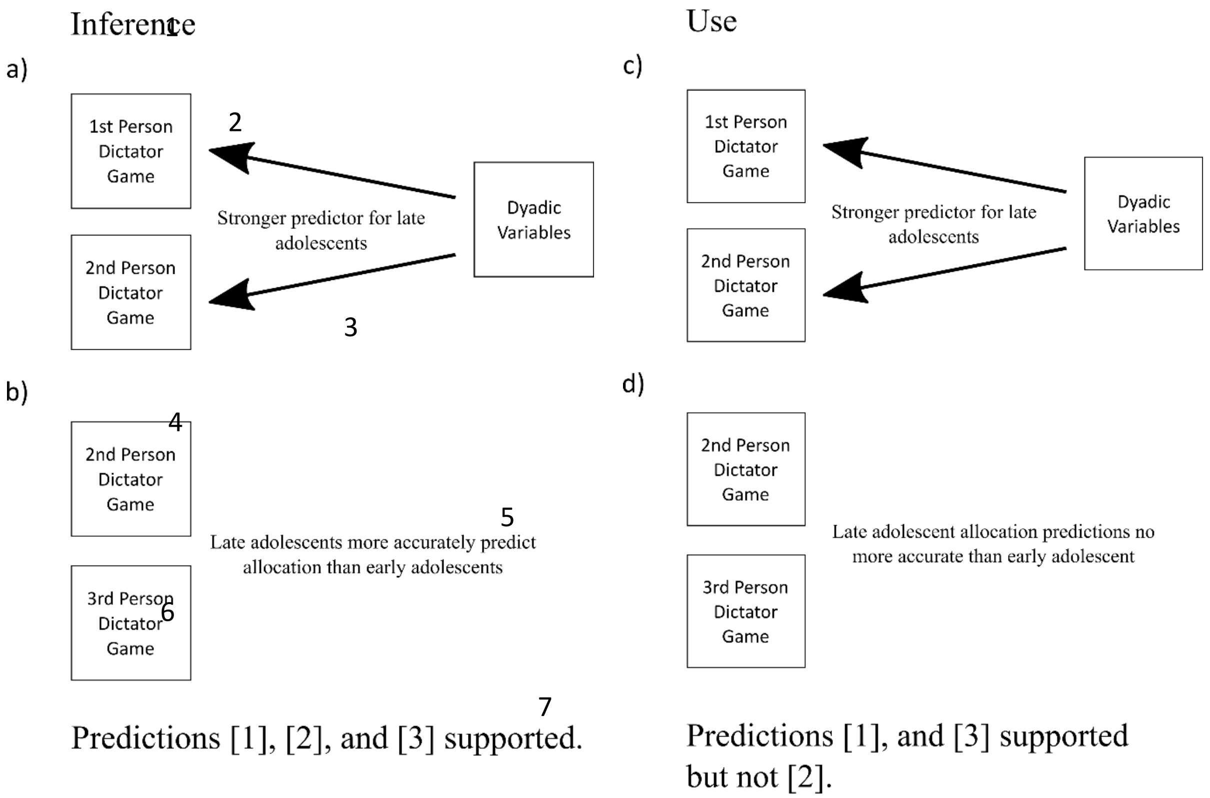


Figure 5.1. A depiction of the possible experimental outcomes of interest. *Inference hypothesis*: a) Directed and dyadic variables predict allocation in the 1pDG and 2pDG, and these predictions are stronger for late adolescents ([1] and [3]). b) Late adolescents more accurately predict allocation in the 2pDG and 3pDG than early adolescents ([2]). *Use hypothesis*: c) Directed and dyadic variables predict allocation in the 1pDG and 2pDG, and these predictions are stronger for late adolescents ([1] and [3]). d) Late adolescent allocation predictions are no more accurate than early adolescent ([2] unsupported).

In this study, the 1st person Dictator Game (1pDG) asked participants to decide how they will distribute a £100 pot of hypothetical money among their classmates. The 2nd person Dictator Game (2pDG) asked participants to predict how much hypothetical money they would be allocated by classmates based on the rules of the 1pDG. Finally, the 3rd person Dictator Game (3pDG) asked participants to predict how much hypothetical money their classmates will allocate to each other based on the rules of the 1pDG. Each game makes different demands of the participant as they decide how much they will give to classmates, predict how much classmates will give to them, and predict how much classmates will give to each other. Note that in the first two games, the participant is themselves a part of the transaction (2PP); in the final game, the participant is not part of the calculation (3PP). In this study, we hypothesise [H1] that directed and dyadic social tie variables will predict decision-making in the 1pDG and 2pDG. [H2] Late adolescent year groups will more accurately predict how much money will be given to them in the 2pDG and to others in the 3pDG. [H3] Late (vs. early) adolescent decision-making in both games will be better predicted by directed and dyadic social tie variables.

5.3 Method

5.3.1 Participants

We recruited 292 participants in 24 networks from three schools (see Appendix D1). Data were obtained from 24 classes within the following year groups: 9 (n = 52, *nNetworks* = 5, *female* = 29, *Mage*(*SD*) = 12.46(0.50) years, *range* = 12 - 13 years), 10 (n = 104, *nNetworks* = 8, *female* = 44, *Mage*(*SD*) = 13.55(0.52) years, *range* = 13 – 15 years), 11 (n = 60, *nNetworks* = 5, *female* = 26, *Mage*(*SD*) = 15.01(0.53) years, *range* = 14 - 16 years), and 12/13 (n = 76, *nNetworks* = 6, *female* = 59, *Mage*(*SD*) = 16.66(0.58) years, *range* = 16 - 18 years). Note that Years 12 and 13 were grouped together as there was only one Year 13 class. Consent was gained from the parents or guardians of all participants, and assent was obtained from the participants themselves. The study was approved by the University of Birmingham Science, Technology, Engineering and Mathematics Ethical Review Committee.

5.4 Measures

5.4.1 1st Person Dictator Game (1pDG)

Giving was measured using a pen-and-paper questionnaire version of the Dictator Game (1pDG). Participants were told to imagine that they have £100 and that they must distribute this among their classmates; however, they may not allocate any of this total to themselves. It was decided that participants should not be able to allocate any hypothetical money to themselves as in previous experiments it was not possible to discriminate between participants who had incorrectly understood the game and did not realise they could give money to themselves, and those that correctly understood the game and chose selflessly not to allocate any money to themselves. On the questionnaire, participants saw a list of their classmates' names, and a space next to each name in which they could indicate the amount of hypothetical money they would allocate (Figure 5.2.). There were no upper or lower limits on how much a participant could allocate to any classmate; they were able to give the full £100, nothing, or any value in-between. This game is structurally similar to a one-shot, non-costly Dictator Game with multiple recipients, but differs because participants cannot give any money to themselves. Hypothetical money was used for the task as opposed to real money in accordance with the preferences of the schools from which participants were recruited. Past research also suggests that hypothetical money motivates participant behaviour, including in the Dictator Game (Burnett Heyes et al., 2015; Miyapuram, Tobler, Gregorios-Pippas, & Schultz, 2012). Within the design of this study, this version of the Dictator Game is 1st person, as it represents how much the participant (ego) chooses to give to each classmate (alter).

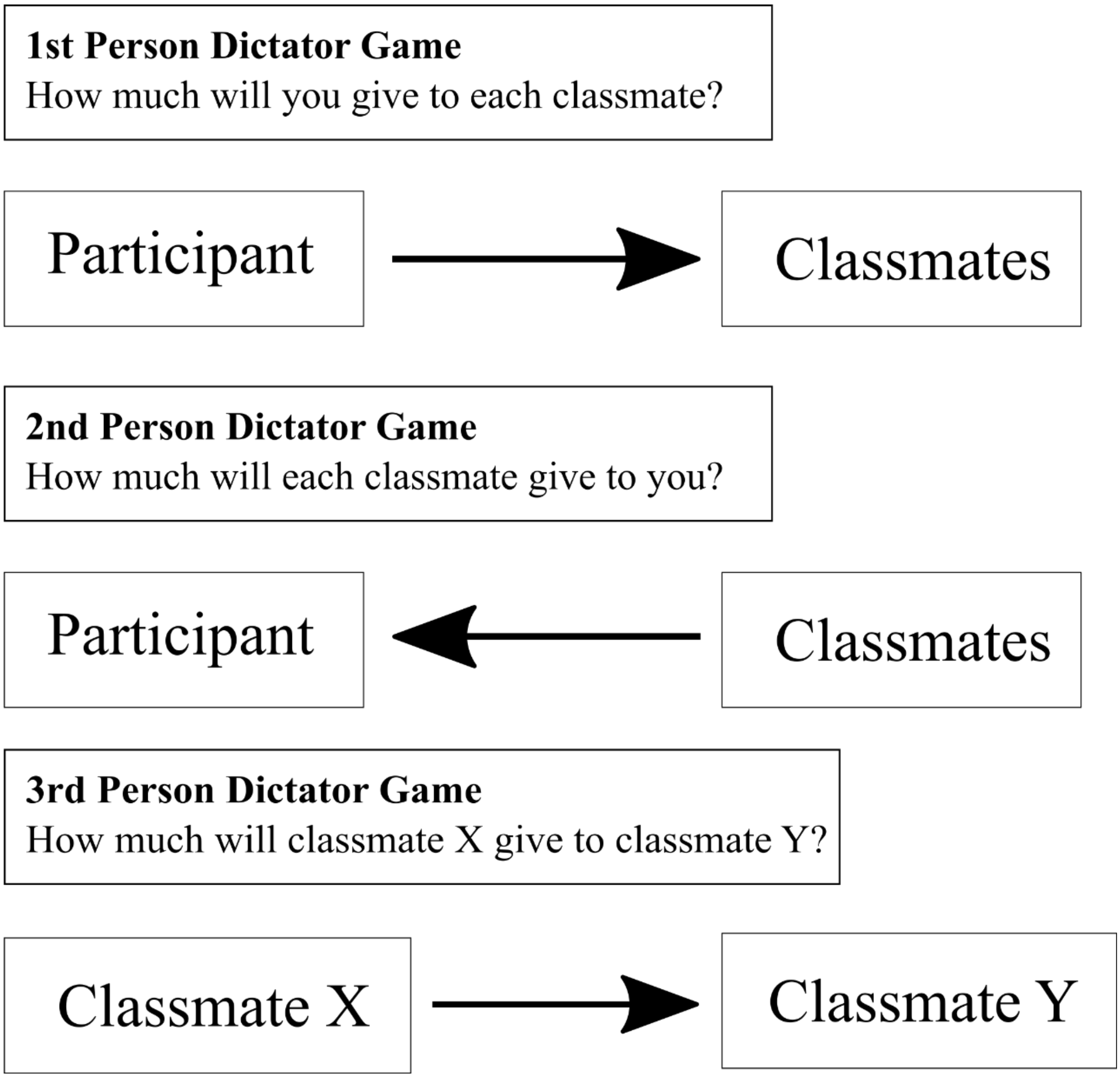
5.4.2 2nd Person Dictator Game (2pDG)

Expected receiving was measured using another Dictator Game questionnaire. Participants were asked to imagine, based on the rules established in the 1pDG, how much hypothetical money they would be allocated by each classmate. On the questionnaire, participants saw a list of their classmates' names, and a space next to each name in which they could indicate the amount of hypothetical money they expected to be allocated by that person (Figure 5.2.). There were no upper or lower limits on the amounts the participant could predict to receive from each classmate. They could predict that they would be given £100, nothing, or any value in-between.

5.4.3 3rd Person Dictator Game (3pDG)

Expected giving was measured using another modified Dictator Game questionnaire. Participants were asked to imagine, based on the rules established by the 1pDG, how much hypothetical money classmates would allocate to each other. On the questionnaire, participants saw two lists of classmates' names, and a space next to each name (Figure 5.2.). Participants had to indicate how much they expected the classmate in the first list would allocate to the classmate in the second list. They would then repeat this for each pairing. In order to create a full matrix of predicted allocations, participants would be required to make a number of predictions equal to *nNetwork* x *nNetwork* – *nNetwork*, which would not be practical. Therefore, a maximum of 20 names were randomly generated from an original class list in a random order, with the only two rules being that the pairings must be unique, and the participant's name should not be on the list. It was possible for the randomisation algorithm to select the same name any number of times from the original class list. When original class lists had fewer than 20 names, then randomly chosen individual names would be repeated within the randomly generated list. When original class lists had greater than 20 names, some names might not be included on the final randomly generated list. There were no upper or lower limits on the amounts the participant could predict that classmates would allocate to each other. They could predict that classmates would allocate £100, nothing, or any value in-between.

a)


1st Person Dictator Game
How much will you give to each classmate?
Participant
Classmates
2nd Person Dictator Game
How much will each classmate give to you?
Participant
Classmates
3rd Person Dictator Game
How much will classmate X give to classmate Y?
Classmate X
Classmate Y

b)

1pDG

Classmates	Divide £100 among your classmates
Alex	50
Per	2
Miriam	...

2pDG

Classmates	How much will your classmates give to you?
Alex	65
Per	0
Miriam	...

3pDG

Classmates	How much will your classmates give to each other?	Classmates
Alex	100	Miriam
Per	83	Alex
Miriam	...	Per

Figure 5.2. a) A depiction of the three Dictator Games and the interactions participants had to consider. b) The format of the questionnaires completed by participants.

5.4.4 Social Network Questionnaire

A seven-item version of the SNQ (Burnett Heyes et al., 2015; Harrison et al., 2011) adapted for adolescents was used to assess the strength of the social ties between participants. The SNQ version was identical to that used in chapters 2 and 3. *Ego-rated social tie strength* represented the strength of the relationship between the participant (ego) and classmate (alter), as assessed by the participant. *Relationship reciprocation* represented the difference between the participant's and the classmate's assessment of relationship strength, referenced to *ego-rated social tie strength*. Control variables were also derived from the SNQ: *duration* represented how long the participant had known each classmate, and *familial ties* represented whether the participant was related to any classmates.

5.4.5 Gender

Gender was recorded on the SNQ. Participants could indicate male, female, or a self-identified gender identity term. Past research using the Dictator Game suggests that male participants tend to give less to others in their network than other classmates and that the demand curves for altruism are different for males and females – males are more likely to be highly selfish or selfless, and females are more likely to share (Andreoni & Vesterlund, 2001; Burnett Heyes et al., 2015). In the present study, female gender was coded as 1 and male gender was coded as 0.

5.5 Experimental Procedure

Participants completed all the measures with pen and paper in large testing rooms that allowed privacy for each individual. The experiment took approximately 60 minutes to complete. The rules for the 1st person, 2nd person, and 3rd person mDG were explained at the beginning of the session and participants were informed that there was no time pressure to complete the battery of measures in time for the end of the testing session.

5.6 Statistical Procedures

5.6.1 1st Person mDG Matrices

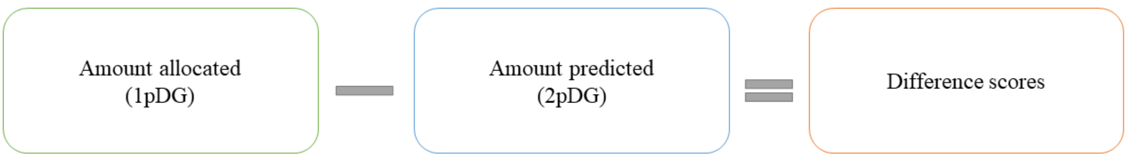
For each participant (ego)-classmate (alter) dyad, responses to the 1st person mDG were entered into a classroom network matrix whereby each cell indicates how much hypothetical money each ego (rows) allocated to each alter (columns).

5.6.2 2nd Person mDG Matrices

For each participant (ego)-classmate (alter) dyad, responses to the 2nd person mDG were entered into a classroom network matrix whereby each cell indicates how much hypothetical money each ego (rows) expected to receive from each alter (columns).

5.6.3 2nd Person mDG Accuracy Scores

For each network, the 2pDG matrix was subtracted from a transposed 1pDG matrix, creating a matrix of difference scores. These difference scores were then transformed into absolute figures and averaged across each row, giving a single score for each participant representing the magnitude of the difference between what the participant expected to receive, and what they actually received (Figure 5.3.).



X	John	Rachel	Jessica
John	X	£10	£50
Rachel	£12	X	£60
Jessica	£2	£0	X

X	John	Rachel	Jessica
John	X	£20	£5
Rachel	£0	X	£60
Jessica	£100	£0	X

X	John	Rachel	Jessica
John	X	-10	45
Rachel	12	X	0
Jessica	-98	0	X

X	John	Rachel	Jessica	**Average (absolute) error**
John	X	-10	45	**27.5**
Rachel	12	X	0	**6**
Jessica	-98	0	X	**49**

Figure 5.3. Accuracy scores were derived by subtracting the 2pDG matrix from the 1pDG matrix.

5.6.4 3rd Person mDG Accuracy Scores

For each participant, a matrix was constructed in which each cell represented what the participant believed each classmate in one list (ego) would give to the classmate in a second list (alter) in the 1pDG. Most cells in the matrix were necessarily blank as the selection of 3rd person dyads was sparse due to practicality constraints. This matrix was then subtracted from the 1st person mDG matrix to give a matrix of difference scores representing the difference between what the participant thought the allocation between classmates would be, and what they actually were. Note that most cells in this matrix were also blank. These difference scores were then transformed into absolute values and averaged across the whole matrix to give a single score for each participant representing the magnitude of difference between what the participant expected classmates to allocate, and what classmates actually allocated (Figure 5.4.).

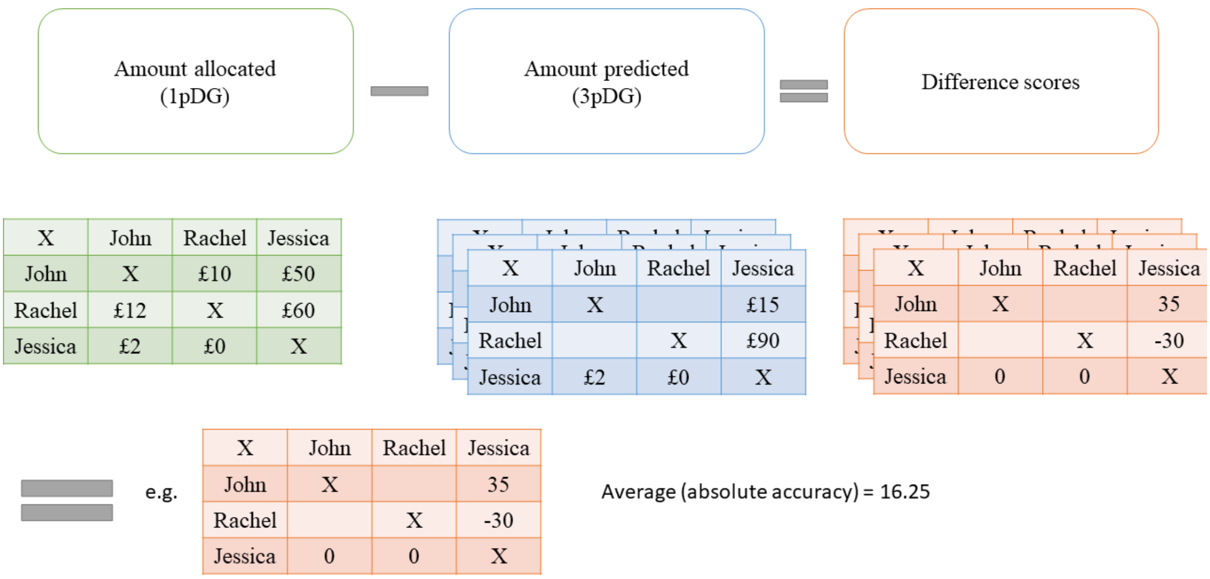


Figure 5.4. 3pDG data processing. Accuracy scores were derived for each participant by subtracting the 3pDG matrix from the 1pDG matrix for each participant. Single accuracy scores were then computed from the whole matrix.

Social Network Questionnaire

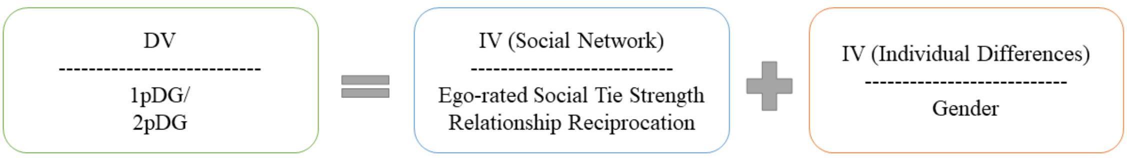
The five variable matrices derived from the SNQ for each classroom were processed as in chapters 2 and 3.

5.6.5 Gender

Gender matrices were processed as in chapters 2 and 3.

5.7 Statistical Analyses

The statistical analyses were comprised of four parts. 1) An analysis of the descriptive differences of network and non-network variables between networks (see Appendix D2-D3; Table 5.1; Table 5.2). 2) A within-network analysis of network variables as predictors of giving and expected receiving in the 1pDG and 2pDG (see Appendix D4-D7. 3) A pooled-network analysis of network variables as predictors of giving and expected receiving in the 1pDG and 2pDG (Figure 5.; also see Appendix D8- D11). 4) An analyses of variance (ANOVAs) comparing year group mean accuracy scores in both the 2pDG and 3pDG.



X	John	Rachel	Jessica
John	X	£9	£50
Rachel	£12	X	£60
Jessica	£2	£0	X
X	John	Rachel	Jessica
John	X	£9	£70
Rachel	£10	X	£50
Jessica	£1	£0	X

X	John	Rachel	Jessica
John	X	3	2
Rachel	7	X	5
Jessica	5	5	X
X	John	Rachel	Jessica
John	X	4	3
Rachel	-4	X	0
Jessica	-3	0	X

X	John	Rachel	Jessica
John	X	0	0
Rachel	1	X	1
Jessica	1	1	X

Figure 5.5. The MG-MRQAP analysis framework.

5.7.1 Sample Descriptives

Means and standard errors were calculated for the non-network variable *age*. Frequencies were computed for *gender* within networks and a chi-square test was conducted to test for differences in frequencies between year groups. Bootstrapped mean densities and standard errors were calculated for network variables: *giving*, *expected receiving*, *ego-rated social tie strength*, *relationship reciprocation*, and *duration*. Note that other individual difference variables were included in a separate analysis and did not change the results described below (see Appendix D4-D11).

5.7.2 Model Selection

As in Chapter 2, the variables were selected for entry in the initial MG-MRQAP models if they had predicted *giving* and *expected receiving* in any of the single-group MRQAP models (Dekker, Krackhardt & Snijders, 2007; Krackhardt, 1988). Additionally, terms were entered into the model to account for hypothesised interactions with year group. This selection resulted in all variables being included in both initial Giving MG-MRQAP and Expected Receiving MG-MRQAP models apart from *familial ties*.

5.7.3 Multiple Regression Predicting Resource Allocation Across all Networks

As in chapters 2 and 3, a multi-group multiple regression with quadratic assignment procedure (MG-MRQAP) was used to analyse the relationship between explanatory variables and *giving* and *expected receiving* in the 1pDG and 2pDG across all networks. Dependent variable matrices were regressed on to explanatory variable matrices within networks in order to obtain regression coefficients. Year group was coded using a dummy variable and then multiplied by the explanatory matrix values, allowing for the examination of network-level (year group) variable interactions with explanatory variables. Analysis was conducted in R (R Development Core Team, 2011). Statistical significance was set at $p < .05$, two-tailed for non-directional, and one-tailed for directional hypotheses. No directional hypotheses were postulated for the relationship between *giving* or *expected receiving* and *duration*; hypotheses relating to all other predictors were directional. Nonsignificant variables were dropped from the analysis in a stepwise manner, beginning with the variable for which the two-tailed *p* value was closest to 1. An exception to this order of predictor elimination was made for cases where the main effect p-value was larger than its corresponding interaction term; in this case the main effect for a significant interaction was retained in the model. Note that MRQAP and MG-MRQAP models were also run including *alter-rated social tie strength*. *Relationship reciprocation* and *alter-rated social tie strength* cannot be run in the same model as *relationship reciprocation* is a combination of *ego-rated* and *alter-rated social tie strength*. Both models were run to investigate whether *relationship reciprocation* and *alter-rated social tie strength* predicted different behaviour. For this study, the analysis including *alter-rated social tie strength* was not included (see Appendix D8-D11).

5.7.4 Analyses of Variance for Differences Between Year Groups in Mean Accuracy

One-way ANOVAs were conducted to compare year group mean accuracy scores in the 2pDG and 3pDG.

5.8 Results

5.8.1 Sample Descriptives

Chi-square tests revealed a significant difference between age groups in gender distributions $X^2(3, N = 292) = 18.34, p < .001$). Post-hoc tests revealed a significant difference between Year 12/13 and Years 9, 10, and 11. Year 12/13 had a greater number of female participants than in comparison groups.

	Year 9			Year 10		
Non-network variables	*M*(*SD*)	*Range*	*n*	*M*(*SD*)	*Range*	*n*
Age (Years)	12.46(0.50)	12 – 13	52	13.55(0.52)	13 – 15	104
Gender			29			44
	Year 11			Year 12/13		
	M(*SD*)	*Range*	*n*	*M*(*SD*)	*Range*	*n*
Age (Years)	15.01(0.53)	14 – 16	60	16.66(0.58)	16 – 18	76
Gender			26			59

Table 5.1. Non-network sample descriptives.

	Year 9			Year 10		
Network descriptives	Mean density (SEM)	*Range*	*n*	Mean density (SEM)	*Range*	*n*
1pDG	5.01(1.40)	0 – 50	1107	4.38(0.78)	0 – 75	2211
2pDG	5.75(1.53)	0 – 70	1107	4.52(1.43)	0 – 100	2211
Ego-rated social tie strength	4.93(0.73)	-3 – 7	1107	4.84(0.72)	-3 – 7	2211
Relationship reciprocation	1.47(0.39)	0 – 7	1107	1.37(0.25)	0 – 7	2211
Duration	1.52(0.50)	0 – 12	1107	1.81(0.26)	0 – 13	2211
	Year 11			Year 12/13		
	Mean density (SEM)	*Range*	*n*	Mean density (SEM)	*Range*	*n*
1pDG	5.01(0.86)	0 – 100	938	5.09(0.71)	0 – 100	1389
2pDG	5.24(1.21)	0 – 100	938	4.12(0.69)	0 – 100	1389
Ego-rated social tie strength	5.99(0.73)	-3 – 7	938	4.13(0.44)	-3 – 7	1389
Relationship reciprocation	2.19(0.34)	0 – 7	938	1.15(0.18)	0 – 7	1389
Duration	1.84(0.26)	938	1 – 15	1.88(0.36)	0 – 14	1389

Table 5.2. Network sample descriptives.

5.8.2 1pDG MG-MRQAP Model

Social network and individual difference variables (see Methods) were included in a MG-MRQAP model as predictors for giving in a repeated one-shot mDG across all classes in all age groups. In the final MG-MRQAP model (Table 3; $R^2_{adj} = .21$, $p < .001$), *Ego-rated social tie strength* significantly predicted more giving, whereas higher *relationship reciprocation*, *gender(ego)* and *gender(alter)* predicted less giving. There was also a negative interaction between *relationship reciprocation* and year group, as well as a positive interaction between *gender (ego)* and year group (Table 5.3). All else being equal, participants gave more to classmates with whom they reported a stronger relationship, and to classmates who reported a stronger relationship with the participant than the participant reported with them. Female participants also gave less and received less than male participants. The interactions indicate that *relationship reciprocation* better predicted early adolescent than late adolescent giving, and that *gender (ego)* better predicted late (vs. early) adolescent giving. This means that early adolescents were more likely to give to classmates who liked them more than they liked the classmate, and late adolescent female participants were more likely to give less than early adolescent female participants.

Independent Variable	Unstandardised Regression Coefficient	*p* value
MG-MRQAP model		
$R^2_{adj} = .21$, $p < .001$		
Ego-rated Social Tie Strength	1.19	< .001

Relationship Reciprocation	-0.23	.003
Gender (Ego)	-1.11	.002
Gender (Alter)	-0.68	.01
Relationship Reciprocation x Year Group	-0.10	.03
Gender (Ego) x Year Group	0.59	< .001

Table 5.3. MG-MRQAP model 1 predicting giving in the 1pDG. Class intercepts for the model were: Year 9A (b = 2.70, p = .04), Year 9B (b = 1.98, p = .69), Year 9C (b = 2.36, p = .69), Year 9D (b = 1.22, p = .70), Year 9E (b = 1.21, p = .69), Year 10A (b = -0.04, p = .46), Year 10B (b = 0.62, p = .99), Year 10C (b = 1.88, p = .82), Year 10D (b = 1.66, p = .79), Year 10E (b = 2.73, p = .69), Year 10F (b = 0.25, p = .69), Year 10G (b = 1.46, p = .69), Year 10H (b = 1.79, p = .69), Year 11A (b = -0.20, p = .69), Year 11B (b = 0.05, p = .69), Year 11C (b = 0.19, p = .69), Year 11D (b = 0.98, p = .69), Year 11E (b = 6.46, p = .97), Year 12A (b = 1.45, p = .69), Year 12B (b = 2.82, p = .69), Year 12C (b = 1.14, p = .69), Year 12D (b = 1.34, p = .73), Year 12E (b = 8.85, p = .72), Year 13A (b = 2.98, p = .87). Independent variables eliminated due to non-significance were Duration x Year Group (b = 0.01, p = .45), Ego-rated social tie strength x Year Group (b = -0.01, p = .38), Gender (Alter) x Year Group (b = 0.28, p = .19), Duration (b = -0.07, p = .12).

5.8.3 2pDG MG-MRQAP Model

Social network and individual difference variables (see Methods) were included in a MG-MRQAP model as predictors for expected receiving in the 2pDG across all classes in all age groups. In the final MG-MRQAP model (Table 4; R^2_{adj} = .15, p < .001). *Ego-rated social tie strength* positively predicted *expected receiving* amounts, whereas higher *relationship* *reciprocation*, and *gender alter* predicted lower *expected receiving* amounts (Table 5.4). All else being equal, participants across all year groups expected to receive more from classmates with whom they reported a strong relationship, from classmates who reported a stronger relationship with the participant than the participant reported to the classmate, and they expected to receive less from female classmates.

Independent Variable	Unstandardised Regression Coefficient	p value
MG-MRQAP model		
$R^2_{adj} = .15, p < .001$		
Ego-rated social tie strength	1.24	<.001
Relationship reciprocation	-0.3	<.001
Gender (Alter)	-0.73	< .01

Table 5.4. Relationship In-link Strength MG-MRQAP model. Class intercepts for the model were: Year 9A (b = 1.89, p = .001), Year 9B (b = 12.60, p = .66), Year 9C (b = 1.96, p = .73), Year 9D (b = 0.69, p = .99), Year 9E (b = 0.69, p = .94), Year 10A (b = -0.84, p = .23), Year 10B (b = 0.43, p = .001), Year 10C (b = 1.56, p = .91), Year 10D (b = 9.55, p = .66), Year 10E (b = 2.23, p = .81), Year 10F (b = -0.14, p = .77), Year 10G (b = 1.17, p = .001), Year 10H (b = 1.21, p = .001), Year 11A (b = 4.75, p = .70), Year 11B (b = 1.62, p = .99), Year 11C (b = 0.08, p = .99), Year 11D (b = 0.91, p = .68), Year 11E (b = 8.17, p = .001), Year 12A (b = 2.32, p = .001), Year 12B (b = 2.50, p = .001), Year 12C (b = 1.39, p = .001), Year 12D (b = 0.10, p = .77), Year 12E (b = 7.44, p = .001), Year 13A (b = 3.28, p = .001). Independent variables eliminated due to non-significance were Relationship reciprocation x Year Group (b = -0.01, p = .48), Duration x

Year Group (b = 0.02, p = .37), Duration (b = 0.01, p = .53), Gender (Alter) x Year Group (b = -0.04, p = .45), Gender (Ego) x Year Group (b = 0.62, p = .69), Gender (Ego) (b = -0.47, p = .48), Ego-rated social tie strength x Year Group (b = -0.07, p = .13).

5.8.4 2pDG Accuracy

An ANOVA was conducted to investigate whether there were any differences between year groups in mean accuracy in the 2pDG (Figure 5.6.). The analysis did not reveal any significant differences between year groups in accuracy when predicting how much money they would receive, F(296) = 1.36, p = .26, η2 = .01.

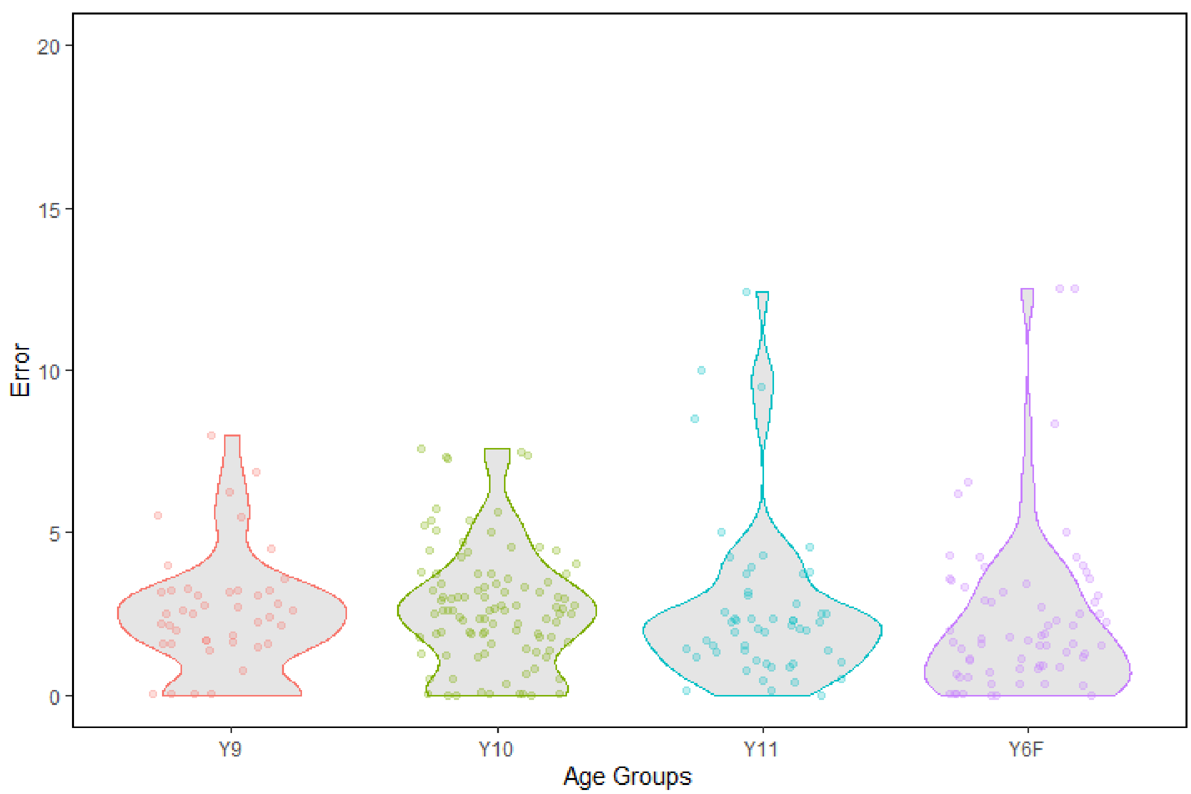


Figure 5.6. Accuracy scores by year group in the 2nd Person mDG.

5.8.5 3pDG Accuracy

An ANOVA was conducted to investigate whether there were any differences between year groups in accuracy in the 3pDG (Figure 5.7.). The analysis did not reveal any significant differences between year groups in accuracy when predicting how much money others would allocate to each other, F(223) = 1.01, p = .39, η2 = .01.

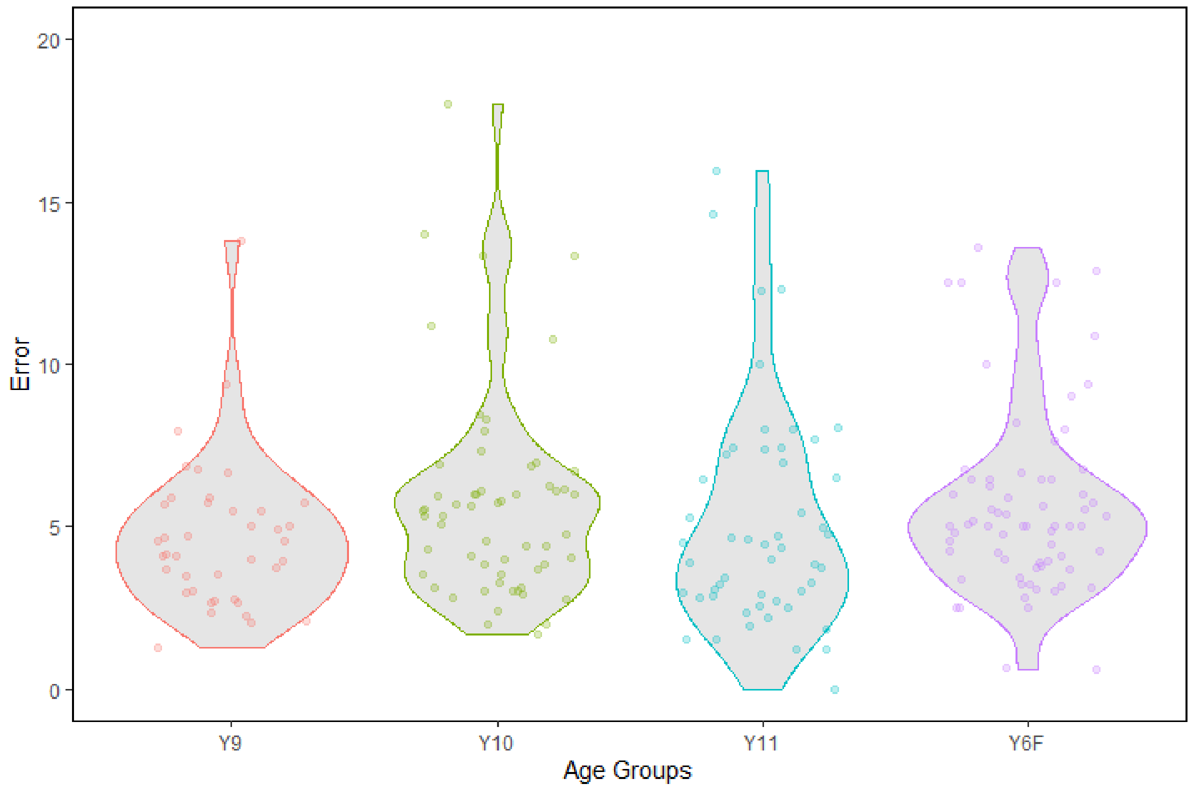


Figure 5.7. Accuracy scores by year group in the 3rd Person mDG.

5.9 Discussion

This study was designed to investigate: [1] whether adolescent giving and the amount adolescents expected to receive was predicted by directed and dyadic social tie variables; [2] whether late adolescents made more accurate predictions than early adolescents about the exchange of hypothetical money in both reciprocal and non-reciprocal contexts; [3] and whether late adolescent giving and the amounts late adolescents expected to receive were better predicted by directed and dyadic social network variables relative to those of early adolescents. Analyses revealed that while directed and dyadic social tie variables strongly predicted economic decision-making across all adolescent year groups, in fact, early (vs. late) adolescent decision-making was better predicted by mutual dyadic variables, and there was no difference between year groups in how accurately participants inferred the decision-making of their classmates.

5.9.1 Social tie predictors of giving and expected receiving

In the 1pDG, single classroom (MRQAP) and group-level (MG-MRQAP) network models revealed that participants gave more to classmates with whom they reported a strong relationship, and to classmates who reported a stronger relationship with the participant than the participant reported with the classmate. Female participants also gave less and received less than male participants, meaning that male participants gave and received more. Interactions with year group also revealed that late adolescent female participants were more likely to give less than early adolescent female participants, with the reverse being true for male participants. Finally, early (vs. late) adolescent giving was better predicted by unbalanced relationships whereby the classmate reported a stronger relationship with the participant than the participant reported with them. In the 2pDG, single classroom (MRQAP) and group-level (MG-MRQAP) network models demonstrated that participants across all year groups expected to receive more from classmates with whom they reported a stronger relationship, from classmates who reported a stronger relationship to the participant than the participant reported to the classmate, and from female classmates.

Replicating and extending the results found in chapters 2, 3, and in Burnett Heyes et al. (2015), directed and dyadic social tie variables predicted *giving* and *expected receiving* in the 1pDG and 2pDG. Participants gave more to and expected more from classmates with whom they reported a stronger relationship, and classmates who reported a stronger relationship with the participant than the participant reported with the classmate. This result once again supports the claim that directed and dyadic social tie variables are powerful and often overlooked predictors of decision-making in economic games. It suggests that the perception of the relationship matters when deciding how to allocate resources, and that adolescents not only take into account how strong they feel their relationships are, but that they also incorporate the perspectives of other members of their network.

However, in contradiction of our predictions, early (vs. late) adolescent giving was better predicted by *relationship reciprocation*, which may be due to the Dictator Game's sensitivity to small design changes. The Dictator Game is one of the most susceptible games to minor modifications that produce substantial changes in outcomes (Zizzo, 2010). One difference between this game and the original study that informed it is that participants were not able to give money to themselves. Although some past research seems to indicate that late adolescents do increasingly differentiate social contexts even in non-costly allocation games (Güroğlu, van den Bos & Crone, 2014), it is possible that late adolescent dictators did not see the utility of pursuing any social strategy in a situation where they did not stand to gain, possibly supporting research that dictators will pay to leave the Dictator Game if presented with the option (Broberg, Ellingsen & Johannesson, 2007; Lazear, Malmendier & Weber, 2012). However, all post-hoc interpretation of this result should be regarded as highly speculative due to the results not following our original predictions.

5.9.2 Individual difference predictors of giving and expected receiving

MG-MRQAP analyses revealed that female participants gave less, were given less, and expected to receive less than male participants. The interaction with year group also demonstrates that late adolescent female participants were more likely to give less than early adolescents. This finding contradicts past research, which suggests female participants are more likely to share than male participants, or that there is no significant difference (Burnett Heyes et al., 2015; Eckel et al., 2011; Engel, 2011). This effect may have been driven by male participants being more inclined to make more selfless offers, which is supported by past research (Andreoni & Vesterlund, 2001).

5.9.3 Accuracy in predicted allocation to self and others

ANOVAs were conducted to investigate whether there were any differences between year groups in accuracy in the 2pDG and the 3pDG, but the analysis did not reveal any significant differences between year groups when predicting allocation in either game. There was no statistical evidence that late adolescent year groups were better at predicting how much hypothetical money they would receive, or how much classmates would give to each other. Therefore, our results do not find that late adolescents have greater inferential abilities than early adolescents. In combination with the lack of evidence for an age trend in the predictive power of social tie variables on allocation, it is not possible to interpret whether late adolescents demonstrate greater capacities to infer or use information.

5.9.4 Limitations and future studies

Since interaction effects were not found it is not strictly necessary to focus on the results of the prediction accuracy analyses. However, it could be argued that predicted peer ratings would have been a more suitable subject for analysis than predicted allocation. Alternatively, as reflected on in Chapter 4, it may be suggested that predictions of peer ratings and allocation are not a good proxy for mentalising, or indeed, that the study does not test perspective-taking in any sense. It could be that participants may not be engaging their Theory of Mind in order to infer the beliefs of classmates, but that they predict peer ratings and allocation based on social reasoning. There is a debate about the operationalisation of Theory of Mind and whether a number of studies that purport to test Theory of Mind actually do so (Heyes, 2014; Lockwood, Apps & Chang, 2020; Schaafsma, Pfaff, Spunt & Adolphs, 2015). This issue will be explored in more depth in Chapter 6.

These results may not exactly reflect the capacities of adolescents but may instead represent the difficulties in creating a task for adolescents that is challenging enough to produce meaningful variance (Apperly, 2010). Participants were not able to allocate money to themselves as in a prior study it was not possible to determine whether allocation differences were driven by genuinely different decisions, or by a misunderstanding of the rules. But what was gained in clarity may have been lost in complexity by removing this element of the game. It may be that because participants did not have to consider the differences between allocation to classmates and themselves, that an element of intentionality was removed, which has been found to differentiate late and early adolescent decision-making in economic games (e.g. Güroğlu, van den Bos & Crone, 2009; Lee, Jolles & Krabbendam, 2016; van den Bos et al., 2011). It may also be that the use of hypothetical money, as opposed to real money or 'likes' did not adequately motivate participants (e.g. Sherman, Payton, Hernandez, Greenfield & Dapretto, 2016; van Hoorn, van Dijk, Meuwese, Rieffe & Crone, 2014). However, past research investigating allocation in the Dictator Game and BOLD responses in reward regions of the brain suggest that the use of hypothetical money is efficacious within these designs (Burnett Heyes et al., 2015; Miyapuram, Tobler, Gregorois-Pippas & Schultz, 2012). Despite these issues, this design is well-suited to disentangling the differing contributions of *inference* and *use* in adolescent allocative decision-making. We suggest that future studies should employ this design with games that elicit reliable age-related trends in decision-making and require greater incorporation of the perspectives of other players, for example, the Trust Game (Berg et al., 1995), Ultimatum Game (Güth et al., 1982), and perhaps even an iterated version of the Prisoner's Dilemma (Poundstone, 1993).

5.10 Conclusion

In this study, we investigated whether adolescent giving and the amount adolescents expected to receive was predicted by directed and dyadic social tie variables, whether late adolescent giving and the amounts late adolescents expected to receive were better predicted by social network variables relative to early adolescents, and whether late adolescents made more accurate predictions than did early adolescents about the exchange of hypothetical money in both reciprocal and non-reciprocal contexts. Analyses revealed that while directed and dyadic social tie variables predicted economic decision-making across all adolescent year groups, in fact, early (vs. late) adolescent decision-making was better predicted by mutual dyadic variables, and there was no difference between year groups in how accurately participants inferred the decision-making of classmates. While the predictive power of social tie variables is consistent with chapters 2 and 3, the interaction with year group ran counter to what was expected. This may be due to the modifications made to the Dictator Game, which is particularly susceptible to producing substantial changes according to moderate adaptations (Zizzo, 2010). The lack of evidence for age group differences in accurate predictions may also be explained by this confound. However, this research design is uniquely suited to teasing apart Theory of Mind components *inference* and *use*, and future research might seek to employ this design with other games that more reliably elicit age differences in adolescent performance in order to ascertain whether adolescent improvement is underlied by an increasing capacity to *infer* or to *use* social information.

This thesis addressed three questions:

- [Q1] Do directed and dyadic social tie variables predict adolescent decision-making in economic games?
- [Q2] If so, does the strength of this prediction alter with age?
- [Q3] If so, what are the cognitive mechanisms driving this development?

Using the Trust Game, Prisoner's Dilemma, and Dictator Game, this thesis explored whether social tie variables predicted adolescent economic decision-making, and whether these variables better predicted late (vs. early) adolescent gameplay. Additionally, using a social network questionnaire, and the Dictator Game, we tested whether late (vs. early) adolescents more accurately predicted the strength of their relationships, and the allocative strategies of their peers.

Chapters 2, **3** and **5** investigated adolescent decision-making in a modified Trust Game, Prisoner's Dilemma, and set of Dictator Games. **[H1]** We hypothesised that adolescent decision-making in the Trust Game, Prisoner's Dilemma, and Dictator Game would be predicted by egocentric, altercentric, and mutual directed and dyadic social tie variables (Burnett Heyes et al., 2015; Harrison, Sciberras & James, 2011). **[H2]** We also predicted that late adolescent (vs. early adolescent) decision-making would be better predicted by these variables in all three economic games (Burnett Heyes et al., 2015; Gutiérrez-Roig, Gracia-Lázaro, Perelló, Moreno, & Sánchez, 2014; van den Bos et al., 2011).

Chapters 4 and **5** investigated whether late adolescents were better at *inferring* or *using* social and strategic information than early adolescents. **[H3]** We hypothesised that late adolescents would predict their peers' ratings of their relationships more accurately than early adolescents.

[H4] We also predicted that late adolescents would predict the allocative decisions of their classmates more accurately than early adolescents (Dumontheil, Apperly & Blakemore, 2010).

6.1 Findings

6.1.1 Do directed and dyadic social tie variables predict adolescent decision-making in economic games, and does the strength of this prediction alter with age?

In **Chapter 2**, the directed and dyadic social tie determinants of trust and expected reciprocity in a modified Trust Game were investigated in late adolescent classrooms (*N* = 169, *Nnetworks* = 11, *range* = 16-19). Past research suggested that late adolescents are more sensitive to the social context of the Trust Game than early adolescents (Lee, Jolles & Krabbendam, 2016; van den Bos et al., 2010). We hypothesised that ego-rated social tie strength (how strong the participant perceives their relationship to be with each classmate) and relationship reciprocation (the difference between the participant's and the classmate's perception of the strength of the relationship) as derived from a social network questionnaire (see Burnett Heyes et al., 2015) would predict trust (how much the participant entrusted to each classmate), and expected reciprocity (how much the participant expected each classmate to return) in the Trust Game.

Single classroom (MRQAP) and group-level (MG-MRQAP) network models revealed that late adolescent decision-making was predicted by both ego-rated social tie strength and relationship reciprocation in the trust and expected reciprocity phases of the Trust Game. Participants entrusted more to, and expected higher levels of reciprocity from, those with whom they reported a stronger relationship. Participants also entrusted more to, and expected higher levels of reciprocity from, classmates who reported a stronger relationship with the participant than the participant reported with them. This finding supports the prior literature, which suggests late adolescents are sensitive to interpersonal information, and will make economic decisions based on the strength of their relationship with their playing partner in both trustor and trustee contexts. The results also suggested the greater relevance of directed and dyadic social tie information to their decision-making than more general individual differences as evidenced by the larger betas of the social tie variables in the MRQAP models (see Appendix A4 – A7) and the fact that most individual difference variables did not survive the MG-MRQAP. Note that due to the narrow age range of the sample, it was not possible to test for age effects.

In **Chapter 3**, the directed and dyadic social tie determinants of cooperation in the Prisoner's Dilemma were investigated in adolescent classrooms (*N* = 156, *nNetworks* = 9, *age range* = 13 - 18). Past studies suggested that interpersonal features of the relationship between two players predict decision-making in the Prisoner's Dilemma. Adult participants cooperate more with humans than computers, friends than strangers, and in-group members than out-group members *(*Dorrough, Glöckner, Hellmann & Ebert, 2015; Ames et al., 2006; Rilling et al., 2008; Rilling, Sanfey, Aronson, Nystrom & Cohen, 2004). Adolescents have also been suggested to increasingly adopt the perspectives of others into their own decision-making in the Prisoner's Dilemma (Gutiérrez-Roig, Gracia-Lázaro, Perelló, Moreno, & Sánchez, 2014). We hypothesised that ego-rated social tie strength, alter-rated social tie strength, and relationship reciprocation would predict cooperation in a modified Prisoner's Dilemma, and that directed and dyadic social tie variables would better predict late (vs. early) adolescent decision-making.

Single classroom (MRQAP) and group-level (MG-MRQAP) network models revealed that cooperation was predicted by ego-rated social tie strength and relationship reciprocation in the Prisoner's Dilemma. However, the direction of effects ran counter to our hypotheses. Participants, in fact, tended to defect more from classmates with whom they reported a stronger relationship, as well as from classmates who reported a stronger relationship with the participant. Across year groups, adolescent participants also tended to cooperate more with classmates with whom they reported a stronger relationship, than the classmate reported to them, contradicting our predictions (see Chapter 2). Finally, a negative interaction between *ego-rated social tie strength* and year group was found, indicating that early adolescents were more likely to defect from friends than late adolescents. These unexpected findings might be partially attributable to the low variance explained by the network models in this experiment. Neither social tie nor individual difference variables predicted decision-making in the Prisoner's Dilemma well, therefore, any conclusions drawn from this experiment must be treated as speculative. Alternative explanation for these results include that participants may have chosen to defect from friends believing that their friends were the most likely to cooperate as evidenced in other economic games (e.g. Chapter 2; Chapter 5), or as a form of teasing (Spear, 2000). Conversely, participants may have chosen to cooperate more with classmates who they reported a stronger relationship with than the classmate reported to them in order to ingratiate themselves with classmates with whom they hoped to share a stronger relationship in the future (Dijkstra, Cillessen & Borch, 2013). The negative interaction between *ego-rated social tie strength* and year group may be explained by early adolescents being more likely to interpret teasing positively, however, this interpretation is given tentatively as past research has only compared children with early adolescents (Jones, Newman & Bautista, 2005).

In **Chapter 5**, the directed and dyadic social tie determinants of giving in a set of modified Dictator Games were investigated in adolescent classrooms (*N* = 292; *Nnetworks* = 24; *age range* = 12 – 18). There are studies that point towards the utility of social network variables as predictors of giving in the Dictator Game. Social integration, social distance, ego-rated social tie strength, and relationship reciprocation have all been found to predict giving (Brañas-Garza et al., 2010; Burnett Heyes et al., 2015; Goeree, McConnell, Mitchell, Tromp & Yariv, 2010; Jones & Rachlin, 2006; Leider, Möbius, Rosenblat & Do, 2009). In an experiment that aimed to replicate and extend past work, we hypothesised that *ego-rated social tie strength* and *relationship reciprocation* would predict giving in a 1st person Dictator Game that asks participants how much they will allocate to each classmate, and a 2nd person Dictator Game that asks participants how much they expect to receive from each classmate. Additionally, we hypothesised that directed and dyadic social tie variables would better predict late (vs. early) adolescent decision-making.

Single classroom (MRQAP) and group-level (MG-MRQAP) network models revealed that adolescent decision-making was predicted by *ego-rated social tie strength* and *relationship reciprocation* in the 1st and 2nd person Dictator Games. In line with our first hypothesis, participants gave more to and expected more from classmates they reported a stronger relationship with, and to classmates who reported a stronger relationship with the participant than the participants reported with them. These findings support the prior literature and suggest the importance of social tie variables as determinants of adolescent decision-making in the Dictator Game (Burnett Heyes et al., 2015). However, in contradiction of our third hypothesis, early (vs. late) adolescent decision-making was better predicted by mutual social network variables. This outcome may have resulted from the participant not being able to allocate any hypothetical money to themselves, as in the classic Dictator Game and in relevant prior research (Burnett Heyes et al., 2015; Camerer, 2003). This, in conjunction with the fact that findings from the Dictator Game are the most susceptible to influences from minor modifications in the design may have led to this contradictory result (Zizzo, 2010). One difference between this game, and the original study that informed it is that participants were not able to give money to themselves, although past research seems to indicate that late adolescents do increasingly differentiate social contexts even in non-costly allocation games (Güroğlu, van den Bos & Crone, 2014).

6.1.2 What are the cognitive mechanisms driving development?

In **Chapter 4**, we investigated whether late (vs. early) adolescents (*n* = 918, *nNetworks* = 58, *age range* = 12-18) were better at predicting how classmates rated their relationships with them. While there is evidence for the improving perspective-taking abilities of adolescents in artificial contexts (e.g. Dumontheil, Apperly & Blakemore, 2010), few studies have sought to obtain this evidence using adolescents' own social networks. Social network methods were used to investigate the developing perspective-taking abilities of adolescents within participants' social networks. This approach is potentially more ecologically valid as it allows for stronger conclusions to be drawn regarding developing adolescent social cognition within authentic social contexts. In this study, we sought to compare participant predictions of how classmates would report the strength of the relationship, against how classmates actually reported the strength of the relationship. We hypothesised that late (vs. early) adolescents would more accurately predict how classmates reported the strength of the relationship.

ANOVAs revealed that late adolescents did predict their classmates' ratings significantly more accurately than did middle and early adolescents. This finding supports past research suggesting that late adolescents infer and incorporate other perspectives better than early adolescents (Dumontheil, Apperly & Blakemore, 2010). Furthermore, it may suggest that improving capacities to *infer* perspectives, as opposed to just a solely improved capacity to *use* inferred perspectives, is a potential driver of the increasing adoption of intentionality into adolescent decision-making in economic games (Burnett Heyes et al., 2015; Lee, Jolles & Krabbendam, 2016; Güroğlu et al., 2014; Güroğlu, van den Bos & Crone, 2009).

In **Chapter 5**, we investigated whether late (vs. early) adolescents were better at inferring the allocative decisions of classmates in a set of Dictator Games. While there is a little direct evidence of the improving perspective-taking abilities of adolescents (Dumontheil, Apperly & Blakemore, 2010; Selman, 1980), there is even less investigating the drivers of the increasing incorporation of perspective-taking into adolescent economic decision-making. Past research does suggest that perspective-taking is both a weak predictor of giving in the Dictator Game (Artinger, Exadaktylos, Koppel & Sääksvuori, 2014), and a mediator of non-costly prosocial allocation (Güroğlu, van den Bos & Crone, 2014). However, this research relies on participants' self-reported level of perspective-taking and does not investigate adolescents' perspective-taking performance when playing economic games and how it drives their decision-making. In this study, we sought to compare predicted allocation decisions with actual allocation decisions in the 2nd person Dictator Game and 3rd person Dictator Game. In the 2nd person Dictator Game, participants had to predict how much classmates would allocate to them (2nd person perspective); in the 3rd person Dictator Game, participants had to predict how much classmates would allocate to each other (3rd person perspective). We hypothesised that late adolescents would make more accurate inferences than early adolescents. Additionally, we investigated whether there was a difference in the accuracy of these inferences dependent on whether the participant was a part of the predicted interaction or not. Past research suggests that there is a fundamental difference between reciprocal (2PP) and third-person modes of interaction (3PP), with reciprocal modes of interaction being easier to infer at an earlier stage of development (Buttelmann et al., 2009; Reddy, 2018; Selman, 1980).

ANOVAs revealed that there was no significant difference between age groups in mean accuracy in either the 2nd person or 3rd person Dictator Game. There was no evidence that late adolescents had greater inferential capacities than early adolescents in this context. However, this result cannot be used as originally intended as an argument for the *use* hypothesis as, counter to our interaction hypothesis, early adolescent decision-making was in fact better predicted by dyadic social tie variables.

6.2 General Discussion

6.2.1 Dyadic social network variables predict adolescent decision-making in economic games and the strength of this prediction alters with age

In **Chapters 2**, **3**, and **5** we investigated whether directed and dyadic social tie variables predict adolescent decision-making in different economic games. Egocentric, altercentric, and mutual directed and dyadic social tie variables were hypothesised to predict decision-making in the Trust Game, Prisoner's Dilemma, and Dictator Game **[H1]**. In all three games, directed and dyadic social tie variables were significant determinants of adolescent economic decision-making. In the Trust Game, egocentric and mutual dyadic variables predicted decision-making in both phases (trust and expected reciprocity). In the Prisoner's Dilemma, egocentric, altercentric, and mutual dyadic variables predicted differing cooperation trends. In the Dictator Game, egocentric and mutual dyadic variables predicted giving when participants took both a 1st and 2nd person perspective. In both the Prisoner's Dilemma and Dictator Game, dyadic variables better predicted early (vs. late) adolescent decision-making. This finding provides evidence that researchers investigating economic decision-making should not only consider individual differences, or even global network characteristics, but also dyadic differences within networks. Superficially, this paradigm offers a more valid approach to the study of social decision-making in adolescence, as it asks researchers to investigate an authentic network of social relationships and consider how elements of the network contribute to behaviour. The presented research has focused on the dyad, the fundamental unit of a social network (Robins, 2015). This thesis makes a concrete case for the validity of the use of social tie predictors, which were found to robustly predict adolescent decision-making.

Hypotheses regarding the direction of the relation between social tie variables and decision-making were supported for two of the three games: The Trust Game and the Dictator Game (1st and 2nd person). In line with past research, participants entrusted more to and expected reciprocity from classmates with whom they reported a stronger relationship, and those that reported a stronger relationship with the participant than the participant reported with them (Trust Game: Güroğlu, van den Bos & Crone, 2014; van den Bos et al., 2010). Similarly, participants gave more and expected to receive more from classmates with whom they reported a stronger relationship, and those that reported a stronger relationship with the participant than the participant reported with them (Dictator Game: Burnett Heyes et al., 2015; Harrison, Sciberras & James, 2011). However, in the case of the Prisoner’s Dilemma, the relation between social tie variables and cooperation we observed ran counter to hypotheses. In this case, participants chose to ‘steal’ more from other classmates who they reported a stronger relationship with, from classmates who reported a stronger relationship with them, and ‘split’ more with classmates who report a weaker relationship with the participant than the participant reports with them. However, these results need to be replicated before any strong conclusions can be drawn. Nevertheless, in all cases, these results suggest that adolescents consider both how they feel about their playing partner, how their partner feels about them, and the intersection of these two perspectives when playing economic games.

Particularly in the case of the Prisoner's Dilemma, these differences between outcomes and hypotheses raise an important question: how might differences between the games and modifications within the games have affected the results? As previously discussed, participants may respond differently in the Prisoner's Dilemma due to the simultaneous nature of the game (Rilling & Sanfey, 2011). A model comparing cooperation in simultaneous and sequential games with complete or incomplete information finds that players are less likely to cooperate in simultaneous games, and in games with incomplete information about the opposite player's tactics (Dijkstra & van Assen, 2016). It may be that in a different version of the Prisoner's Dilemma, greater rates of cooperation would be observed within a game in which participants have more information about both their opposite player, and the tactics they employ.

We also hypothesised that late (vs. early) adolescent decision-making would be better predicted by these social tie variables in the Prisoner's Dilemma and Dictator Game **[H2]**. However, in contradiction of past research, we found the opposite developmental trend indicating that early (vs. late) adolescent decision-making was better predicted by social tie variables in both the Prisoner's Dilemma and Dictator Game. It may be that the use of a costly Dictator Game, or a Prisoner's Dilemma that gave more information to participants may have induced the expected age trends observed in past research (Burnett Heyes et al., 2015). Future work should carefully consider the design of their economic games and the consequences that even minor modifications can have on the behaviour of participants (Zizzo, 2010).

In each study, the predictive power of social tie variables was demonstrated, especially in comparison to individual difference variables. It is clear that researchers interested in the interaction between adolescents' social cognition and their economic decision-making must take into account not only the traits of the individuals themselves, but also their social context

(Burnett Heyes et al., 2015; van den Bos et al., 2018). That the predictive power of both can be tested using social network methods is testament to the flexibility and scientific value of this type of method. The next step is to investigate how authentic social network variables interact with different formulations of classic economic games. Even in explicitly non-social contexts, different versions or even framings of the same games have led to differing results (Evans & Crumbaugh, 1966; Kiesler, Sproull & Waters, 1996; Zizzo, 2010). It could be that as more research using the social network approach is conducted, the first steps will be to disentangle the interactions between complex, multifarious, authentic social relationships and the game design itself.

6.2.2 Late adolescents infer the nature of their relationships more accurately than do early adolescents, but not their classmates' allocative decision-making

In **Chapters 4** and **5** we investigated what drives adolescent development in economic decision-making. We hypothesised that late adolescents would perceive the strength of their relationships more accurately than would early adolescents **[H3]**. A comparison of how adolescents predicted classmates to rate their relationship versus how classmates actually rated the relationship, revealed that late adolescents did indeed make more accurate predictions than did early adolescents. Although the mean accuracy difference was small, it may be qualitatively significant. The difference between thinking someone is a 'good friend' or a 'best friend', a 'friend' or an 'acquaintance' could be a consequential difference. It is also possible that early adolescents have more noisy thresholds for what constitutes a 'good friend' or a 'friend'. In either case, the result is interesting. This study demonstrated the value of obtaining measures of relationship strength from authentic social networks. While it is important to obtain indirect behavioural measures of developing social cognition, it is also important to directly obtain subjective measures of social perspective-taking. This study suggests that adolescents increasingly accurately predict how their peers rate their relationships with increasing age. This could be key to understanding what exactly drives improvements in adolescent perspective-taking and crystallises the corollary questions that should inform future research. Do late adolescents have the same conception of friendship categories as early adolescents? And does a greater capacity to infer social relationships predict a greater capacity to predict decision-making in economic games? One method for answering the former question might be to investigate other items within the social network questionnaire and test whether different variables predict social tie strength in early and late adolescents. In the case of the latter question, future studies should record the accuracy of both social tie strength and peer strategy predictions and investigate whether they correlate.

Finally, we hypothesised that late adolescents would predict the allocative decisions of their classmates more accurately than would early adolescents **[H4]**. Using a set of Dictator Games, we found no evidence that late adolescents were more accurate than early adolescents in predicting how much classmates would give to them or each other. Similarly, we also did not find any evidence that social tie variables better predicted late (vs. early) adolescent decision-making. Therefore, we found no evidence that adolescents became better at inferring and/or using social information with increasing age.

Taking both findings together, this thesis presents evidence that late adolescents are better than early adolescents at adopting the perspectives of others when it comes to relationships, but not to gameplay strategy. This may suggest that past findings indicating that late adolescents are more flexible, reactive, and able to adopt the perspectives of fellow players may reflect their more developed capacity to predict the social dyadic elements (inferred social relationship), rather than the strategic dyadic elements (decision-making in the 2pDG and 3pDG) at play. Although it is not possible to draw firm conclusions as we did not observe the age trends we predicted in any study using an economic game, the design in **Chapter 5** does have the potential to uncover the drivers of developing social cognition in the context of economic decision-making. The design simultaneously tests social network variables as predictors of allocation, and whether predicted age trends reflect greater capacities to infer or use said social information. Research that attempts to draw conclusions regarding the effects of improving perspective-taking on adolescent economic decision-making should consider using these accuracy measures or similar as convergent evidence for the improving intentionality capacity hypothesis.

6.2.3 Research impact

In **Chapters 2**, **3**, and **5** our findings indicated that directed and dyadic social tie variables were significant predictors of behaviour in the Trust Game, Prisoner's Dilemma and Dictator Game. This thesis thus makes a powerful case for the utility of these variables as predictors of behaviour in three distinct economic games. While past research has demonstrated that directed and dyadic social tie variables predict decision-making in a Dictator Game (Burnett Heyes et al., 2015), to our knowledge, no past research has established these variables as general predictors of decision-making in the Trust Game, Prisoner's Dilemma, and in our novel version of the Dictator Game. This research suggests that this social network approach could be used more often in developmental research to model decision-making in a variety of economic games that target distinct relationship features (suggestions for other economic game candidates can be found in section 6.3).

Furthermore, it is easy to see how minor modifications of these studies could be used to better understand participant responses in these games. For example, is late adolescent (vs early adolescent) decision-making in the Trust Game better predicted by directed and dyadic social tie variables? Why do adolescents in the Prisoner's Dilemma choose to defect from those they share a stronger relationship with; would the effect be reversed in an iterated version of the game? Finally, why is late adolescent (vs early adolescent) decision-making in a costly Dictator Game (Burnett Heyes et al., 2015) better predicted by directed and dyadic social tie variables than late adolescent (vs early adolescent) decision-making in a non-costly Dictator Game (Chapter 5)? All of these questions, especially in the context of social tie variables, can be effectively answered within a social network research paradigm that collects egocentric and altercentric datapoints. These studies not only demonstrate the general utility of these variables and their different impacts on decision-making, but also hint at their potential to add further context to an evolving literature that seeks to understand the cognitive underpinnings of decision-making.

Studies in **Chapters 4** and **5** also demonstrate how directed tie variables can be used in combination with traditional statistical analyses to add further context to our understanding of adolescent decision-making and perspective-taking in a social context. These studies show that directed tie variables can be computed within authentic social networks to allow researchers to investigate how accurately adolescents' predictions of peers' relationship strength evaluations and economic decisions match reality. This analysis directly resulted from a social network design framework that collects data from both egocentric and altercentric perspectives. These studies demonstrate that adolescent predictions of peer-rated relationship strength improved with age while predictions of resource allocation did not. This suggests that with age, adolescents improve not only in their capacity to *use* social information (Dumontheil, Apperly & Blakemore, 2010), but that they may also improve in their capacity to *infer* social information (Chapter 4).

Conversely, **Chapter 5** did not report an improvement in adolescent capacities to predict allocation decisions. Nevertheless, this novel paradigm might still be considered a useful framework to make sense of interaction effects between social tie variables and age found in past research (Burnett Heyes et al., 2015). This novel design attempts to do so by investigating hypothesised explanations of said interaction effects with more traditional analyses in conjunction with the social network analyses. In effect, attempting to understand participant responses from two angles: by studying tie variables within the context of the dependent variable, and studying how tie variables interact with each other (egocentric vs altercentric). It may be that the hypotheses were not supported because the novel Dictator Game was incorrectly calibrated, or it may be because our hypotheses were incorrect. In any case, this design has the potential to add necessary context to complex processes within social networks and future studies should seek to improve on it.

In combination, these studies suggest that directed and dyadic social tie variables are reliable predictors of adolescent decision-making and should be considered a useful tool for understanding the complex interactions between social tie and individual difference variables within networks. This is by no means to say that social network methods are a superior form of design, but more simply to suggest that social network methods can complement our traditional investigations of these variables to add a richer understanding of how adolescents interact at the level of the ego, the alter, and the dyad.

Finally, taking a broader perspective, it should also be noted that these designs may more naturally lend themselves to an improved understanding of the school environment by collecting data from whole classes. The greatest benefit of social network designs may be that they have a translational quality that allows non-researchers in the education sector to better relate academic investigations of trust, reciprocity, and prosociality to their classrooms. Past social network research demonstrates this possibility in both promise and practice. Non-experts with access to the academic literature can find whole-classroom studies that show social network cohesion within adolescent classrooms promotes prosocial behaviour (van den Bos et al., 2018), and that social network-based interventions can be effectively implemented in schools to improve the monitoring of student-student and teacher-student collaboration (Saqr, Fors, Tedre & Nouri, 2018). It is often difficult to translate academic progress to the real-world school context, but social network studies may offer an intuitive framework for understanding classroom behaviour, allowing educators to better understand how relationships impact learning outcomes and how to improve educational practice (Grunspan, Wiggins & Goodreau, 2014).

6.2.4 Final Summary

We now know from **Chapters 2**, **3**, and **5** that directed and dyadic social tie predictors are important determinants of economic decision-making and suggest that researchers should consider not only participants' individual circumstances, but also their dyadic context when making economic decisions. We know from **Chapter 4** that late adolescents make more accurate inferences of the nature of their relationships than do early adolescents, and researchers should carefully consider whether the more accurate inference of relationships begets the more accurate inference of strategy (see **Chapter 5**), as is often implied in past work. A social network approach allows researchers to investigate economic decision-making at the level of the individual, and the dyad, as well as offering a unique opportunity to test the gap between differing perceptions of relationships and strategies within the network. We suggest that the combination of a well-calibrated economic game and the design in **Chapter 5** can bring all of these strands together and answer what cognitive mechanisms drive developing adolescent economic decision-making.

6.3 Limitations and suggestions for future research

The games designed for this research were limited to one-shot snapshots of adolescent economic decision-making due to issues of practicality, possibly affecting age trends that have been observed in past research. It was not possible to ask so many adolescent students to engage in repeated dyadic exchanges with fellow classmates. This kind of study would have required a greater investment of resources and time, both of which participating schools could not afford. It would be hugely beneficial if iterated economic games could be combined with directed and dyadic social tie measures to investigate the development of economic decision-making. This would allow researchers to track the baseline strength of a relationship prior to tracking the gameplay interaction between two players. Interactions between strategy and relationship strength may be observed over time through the course of the game. A design such as that used in **Chapter 5** would give researchers even more power to investigate both how adolescents play the games and how they think others will play the games in a true dyadic context.

We believe the Trust Game, iterated Prisoner's Dilemma, costly Dictator Game, and Ultimatum Game could potentially induce age trends in economic decision-making predicted by social network variables. The Trust Game has been reliably used to induce such age trends and we expect that in an age-diverse sample, social tie strength would predict trust and reciprocity to a greater extent in late (vs. early) adolescent networks (e.g. van den Bos et al., 2010; Lee, Jolles & Krabbendam, 2016). In an iterated Prisoner's Dilemma, participants tend to cooperate at a greater rate. This is in part due to the resource-maximising strategy in an iterated game being cooperation, as opposed to the one-shot Prisoner's Dilemma where it is defection (Rilling &

Sanfey, 2011). Participants are also more inclined to cooperate in conditions in which they have more information about the strategy of the other player, and know that their own choices will have consequences for their reputation (Cosmides & Tooby, 2005; Dijkstra & van Assen, 2016). We would anticipate participants in an iterated game to consider the consequences of their decisions more carefully, both in terms of strategy, but also in the context of the relationship, therefore making the game more suitable for answering this research question. As past research demonstrates, adults and adolescents do discriminate allocation in costly contexts (Burnett Heyes et al., 2015; Charness & Gneezy, 2008; Harrison, Sciberras & James, 2011). We suggest that in a costly context, the research paradigm described in **Chapter 5** would be more likely to induce an age trend, and therefore better discern whether such an age trend was driven by the improved capacity to *infer* or *use* social information. Finally, the Ultimatum Game could be a useful game for the study of increasing intentionality in children. Past research suggests that older children exhibit greater levels of disadvantageous inequity aversion than younger children, which was suggested to reflect participants increasingly incorporating intentionality into their decision-making (Bueno-Guerra, Leiva, Colell & Call, 2016). This game may also be suitable for social network methods, as research in adults suggests that social distance decreases sensitivity to fairness when participants either played for themselves or for others (Kim, Schnall, Yi & White, 2013). Therefore, we would expect to see late (vs. early) adolescents increasingly differentiate their rejection of unfair offers according to both their developing incorporation of intentionality and as a function of social distance.

In **Chapters 4** and **5,** we operationalise predictions of peer-ratings of relationship strength and resource allocation as reflecting perspective-taking capacity. However, it could be argued that these measures are poor proxies for perspective-taking and are more likely to reflect social reasoning or another form of submentalising (Heyes, 2014). For example, it may be the case that in order to accurately predict peer ratings or resource allocation the participant is not required to represent the mind of their peers at all, but may instead accurately reason what a given peer will do based on past interactions they have had with that peer. This is certainly a plausible explanation, but it is also plausible that adolescents do represent the minds of their peers when attempting to predict how strong their peers believe a shared relationship to be or how much hypothetical money a peer will give to the participant. It is certainly an assumption of much of the economic decision-making literature that players plan their moves based on what they think their competitors or collaborators are thinking in order to predict their strategy (Camerer, 2003; Sanfey, 2007). Past research makes this case in a variety of ways, including simply interpreting improvements in other-regarding decisions as being likely related to improving Theory of Mind, finding self-reported measures of perspective-taking to be significant within decision-making models, and inferring that Theory of Mind must have been used as Theory of Mind-associated areas of the brain were activated during gameplay (Güroğlu et al., 2014; Sanfey, 2007; van den Bos et al., 2010). Each of these interpretations has flaws: other-regarding behaviour may reflect social reasoning, self-reported measures may not be a reliable measure of 'true' Theory of Mind, and reverse inference is a problematic concept within fMRI studies (Poldrack, 2007).

Similarly, studies in **Chapters 4** and **5** may be flawed as they rely on a novel operationalisation of perspective-taking that relates predicted peer ratings and allocation to actual peer ratings and allocation in order to compute accuracy scores. These accuracy scores were hypothesised to reflect a process by which adolescents attempt to predict the beliefs and decisions of peers, which is assumed to be achieved through representing the mental states of peers. However, as with many studies that are considered 'true' Theory of Mind tests, it may be that prediction accuracy merely reflects another form of submentalising (Heyes, 2014). We acknowledge these alternative interpretations as being plausible and it is a difficult problem to disentangle. We hope for future clarity on this issue as researchers work to conceptualise the nature of Theory of Mind more effectively (Lockwood, Apps & Chang, 2020; Schaafsma, Pfaff, Spunt & Adolphs, 2015).

One final suggestion for future research is to investigate the neural correlates of economic decision-making in a dyadic social context. New innovations combining social network analysis and fMRI have produced compelling work. Recent research has shown that the brain encodes social network position (Parkinson, Kleinbaum & Wheatley, 2018a; Weaverdyck & Parkinson, 2018), and that friends share similar neural responses to the same stimuli (Parkinson, Kleinbaum & Wheatley, 2018b). The network neuroscience approach can be combined with the designs described in this thesis to investigate the neural correlates of dyadic social relationships both within the context of economic decision-making (e.g. Chapter 2; Chapter 3; Chapter 5) or relationship features more broadly (e.g. Chapter 4; Chapter 5) (Bassett & Sporns, 2017; Feldman-Hall, 2017).

6.4 Conclusion

This thesis addressed three questions: Do directed and dyadic social tie variables predict adolescent decision-making in economic games? If so, does the strength of this prediction alter with age? If so, what are the cognitive mechanisms driving this development? We found that directed and dyadic social tie variables were robust predictors of economic decision-making in the Trust Game, Prisoner's Dilemma, and Dictator Games. We found that the strength of this association altered with age in the Prisoner's Dilemma, and Dictator Game, but in the opposite of the hypothesised direction. We found that late adolescents more accurately predicted the strength of their dyadic social relationships than did early adolescents, but no evidence was obtained for a difference when predicting the allocative decisions of classmates in the Dictator Game (Figure 6.1.). This thesis advocates for the utility of the directed and dyadic social tie approach as a tool for understanding adolescent economic decision-making, and a potential framework for investigating the mechanisms that drive developing economic gameplay. It sharpens our understanding of the complex interplay between dyadic network features, individual differences, and economic gameplay. Most importantly, it demonstrates how much richer our analyses can be when we not only focus on the individuals that inhabit a network, but the connections between.

	Chapter 2 Trust Game	Chapter 3 Prisoner's Dilemma	Chapter 4 Relationship prediction	Chapter 5 Dictator Game
Dyadic variables [Q1]	✓	✓	N/A	✓
Age trend [Q2]	×	×	✓	×
Inference [Q3]	N/A	N/A	✓	×
Use [Q3]	N/A	N/A	N/A	×

Figure 6.1. Experiment outcomes in relation to our original research questions.

Appendix A

Glossary

Abbreviations	Measures
TG1	Trust Game – Trust Allocation (1st Phase)
TG2	Trust Game – Expected Reciprocity (2nd Phase)
SNQ-O	Social Network Questionnaire – Out-link Strength (Ego-rated social tie strength)
SNQ-R	Social Network Questionnaire – In-link Strength (Alter-rated social tie strength)
SNQ-I	Social Network Questionnaire – Relationship Reciprocation
KM	Kiddie Mach
IRI-EC	Interpersonal Reactivity Index – Empathic Concern
IRI-PT	Interpersonal Reactivity Index – Perspective-Taking
ECR-RC-ANX	Experiences in Close Relationships Revised Child Version - Anxious
ECR-RC-AV	Experiences in Close Relationships Revised Child Version - Avoidant

Table A1. Glossary of abbreviations.

Network Maps

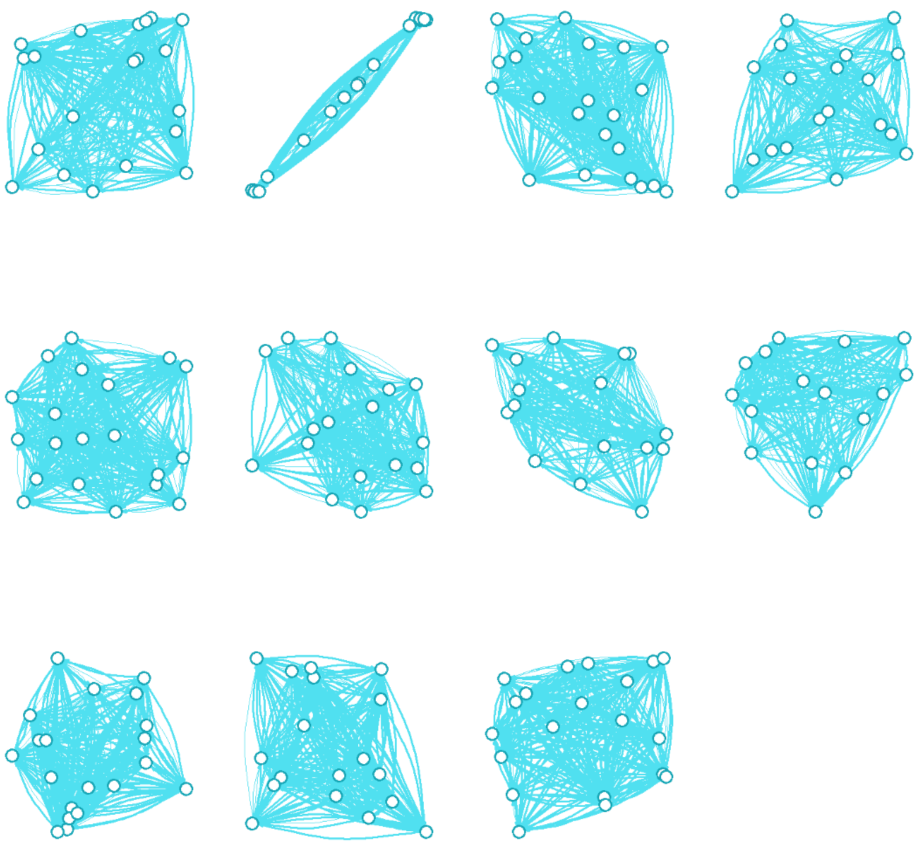


Figure A1. Classroom SNQ-O network maps.

Non-network descriptives

	Year 12A			Year 12B			Year 12C		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	16.47 (0.51)	16-17	19	16.44 (0.51)	16-17	16	16.44 (0.51)	16-17	16
FASII	6.53 (2.17)	2-9	19	7.94 (1.77)	8-9	16	7.94 (1.77)	8-9	16
ECR-RC-Anxiety	1.32 (.91)	1-5	18	1.78 (.95)	1-3.67	16	1.78 (.95)	1-3.67	16
ECR-RC-Avoidance	2.56 (1.80)	1-7	18	3.83 (1.63)	1.17-6.50	16	3.83 (1.63)	1.17-6.50	16
IRI-EC	28.47 (4.70)	20-35	19	26.50 (4.77)	13-33	16	26.5 (4.78)	13-33	16
IRI-PT	24.11 (5.06)	17-33	19	24 (6.00)	11-35	16	24 (6)	11-35	16
KM	69.71 (16.00)	50.8-117.8	19	52.83 (5.70)	42-64	16	52.83 (5.7)	42-64	12
Gender (female)			2			7			4
	Year 13A			**Year 13B**			**Year 13C**		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	17.46 (0.52)	17-18	13	17.20 (0.52)	17-19	20	17.17 (0.38)	17-18	18
FASII	6.54 (1.61)	3-8	13	7.25 (1.21)	6-9	12	7.42 (1.24)	5-9	12
ECR-RC-Anxiety	1.28 (.59)	1-2.8	13	6.85 (1.63)	6-10	13	7.36 (2.27)	6-12	14
ECR-RC-Avoidance	2.64 (2.02)	1-6.3	13	21.62 (3.30)	14-28	13	21.07 (4.36)	12-27	14
IRI-EC	27.00 (4.32)	22-35	13	25.36 (4.65)	13-32	14	26.79 (4.23)	19-35	14
IRI-PT	22.69 (5.81)	11-31	13	23.5 (5.85)	10-31	14	25.64 (5.15)	18-35	14
KM	53.62 (4.98)	46-61	13	80.71 (19.15)	49-131	14	73.68 (15.09)	45-97	14
Gender (female)			3			5			7
	Year 13D			**Year 13E**			**Year 13F**		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	17.29 (0.47)	17-18	17	17.25 (0.45)	17-18	16	17.25 (0.44)	17-18	20
FASII	7.18 (1.40)	5-9	11	7.64 (.92)	6-9	11	6.25 (1.66)	4-9	12
ECR-RC-Anxiety	10 (6.78)	6-26	14	6.25 (.45)	6-7	12	6.08 (.29)	6-7	12
ECR-RC-Avoidance	22.21 (4.17)	12-29	14	18.83 (5.27)	8-24	12	21 (4.57)	11-26	12
IRI-EC	26.07 (4.54)	16-31	15	23 (5.16)	12-29	11	25.88 (5.89)	15-35	17
IRI-PT	24.27 (4.85)	15-32	15	22.73 (5.16)	13-31	11	24.18 (5.10)	16-33	17
KM	77.46 (15.58)	57-113	15	74.32 (14.42)	50-93	12	82.38 (17.48)	55-116	15
Gender (female)			9			5			11

	Year 13G			13H		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	17.17 (0.38)	17-18	18	17.25 (0.44)	17-18	20
FASII	6.82 (1.40)	5-9	11	7.36 (1.03)	6-9	11
ECR-RC-Anxiety	10 (3.78)	6-16	9	8.29 (6.89)	6-32	14
ECR-RC-Avoidance	22.22 (4.97)	13-28	9	21.07 (6.17)	8-32	14
IRI-EC	22.55 (4.89)	10-29	11	26.5 (5.36)	19-35	14
IRI-PT	21.73 (6.17)	9-31	11	22.71 (3.54)	16-29	14
KM	75.66 (12.39)	58-97	11	78.26 (14.35)	53-105	13
Gender (female)			8			6

Table A2. Non-network descriptives for each classroom.

Network descriptives

	Year 12A			Year 12B			Year 12C		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
TG1	2.34 (.23)	0 - 5	380	2.67 (.15)	0 - 5	506	2.43 (.16)	0 - 5	342
TG2	3.59 (.44)	0 - 15	380	3.17 (.28)	0 - 15	506	3.84 (.49)	0 - 15	342
SNQ-O	1.42(0.18)	-3 - 7	380	1.07(0.22)	-3 - 7	506	0.99(0.17)	-3 - 7	342
SNQ-R	1.32(0.10)	0 - 6	380	1.79(0.22)	0 - 7	506	1.12(0.13)	0 - 7	342
	Year 13A			**Year 13B**			**Year 13C**		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
TG1	2.07 (.24)	0 - 5	420	2.01 (.28)	0 - 5	380	2.69 (.33)	0 - 5	306
TG2	2.67 (.35)	0 - 15	420	4.56 (.87)	0 - 15	380	6.08 (.90)	0 - 15	306
SNQ-O	0.73(0.18)	-3 - 7	420	0.74(0.14)	-2 - 7	380	0.74(0.17)	-3 - 7	306
SNQ-R	0.83(0.13)	0 - 7	420	0.83(0.13)	0 - 7	380	0.92(0.15)	0 - 7	306
	Year 13D			**Year 13E**			**Year 13F**		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
TG1	2.58 (.23)	0 - 5	272	2.40 (.38)	0 - 5	240	1.85 (.30)	0 - 5	380
TG2	6.69 (.80)	0 - 15	272	4.06 (.81)	0 - 15	240	6.12 (.74)	0 - 15	380
SNQ-O	0.79(0.18)	-3 - 7	272	0.64(0.18)	-3 - 7	240	0.70(0.18)	-3 - 7	380
SNQ-R	1.16(0.15)	0 - 7	272	1.49(0.19)	0 - 7	240	0.95(0.15)	0 - 7	380
	Year 13G			**13H**					
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**			
TG1	2.69 (.47)	0 - 5	306	1.92 (.32)	0 - 5	380			
TG2	4.96 (.91)	0 - 15	306	5.13 (.92)	0 - 15	380			
SNQ-O	0.51(0.14)	-3 - 7	306	0.61(0.16)	-3 - 7	380			
SNQ-R	0.60(0.14)	0 - 7	306	0.71(0.13)	0 - 7	380			

Table A3. Network descriptives for each classroom.

Single-network MRQAP models – Trust Allocation including Relationship Reciprocation

	Standardised regression coefficient	P value
	Year 12A	
MRQAP final model: R^2_{adj}=.68, *p* = < .001		
Intercept	1.65	.06
SNQ-O	2.53	< .001
KM (Ego)	-0.06	< .001
FAS (Ego)	-0.11	< .01
IRI-EC (Ego)	0.09	< .001
IRI-EC (Alter)	0.03	.02
ECRC1-ANX (Ego)	1.29	< .001
ECRC1-AV (Ego)	-0.38	< .001
Duration	0.04	.03
Gender (Ego)	1.36	< .001
	Year 12B	
MRQAP final model: R^2_{adj}=.53, p<.001		
Intercept	-6.52	< .001
SNQ-O	2.64	< .001
Recip	-0.77	.002
KM (Ego)	0.03	.002
KM (Alter)	0.04	.02
FAS (Ego)	0.14	.001
IRI-EC (Alter)	0.05	< .05
IRI-PT (Ego)	0.07	< .001
ECRC1-ANX (Ego)	0.36	.02
ECRC1-AV (Ego)	-0.19	< .001
Gender (Ego)	0.31	.04
	Year 12C	
MRQAP final model: R^2_{adj}=.56, p<.001		
Intercept	2.74	< .001
SNQ-O	8.51	< .001
Recip	-0.96	< .001
KM (Ego)	-0.02	.03
ECRC1-AV (Ego)	0.30	< .001
Gender (Alter)	-0.31	.03
	Year 13A	
MRQAP final model: R^2_{adj}=.71, p<.001		
Intercept	9.85	< .001
SNQ-O	2.90	< .001
KM (Ego)	-0.11	< .001
FAS (Ego)	-0.11	.002
IRI-EC (Ego)	-0.06	< .001

Duration	0.04	.03
Year 13B		
MRQAP final model: R^2_{adj}=.73, p<.001		
Intercept	-4.9	< .001
SNQ-O	3.59	< .001
KM (Ego)	0.10	< .001
KM (Alter)	-0.03	< .01
FAS (Ego)	0.22	.001
IRI-PT (Ego)	0.12	< .001
ECRC1-ANX (Ego)	-3.19	< .001
ECRC1-AV (Ego)	0.62	< .001
Gender (Ego)	-3.17	< .001
Year 13C		
MRQAP final model: R^2_{adj}=.57, p<.001		
Intercept	10.93	< .001
SNQ-O	2.35	< .001
FAS (Ego)	-0.72	< .001
IRI-PT (Ego)	-0.09	< .001
ECRC1-AV (Ego)	0.19	< .01
Gender (Ego)	-1.71	< .001
Gender (Alter)	-0.62	< .001
Year 13D		
MRQAP final model: R^2_{adj}=.70, p<.001		
Intercept	10.01	< .001
SNQ-O	3.86	< .001
KM (Ego)	0.07	< .05
FAS (Ego)	-0.65	< .001
IRI-EC (Ego)	-0.18	< .001
ECRC1-ANX (Ego)	-1.20	< .001
Gender (Alter)	-0.45	.01
Year 13E		
MRQAP final model: R^2_{adj}=.88, p<.001		
Intercept	-20.31	< .001
SNQ-O	3.35	< .001
FAS (Ego)	0.68	< .001
IRI-EC (Ego)	0.44	< .001
IRI-PT (Ego)	0.11	.001
IRI-PT (Alter)	0.04	.01
ECRC1-AV (Ego)	0.90	< .001
Duration	-0.12	.03
Gender (Ego)	1.41	< .001
Year 13F		
MRQAP final model: R^2_{adj}=.68, p=.08		

SNQ-O	2.83	< .001
Gender (Ego)	-2.64	< .01
	Year 13G	
MRQAP final model: R^2_{adj}=.69, p<.001		
Intercept	2.14	.04
SNQ-O	3.00	< .001
IRI-PT (Ego)	0.07	.04
Gender (Ego)	-2.63	< .001
	Year 13H	
MRQAP final model: R^2_{adj}=.87, p<.001		
Intercept	36.27	< .001
SNQ-O	3.61	< .001
KM (Ego)	-0.29	< .001
FAS (Ego)	-1.74	< .001
IRI-EC (Alter)	0.03	< .05
IRI-PT (Ego)	-0.75	< .001
ECRC1-ANX (Ego)	5.13	< .001
ECRC1-ANX (Alter)	-0.14	< .05
ECRC1-AV (Ego)	0.93	< .001
Gender (Ego)	2.37	< .001

Table A4. Single-classroom MRQAP models predicting Trust Allocation with network and non-network variables including Relationship Reciprocation.

Single-network MRQAP models – Trust Allocation including Alter-rated Social Tie Strength

	Standardised regression coefficient	**P value**
	Year 12A	
MRQAP final model: R^2_{adj} =.68, *p* = < .001		
Intercept	1.65	.064
SNQ-O	2.54	< .001
KM (Ego)	-0.06	< .001
FAS (Ego)	-0.11	.002
IRI-EC (Ego)	0.09	< .001
IRI-EC (Alter)	0.03	.02
ECRC1-ANX (Ego)	1.30	< .001
ECRC1-AV (Ego)	-0.38	< .001
Duration	0.04	.03
Gender (Ego)	1.36	< .001
	Year 12B	
MRQAP final model: R^2_{adj}=.53, p<.001		
Intercept	-6.52	< .001
SNQ-O	1.87	< .001

SNQ_I	0.77	< .01
KM (Ego)	0.03	.002
KM (Alter)	0.04	.02
FAS (Ego)	0.14	< .001
IRI-EC (Alter)	0.05	< .05
IRI-PT (Ego)	0.07	< .001
ECRC1-ANX (Ego)	0.36	.02
ECRC1-AV (Ego)	-0.19	< .001
Gender (Ego)	0.31	.04
Year 12C		
MRQAP final model: R^2_{adj}=.56, p<.001		
Intercept	2.73	< .001
SNQ-O	1.78	< .001
SNQ-I	0.96	< .001
KM (Ego)	-0.02	.03
ECRC1-AV (Ego)	0.30	< .001
Gender (Alter)	-0.31	.04
Year 13A		
MRQAP final model: R^2_{adj}=.70, p<.001		
Intercept	9.23	< .001
SNQ-O	2.88	< .001
KM (Ego)	-0.10	< .001
IRI-EC (Ego)	-0.08	< .001
Duration	0.06	.003
Year 13B		
MRQAP final model: R^2_{adj}=.73, p<.001		
Intercept	-4.91	< .001
SNQ-O	3.59	< .001
KM (Ego)	0.10	< .001
KM (Alter)	-0.03	< .01
FAS (Ego)	0.22	< .001
IRI-PT (Ego)	0.12	< .001
ECRC1-ANX (Ego)	-3.19	< .001
ECRC1-AV (Ego)	0.62	< .001
Gender (Ego)	-3.17	< .001
Year 13C		
MRQAP final model: R^2_{adj}=.57, p<.001		
Intercept	10.93	< .001
SNQ-O	2.35	< .001
FAS (Ego)	-0.72	< .001
IRI-PT (Ego)	-0.09	< .001
ECRC1-AV (Ego)	0.18	< .001
Gender (Ego)	-1.71	< .001

Gender (Alter)	-0.62	.002
Year 13D		
MRQAP final model: R^2_{adj}=.70, p<.001		
Intercept	10.00	< .001
SNQ-O	3.86	< .001
KM (Ego)	0.06	.03
FAS (Ego)	-0.65	< .001
IRI-EC (Ego)	-0.18	< .001
ECRC1-ANX (Ego)	-1.20	< .001
Gender (Alter)	-0.45	.02
Year 13E		
MRQAP final model: R^2_{adj}=.88, p<.001		
Intercept	-20.31	< .001
SNQ-O	3.35	< .001
FAS (Ego)	0.68	< .001
IRI-EC (Ego)	0.44	< .001
IRI-PT (Ego)	0.11	< .001
IRI-PT (Alter)	0.04	.02
ECRC1-AV (Ego)	0.90	< .001
Duration	-0.12	.03
Gender (Ego)	1.41	< .001
Year 13F		
MRQAP final model: R^2_{adj}=.68, p=.09		
SNQ-O	2.99	< .001
Gender (Ego)	-2.73	< .01
Year 13G		
MRQAP final model: R^2_{adj}=.68, p<.001		
Intercept	4.03	< .001
SNQ-O	2.99	< .001
Gender (Ego)	-2.74	< .001
Year 13H		
MRQAP final model: R^2_{adj}=.87, p<.001		
Intercept	36.27	< .001
SNQ-O	3.61	< .001
KM (Ego)	-0.29	< .001
FAS (Ego)	-1.75	< .001
IRI-EC (Alter)	0.03	< .05
IRI-PT (Ego)	-0.75	< .001
ECRC1-ANX (Ego)	5.12	< .001
ECRC1-ANX (Alter)	-0.14	< .05
ECRC1-AV (Ego)	0.93	< .001
Gender (Ego)	2.37	< .001

Table A5. Single-classroom MRQAP models predicting Trust Allocation with network and non-network variables including Alter-rated Social Tie Strength.

Single-network MRQAP models – Expected Reciprocity including Relationship Reciprocation

	Standardised regression coefficient	**P value**
	Year 12A (AD1)	
MRQAP final model: R^2_{adj} =.56, *p* = < .001		
Intercept	-4.28	< .001
SNQ-O	5.66	< .001
IRI-PT (Ego)	0.26	< .001
ECRC1-ANX (Ego)	0.57	< .001
	Year 12B (CK1)	
MRQAP final model: R^2_{adj}=.48, p<.001		
Intercept	-0.05	.97
SNQ-O	5.25	< .001
SNQ-R	-1.87	< .001
KM (Ego)	0.04	.03
FAS (Ego)	0.26	.001
ECRC1-AV (Ego)	-0.73	< .001
Gender (Ego)	-0.67	.01
	Year 12C (CK2)	
MRQAP final model: R^2_{adj}=.55, p<.001		
Intercept	-7.03	.002
SNQ-O	13.40	< .001
SNQ-R	-1.26	< .05
FAS (Ego)	0.56	< .001
IRI-PT (Ego)	0.10	< .001
ECRC1-ANX (Ego)	-1.45	< .001
ECRC1-AV (Ego)	1.27	< .001
	Year 13A (AD2)	
MRQAP final model: R^2_{adj}=.57, p<.001		
Intercept	8.32	< .001
SNQ-O	3.98	< .001
KM (Ego)	-0.07	< .001
FAS (Ego)	-0.31	< .001
Gender (Ego)	-1.38	< .001
	Year 13B (JK1)	
MRQAP final model: R^2_{adj}=.74, p<.001		
Intercept	-23.14	< .001
SNQ-O	7.16	< .001

SNQ-R	-3.70	< .01
KM (Ego)	0.33	< .001
KM (Alter)	-0.11	< .001
FAS (Ego)	1.13	< .001
IRI-PT (Ego)	0.49	< .001
ECRC1-ANX (Ego)	-11.60	< .001
ECRC1-AV (Ego)	2.55	< .001
Gender (Ego)	-11.27	< .001
	Year 13C (JK2)	
MRQAP final model: R^2_{adj}=.56, p<.001		
Intercept	8.94	.20
SNQ-O	8.90	< .001
KM (Ego)	-0.48	< .001
FAS (Ego)	-1.57	< .001
IRI-EC (Ego)	2.11	< .001
IRI-PT (Ego)	-1.62	< .001
ECRC1-ANX (Ego)	13.26	< .001
ECRC1-AV (Ego)	4.06	< .001
Gender (Ego)	-10.77	< .001
Gender (Alter)	-1.51	.005
	Year 13D (JK3)	
MRQAP final model: R^2_{adj}=.60, p<.001		
Intercept	24.30	< .001
SNQ-O	10.64	< .001
KM (Ego)	0.44	< .001
FAS (Ego)	-2.40	< .001
IRI-EC (Ego)	-0.62	< .001
ECRC1-ANX (Ego)	-5.79	< .001
Gender (Alter)	-1.81	< .01
	Year 13E (JK4)	
MRQAP final model: R^2_{adj}=.71, p<.001		
Intercept	15.94	< .001
SNQ-O	8.11	< .001
IRI-EC (Ego)	-0.39	.001
IRI-PT (Ego)	-0.11	.02
Gender (Ego)	-1.61	.004
	Year 13F (JK5)	
MRQAP final model: R^2_{adj}=.17, p=.06		
Intercept	-3.82	<.001
SNQ-O	5.17	<.001
KM (Alter)	0.11	.01
IRI-PT (Alter)	0.09	.03
	Year 13G (JK6)	

MRQAP final model: R^2_{adj}=.43, p<.001		
Intercept	-10.03	< .001
SNQ-O	5.16	< .001
IRI-PT (Ego)	0.44	< .001
ECRC1-ANX (Ego)	1.46	.003
	Year 13H (JK7)	
MRQAP final model: R^2_{adj}=.86, p<.001		
Intercept	125.94	< .001
SNQ-O	11.06	< .001
KM (Ego)	-0.98	< .001
FAS (Ego)	-4.28	< .001
IRI-PT (Ego)	-2.70	< .001
ECRC1-ANX (Ego)	8.04	< .001
ECRC1-AV (Ego)	3.09	< .001
Gender (Ego)	4.87	< .001

Table A6. Single-classroom MRQAP models predicting Trust Allocation with network and non-network variables including Relationship Reciprocation.

Single-network MRQAP models – Expected Reciprocity including Relationship Reciprocation

	Standardised regression coefficient	**P value**
	Year 12A (AD1)	
MRQAP final model: R^2_{adj} =.56, p = < .001		
Intercept	-4.93	< .001
SNQ-O	5.66	< .001
FAS (Ego)	0.14	.04
IRI-PT (Ego)	0.25	< .001
ECRC1-ANX (Ego)	0.45	.004
	Year 12B (CK1)	
MRQAP final model: R^2_{adj}=.48, p<.001		
Intercept	-0.05	0.96
SNQ-O	3.39	< .001
SNQ-I	1.86	< .001
KM (Ego)	0.05	.03
FAS (Ego)	0.26	< .001
ECRC1-AV (Ego)	-0.74	< .001
Gender (Ego)	-0.68	.03
	Year 12C (CK2)	
MRQAP final model: R^2_{adj}=.55, p<.001		
Intercept	-9.22	< .001
SNQ-O	4.50	< .001
SNQ-I	1.35	< .05

FAS (Ego)	0.54	< .001
IRI-EC (Alter)	0.08	.03
IRI-PT (Ego)	0.09	.002
ECRC1-ANX (Ego)	-1.48	< .001
ECRC1-AV (Ego)	1.27	< .001
Year 13A (AD2)		
MRQAP final model: R^2_{adj}=.58, p<.001		
Intercept	8.32	< .001
SNQ-O	3.98	< .001
KM (Ego)	-0.07	.002
FAS (Ego)	-0.31	< .001
Gender (Ego)	-1.38	< .001
Year 13B (JK1)		
MRQAP final model: R^2_{adj}=.74, p<.001		
Intercept	-23.14	< .001
SNQ-O	3.46	< .01
SNQ-I	3.70	< .01
KM (Ego)	0.33	< .001
KM (Alter)	-0.11	< .001
FAS (Ego)	1.12	< .001
IRI-PT (Ego)	0.49	< .001
ECRC1-ANX (Ego)	-11.60	< .001
ECRC1-AV (Ego)	2.55	< .001
Gender (Ego)	-11.26	< .001
Year 13C (JK2)		
MRQAP final model: R^2_{adj}=.56, p<.001		
Intercept	8.94	0.20
SNQ-O	8.90	< .001
KM (Ego)	-0.48	< .001
FAS (Ego)	-1.56	< .001
IRI-EC (Ego)	2.11	< .001
IRI-PT (Ego)	-1.61	< .001
ECRC1-ANX (Ego)	13.26	< .001
ECRC1-AV (Ego)	4.06	< .001
Gender (Ego)	-10.77	< .001
Gender (Alter)	-1.51	.02
Year 13D (JK3)		
MRQAP final model: R^2_{adj}=.60, p<.001		
Intercept	24.30	< .001
SNQ-O	10.64	< .001
KM (Ego)	0.44	< .001
FAS (Ego)	-2.39	< .001
IRI-EC (Ego)	-0.63	< .001

ECRC1-ANX (Ego)	-5.79	< .001
Gender (Alter)	-1.81	.02
	Year 13E (JK4)	
MRQAP final model: R^2_{adj}=.70, p<.001		
Intercept	15.94	< .001
SNQ-O	8.11	< .001
IRI-EC (Ego)	-0.39	< .001
IRI-PT (Ego)	-0.11	.02
Gender (Ego)	-1.61	.002
	Year 13F (JK5)	
MRQAP final model: R^2_{adj}=.17, p=.06		
Intercept	-3.82	<.001
SNQ-O	5.17	<.001
KM (Alter)	0.11	.01
IRI-PT (Alter)	0.09	.05
	Year 13G (JK6)	
MRQAP final model: R^2_{adj}=.42, p<.001		
Intercept	-10.03	< .001
SNQ-O	5.16	< .001
IRI-PT (Ego)	0.44	< .001
ECRC1-ANX (Ego)	1.46	.004
	Year 13H (JK7)	
MRQAP final model: R^2_{adj}=.86, p<.001		
Intercept	125.93	< .001
SNQ-O	11.06	< .001
KM (Ego)	-0.97	< .001
FAS (Ego)	-4.27	< .001
IRI-PT (Ego)	-2.69	< .001
ECRC1-ANX (Ego)	8.04	< .001
ECRC1-AV (Ego)	3.09	< .001
Gender (Ego)	4.87	< .001

Table A7. Single-classroom MRQAP models predicting Trust Allocation with network and non-network variables including Alter-rated Social Tie Strength.

MG-MRQAP models – Trust Allocation including Alter-rated Social Tie Strength

Independent Variable	Unstandardized Regression Coefficient	*p* value
MG-MRQAP model		
R^2_{adj} = .46, p < .001		
Ego-rated social tie strength	3.02	< .001
Alter IRI-EC	0.02	.02

Table A8. Trust Allocation MG-MRQAP model including Alter-rated Social Tie Strength.

Note. Class intercepts for the model were: Year 12A (b = 1.30, p <.001), 12B (b = -0.27, p = .24), 12C (b = 0.52, p = .55), 13A (b = 0.35, p = .83), 13B (b = -0.03, p = .94), 13C (b = 0.51, p = .64), 13D (b = 0.27, p = .84), 13E (b = 0.37, p = .92), 13F (b = -0.37, p = .80), 13G (b = 0.51, p = .54), 13H (b = -0.24, p = .64). Independent variables eliminated due - non-significance were Avoidant Attachment alter (b = -0.01, p = 0.50), Perspective-taking alter (b = 0.01, p = 0.50), Empathic Concern giving (b = 0.01, p = 0.43), Gender giving (b = 0.05, p = 0.44), Anxious Attachment receiving (b = -0.02, p = 0.38), Family Affluence receiving (b = -0.01, p = 0.42), Avoidant Attachment giving (b = -0.02, p = 0.42), Family Affluence giving (b = 0.04, p = 0.34), Machiavellianism giving (b = -0.01, p = 0.36), Anxious Attachment giving (b = 0.08, p = 0.35), Gender receiving (b = -0.05, p = 0.36), Machiavellianism receiving (b = -0.01, p = 0.20), Relationship Duration (b = 0.02, p = 0.22), Perspective-taking giving (b = 0.02, p = 0.11), and Alter-rated Social Tie Strength (b = 0.26, p = 0.14).

MG-MRQAP models – Expected Reciprocity including Alter-rated Social Tie Strength

Independent Variable	Unstandardized Regression Coefficient	*p* value
MG-MRQAP model		
R^2_{adj} = .38, $p < .001$		
Ego-rated social tie strength	5.63	< .001
Alter-rated social tie strength	1.16	< .01
Alter IRI-EC	0.04	.02

Table A9. Expected Reciprocity MG-MRQAP model including Alter-rated social tie strength.

Note. Class intercepts for the model were: Year 12A (*b* = 2.08, *p* .007), 12B (*b* = 1.08, *p* = .80), 12C (*b* = -0.61, *p* = .27), 13A (*b* = 0.43, *p* = .52), 13B (*b* = -1.58, *p* = .03), 13C (*b* = 2.62, *p* = .61), 13D (*b* = 2.78, *p* = .50), 13E (*b* = 0.36, *p* = .70), 13F (*b* = 1.00, *p* = .21), 13G (*b* = 1.37, *p* = .57), 13H (*b* = 2.49, *p* = .77). Independent variables eliminated due - non-significance were Relationship Duration (*b* = 0.01, *p* = 0.49), Empathic Concern giving (*b* = -0.01, *p* = 0.51), Machiavellianism giving (*b* = -0.01, *p* = 0.49), Family Affluence receiving (*b* = 0.02, *p* = 0.51), Avoidant Attachment alter (*b* = -0.02, *p* = 0.39), Anxious Attachment giving (*b* = -0.24, *p* = 0.34), Avoidant Attachment ego (*b* = 0.06, *p* = 0.38), Perspective-taking alter (*b* = -0.02, *p* = 0.27), Anxious Attachment receiving (*b* = 0.04, *p* = 0.26), Machiavellianism receiving (*b* = -0.01, *p* = 0.17), Gender giving (*b* = -0.54, *p* = 0.16), Perspective-taking giving (*b* = 0.07, *p* = 0.11), Gender receiving (*b* = -0.33, *p* = 0.08), and Family Affluence giving (*b* = 0.24, *p* = 0.07).

Modified Trust Game Comprehension Control

A control task that required participants - calculate how much hypothetical money they would have trusted their classmate with following the tripling of their original stake was used - ensure that participants understood the mTG paradigm. Across the entire sample, participants correctly calculated the total amount trusted on 97% of occasions (*range* = 89% - 100%).

Class	Percent Correct Calculations
Year 12A	89%
Year 12B	97%
Year 12C	99%
Year 13A	97%
Year 13B	97%
Year 13C	100%
Year 13D	99%
Year 13E	100%
Year 13F	99%
Year 13G	98%
Year 13H	99%
Entire Sample	97%

Table A10. Percent correct investment calculation by classroom network.

QAP correlations

Classroom	SNQ-R	SNQ-I
Year 12A	0.34	0.79
Year 12B	0.56	0.35
Year 12C	0.56	0.66
Year 13A	0.50	0.71
Year 13B	0.54	0.86
Year 13C	0.62	0.71
Year 13D	0.54	0.84
Year 13E	0.72	0.65
Year 13F	0.64	0.75
Year 13G	0.73	0.90
Year 13H	0.60	0.82

Table A11. Correlations between SNQ-O and SNQ-R/SNQ-I variables.

Appendix B

Glossary

Abbreviations	Measures
CD	Cooperation decisions
SNQ-O	Social Network Questionnaire – Out-link Strength (Ego-rated social tie strength)
SNQ-R	Social Network Questionnaire – In-link Strength (Alter-rated social tie strength)
SNQ-I	Social Network Questionnaire – Relationship Reciprocation
KM	Kiddie Mach
FAS-II	Family Affluence Scale II
SVO-E	Social Value Orientation - Egoistic
SVO-P	Social Value Orientation - Prosocial
SVO-C	Social Value Orientation - Competitor

Table B1. Glossary of abbreviations.

Network maps

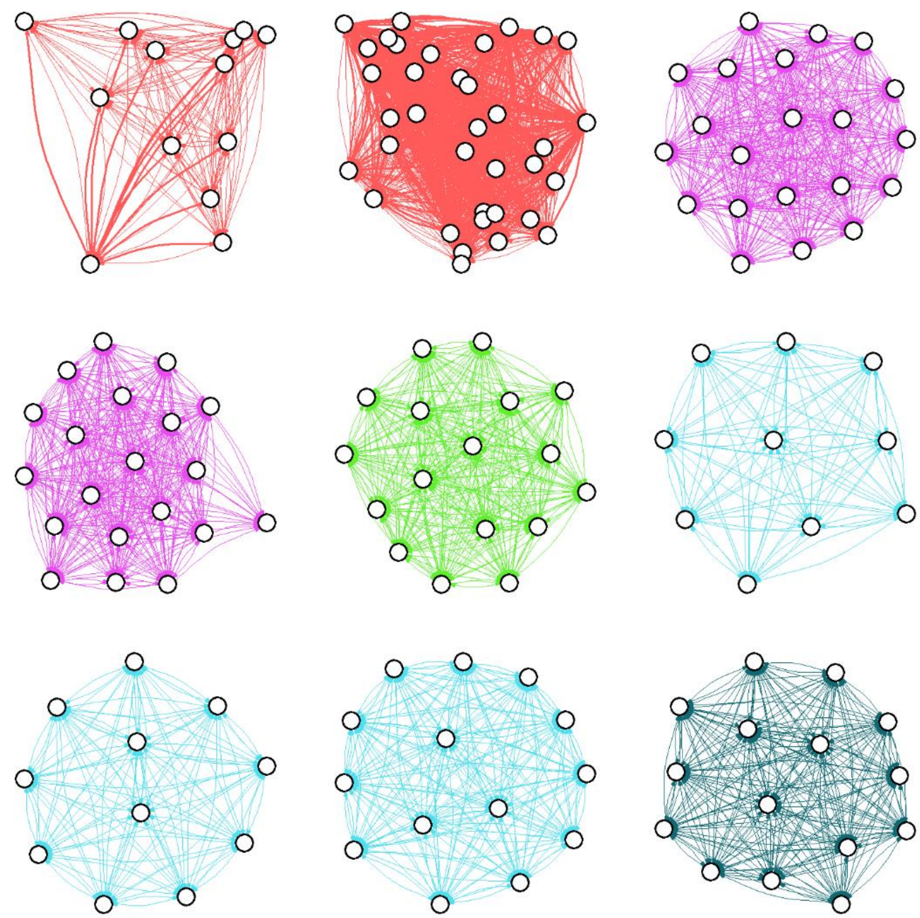


Figure B1. Classroom SNQ-O network maps (Red: Year 9; Purple: Year 10; Green: Year 11; Light blue: Year 12; Dark blue: Year13).

Non-network descriptives

	Year 9A			Year 9B			Year 10A		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	13.30(0.49)	13 – 14	13	13.34(0.46)	13 – 14	36	14.30(0.46)	14 – 15	21
FASII	5.92(3.13)	0 - 9	13	7.57(1.44)	8 - 9	36	6.57(2.89)	0 - 9	21
KM	53.54(16.82)	20 - 69	13	61(8.29)	46 - 83	36	61.48(7.73)	47 - 78	21
SVO-E			1			3			2
SVO-P			5			11			9
SVO-C			2			9			2
Gender (female)			13			36			21
	Year 10B			**Year 11A**			**Year 12A**		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	14.30(0.47)	14 – 15	20	15.20(0.39)	15 – 16	17	16.00(0.00)	16	10
FASII	7.20(1.63)	7 - 9	20	6.65(1.45)	6 - 9	17	8.70(1.49)	6 - 9	10
KM	53.9(13.84)	20 - 69	20	56.35(6.96)	47 - 72	17	55.80(4.04)	47 - 63	10
SVO-E			2			0			2
SVO-P			14			9			2
SVO-C			0			4			4
Gender (female)			20			12			6
	Year 12B			**Year 12C**			**Year 13A**		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	16.10(0.33)	16 – 17	11	16.6(0.63)	16 – 17	14	17.10(0.36)	17 – 18	15
FASII	8.09(1.73)	8 - 9	11	7.86(1.46)	8 - 9	14	8.47(1.89)	7 - 9	15
KM	57.54(4.79)	52 - 67	11	50.64(15.21)	22 - 63	14	55.20(7.63)	41 - 72	15
SVO-E			1			2			1
SVO-P			4			5			10
SVO-C			3			4			1
Gender (female)			9			11			15

Table B2. Non-network descriptives for each classroom.

https://drive.google.com/file/d/11KlOnrAMr27cHzglJPMVkmza9A-77Im9/view?usp=sharing

Figure B2. Prisoner's Dilemma video.

Network descriptive

	Year 9A			Year 9B			Year 10A		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
CD	5.89(0.98)	0 - 9	169	5.68(0.64)	0 - 9	1296	8.35(0.54)	0 - 11	441
SNQ-O	2.44(0.33)	-2 – 6	169	0.64(0.11)	-3 – 7	1296	1.84(0.17)	-3 – 7	441
SNQ-R	1.07(0.18)	0 – 4	169	0.68(0.11)	0 – 7	1296	1.44(0.11)	0 – 7	441
Duration	2.23(0.28)	0 - 9	169	0.94(0.11)	0 - 9	1296	3.06(0.15)	0 - 11	441
	Year 10B			**Year 11A**			**Year 12A**		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
CD	7.81(0.72)	1 - 14	400	6.11(0.78)	1 - 15	289	4.01(0.85)	1 - 13	100
SNQ-O	2.12(0.24)	-3 – 6	400	2.22(0.22)	-1 – 7	289	2.66(0.27)	-1 – 7	100
SNQ-R	2.24(0.42)	0 – 7	400	1.31(0.09)	0 – 5	289	1.22(0.18)	0 – 5	100
Duration	3.44(0.19)	1 - 14	400	3.76(0.41)	1 - 15	289	4.68(0.68)	1 – 13	100
	Year 12B			**Year 12C**			**Year 13A**		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
CD	4.27(0.89)	0 - 12	121	6.89(0.87)	0 - 14	196	5.46(0.70)	0 - 7	225
SNQ-O	1.95(0.25)	-1 – 5	121	1.55(0.12)	0 – 5	196	1.89(0.19)	0 – 6	225
SNQ-R	0.94(0.16)	0 – 3	121	0.67(0.08)	0 – 2	196	1.05(0.12)	0 – 4	225
Duration	1.52(0.38)	0 - 12	121	1.25(0.26)	0 - 14	196	1.17(0.29)	0 - 7	225

Table B3. Network descriptives for each classroom.

MRQAP models – Including Relationship Reciprocation

	Unstandardised regression coefficient	P value
	Year 9A	
MRQAP final model: R^2_{adj}=.25, *p* = < .001		
Intercept	33.27	< .001
SNQ-R	-12.33	< .001
KM (Ego)	-0.25	.002
SVO-P (Ego)	-4.61	< .001
SVO-C (Alter)	2.78	.03
	Year 9B	
MRQAP final model: R^2_{adj}=.04, p<.001		
Intercept	9.61	< .001
SNQ-R	-4.15	< .001
SVO-C (Ego)	2.09	< .001
	Year 10A	
MRQAP final model: R^2_{adj}=.02, p=.03		
Intercept	11.53	<.001
SNQ-O	-2.86	.03
	Year 10B	
MRQAP final model: R^2_{adj}=.09, p<.001		
Intercept	15.11	<.001
SNQ-O	-6.60	<.001
SNQ-R	3.01	<.001
	Year 11A	
MRQAP final model: R^2_{adj}=.09, p<.01		
Intercept	16.71	< .001
SNQ-R	-11.69	< .001
SVO-C (Ego)	3.73	.03
Duration	-0.41	< .01
	Year 12A	
MRQAP final model: R^2_{adj}=.57, p<.001		
Intercept	9.73	< .001
SNQ-R	-4.96	.005
	Year 12B	
MRQAP final model: R^2_{adj}=.01, p=.03		
Intercept	3.91	<.001
Gender (Alter)	1.98	.03
	Year 12C	
MRQAP final model: R^2_{adj}=.43, p<.001		
Intercept	21.32	<.001
SNQ-O	-8.13	<.001
KM (Ego)	-0.10	.02

SVO-P (Ego)	-4.40	<.01
Gender (Ego)	4.88	.01
Year 12D		
MRQAP final model: R^2_{adj}=.03, p<.05		
Intercept	9.75	< .001
SNQ-R	-5.43	.02

Table B4. Single-classroom MRQAP models predicting cooperation with network and non-network variables including Relationship Reciprocation.

MRQAP models – Including Alter-rated Social Tie Strength

	Unstandardised regression coefficient	**P value**
Year 9A		
MRQAP final model: R^2_{adj} =.24, *p* = < .001		
Intercept	33.27	< .001
SNQ-O	-12.33	< .001
KM (Ego)	-0.25	< .001
SVO-P (Ego)	-4.61	< .001
SVO-C (Alter)	2.77	.03
Year 9B		
MRQAP final model: R^2_{adj}=.04, p<.001		
Intercept	9.61	< .001
SNQ-O	-4.15	< .001
SVO-C (Ego)	2.09	< .001
Year 10A		
MRQAP final model: R^2_{adj}=.02, p<.05		
Intercept	10.95	< .001
SNQ-O	-3.35	.03
Year 10B		
MRQAP final model: R^2_{adj}=.10, p<.001		
Intercept	15.11	<.001
SNQ-O	-3.59	.03
SNQ-I	-3.00	<.001
Year 11A		
MRQAP final model: R^2_{adj}=.35, p<.001		
Intercept	3.32	.59
SNQ-O	-10.43	< .001
FAS (Ego)	1.21	< .05
SVO-C (Ego)	5.16	< .01
Duration	-0.39	< .01
Year 12A		

MRQAP final model: R^2_{adj}=.09, p<.01		
Intercept	9.73	< .001
SNQ-O	-4.96	< .01
	Year 12B	
MRQAP final model: R^2_{adj}=.02, p<.05		
Intercept	3.91	<.001
Gender (Alter)	1.98	.03
	Year 12C	
MRQAP final model: R^2_{adj}=.03, p<.01		
Intercept	9.75	< .001
SNQ-O	-5.43	.03
	Year 13A	
MRQAP final model: R^2_{adj}=.09, p=.01		
Intercept	10.68	<.001
SNQ-O	-2.91	.03
SVO-P (Ego)	-2.90	.03

Table B5. Single-classroom MRQAP models predicting cooperation with network and non-network variables including Alter-rated Social Tie Strength.

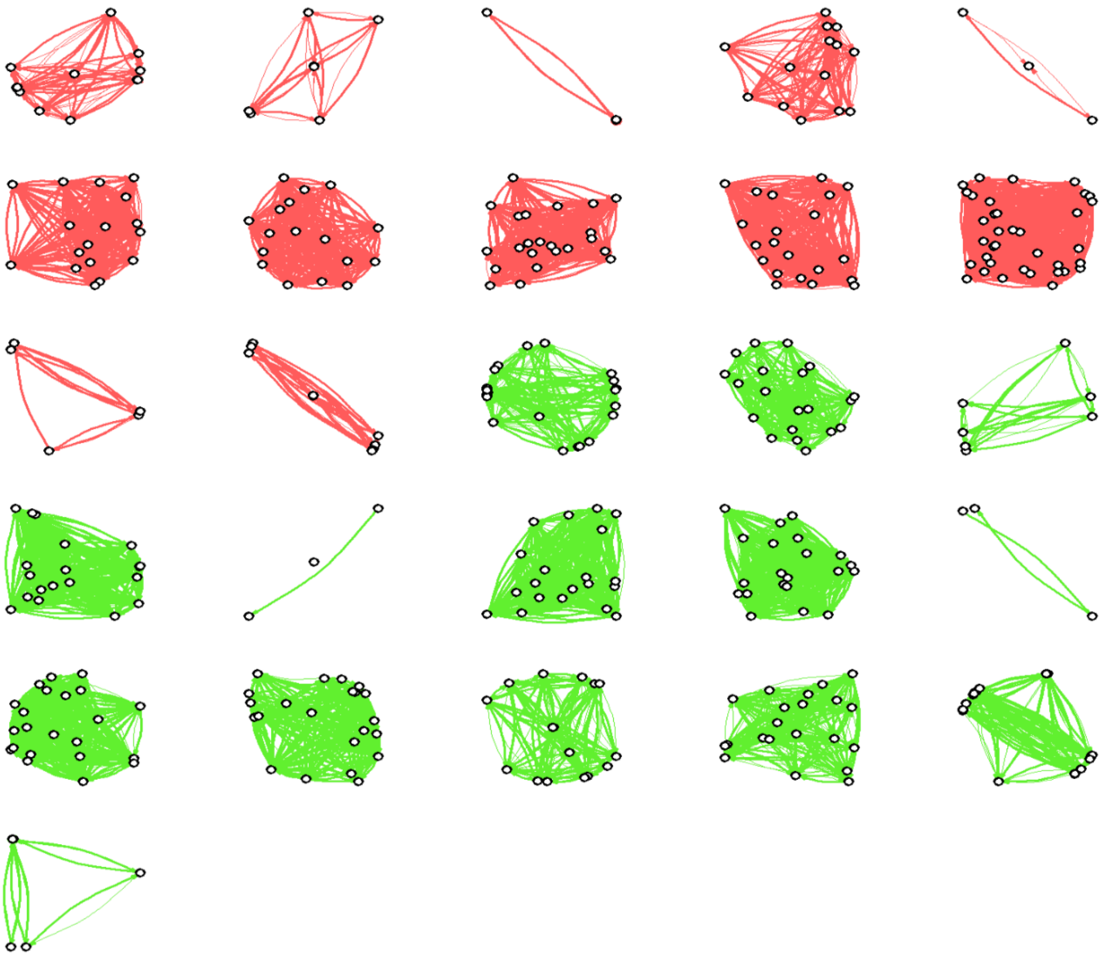
QAP correlations

Classroom	SNQ-R	SNQ-I
Year 9A	0.42	0.63
Year 9B	0.41	0.66
Year 10A	0.53	0.42
Year 10B	0.62	0.21
Year 11A	0.46	0.56
Year 12A	0.39	0.68
Year 12B	0.49	0.50
Year 12C	0.42	0.63
Year 13A	0.46	0.57

Table B6. Correlations between SNQ-O and SNQ-R/SNQ-I variables.

Appendix C

Network maps



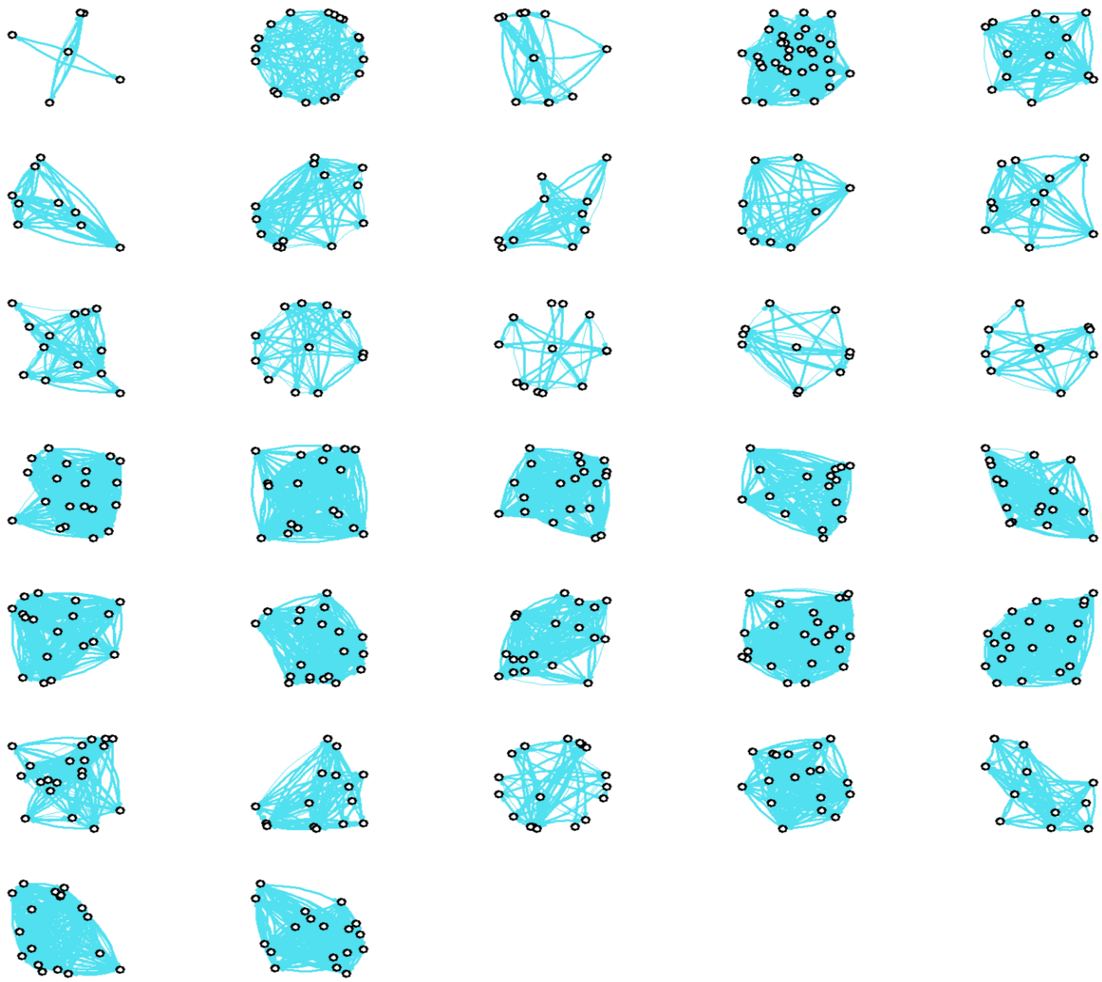


Figure C1. Classroom network maps (SNQ-O/alter-rated).

ANOVA – Year Groups

The ANOVA revealed that there was a significant difference between year groups, $F(715) = 50.22$, $p < .001$, $\eta2 = 0.35$.

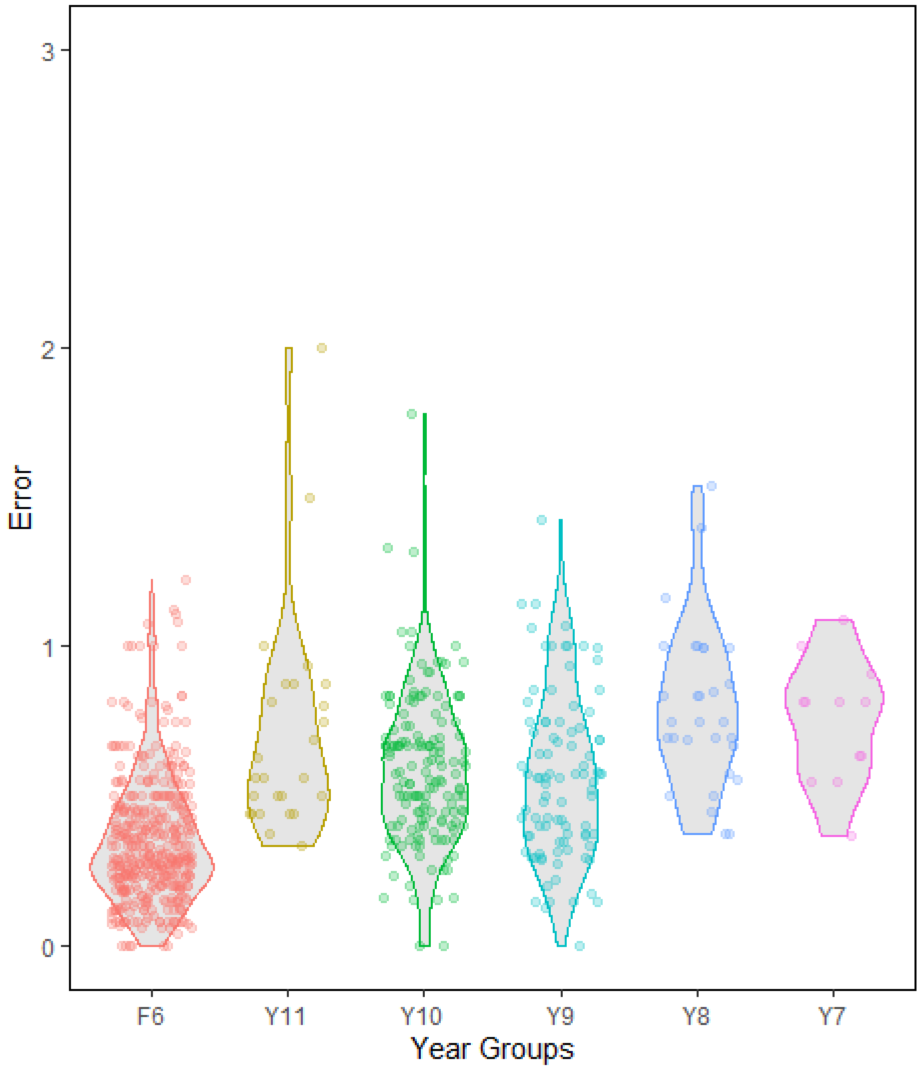


Figure C2. Plot of the distribution of perceived vs actual alter relationship difference scores in all year groups. A jitter was applied to each group to improve transparency.

Appendix D

Glossary

Abbreviations	Measures
DG1	1st person Dictator Game
DG2	2nd person Dictator Game
SNQ-O	Social Network Questionnaire – Out-link Strength (Ego-rated social tie strength)
SNQ-R	Social Network Questionnaire – In-link Strength (Alter-rated social tie strength)
SNQ-I	Social Network Questionnaire – Relationship Reciprocation
KM	Kiddie Mach
IRI-EC	Interpersonal Reactivity Index – Empathic Concern
IRI-PT	Interpersonal Reactivity Index – Perspective-taking
BF	Best Friend Nominations
LOTR	Revised Life Orientation Test

Table D1. Glossary of abbreviations.

Network maps

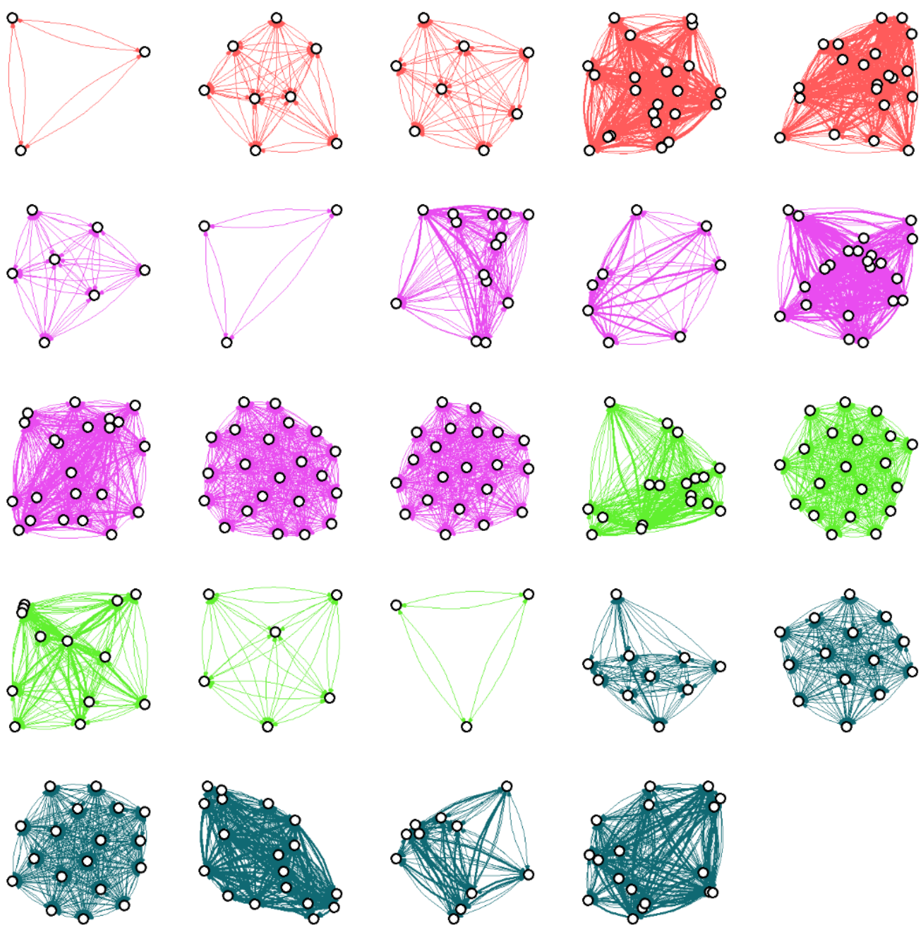


Figure D1. Classroom SNQ-O network maps (Red: Year 9; Purple: Year 10; Green: Year 11; Dark blue: Year 12/13).

Non-network age group comparisons

There was no significant difference between age groups in Kiddie Mach scores ($F(3,272) = 1.81$, $p = .14$).

There was a significant difference between age groups in Revised Life Orientation Test scores ($F(3,276) = 9.44$, $p = <.001$). Post-hoc tests (Tukey HSD) revealed that there were significant differences between Year 12/13 and Years 9 (*diff* = -1.84; $p < .05$), 10 (*diff* = -1.94; $p < .01$); as well as Year 11 and Years 9 (*diff* = -2.39; $p < .01$), and 10 (*diff* = -3.95; $p < .001$).

There was also a significant difference between age groups in Empathic Concern scores ($F(3,272) = 13.66$, $p = <.001$). Post-hoc tests (Tukey HSD) revealed that there were significant differences between Year 12/13 and Years 9 (*diff* = 2.68; $p < .001$), 10 (*diff* = 2.25; $p < .001$), and 11 (*diff* = 4.14; $p < .001$); as well as Year 11 and 10 (*diff* = -1.88; $p < .05$).

There was a significant difference between age groups in Perspective-taking scores ($F(3,280) = 11.05$, $p = <.001$). Post-hoc tests (Tukey HSD) revealed that there were significant differences between Year 12/13 and Years 9 (*diff* = 2.84; $p < .001$), 10 (*diff* = 1.68; $p < .05$), and 11 (*diff* = 3.66; $p < .001$); as well as Year 11 and Year 10 (*diff* = -1.97; $p < .05$).

Chi-square tests revealed a significant difference between age groups in gender distributions $X^2(3, N = 292) = 24.13$, $p < .001$). Post-hoc tests revealed a significant difference between Year 12/13 and Years 9, 10, and 11; as well as a difference between Year 10 and 9. In both cases, Years 12/13 and 10 had a lower number of best friend nominations than in comparison groups.

Non-network descriptives

	Year 9A			Year 9B			Year 9C		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	13.00(0.00)	13	3	12.57(0.53)	12 – 13	8	12.75(0.50)	12 – 13	8
KM	47.00(5.19)	41 – 53	3	54.42(6.86)	43 – 66	8	51.66(10.56)	33 – 68	8
LOTR_OPT	10.33(1.32)	9 – 12	3	8.00(1.16)	7 – 10	8	9.42(2.34)	6 – 12	8
IRI-EC	23.16(1.63)	21 – 24.5	3	22.00(3.06)	16 – 26	8	21.33(3.28)	18 – 28	8
IRI-PT	20.00(3.12)	17 – 24	3	20.87(3.50)	16 – 26	8	21.83(3.42)	15 – 26	8
BF			4			15			15
Gender (female)			1			7			5
	Year 9D			**Year 9E**			**Year 10A**		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	12.35(0.49)	12 – 13	23	12.40(0.50)	12 – 13	21	13.75(0.5)	13 – 14	7
KM	55.38(8.75)	40 – 71	23	59.58(11.58)	44 – 80	21	53.59(12.89)	34 – 78	7
LOTR_OPT	12.76(3.10)	7 – 18	23	12.07(3.36)	5 – 16	21	9.67(1.51)	7 – 12	7
IRI-EC	24.03(3.99)	18 – 31	23	25.75(4.17)	18 – 33	21	19.25(2.73)	15 – 23	7
IRI-PT	20.86(4.02)	14 – 30	23	21.25(3.82)	13 – 27	21	23.17(2.77)	19 – 27	7
BF			27			25			5
Gender (female)			7			9			1
	Year 10B			**Year 10C**			**Year 10D**		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	14.00(0.00)	14	3	13.90(0.53)	13 – 15	14	13.71(0.48)	13 – 14	8
KM	55.66(5.76)	50 – 63	3	57.10(6.91)	47 – 71	14	53.57(7.47)	46 – 65	8
LOTR_OPT	10.33(0.50)	10 – 11	3	9.85(2.10)	6 – 14	14	10.28(1.03)	8 – 11	8
IRI-EC	23.33(1.32)	22 – 25	3	21.03(1.93)	18 – 24	14	???(1.66)	20 – 25	8
IRI-PT	19.66(1.00)	19 – 21	3	21.64(1.99)	18 – 25	14	20.62(3.14)	16 – 25	8
BF			1			11			3
Gender (female)			1			8			4

	Year 10E			Year 10F			Year 10G		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	13.50(0.51)	13 – 14	22	13.50(0.51)	13 – 14	22	13.42(0.50)	13 – 14	22
KM	54.58(7.01)	43 – 66	22	56.80(8.69)	44 – 79	22	54.82(7.38)	42 – 67	22
LOTR_OPT	11.58(4.41)	2 – 18	22	11.83(4.15)	2 – 21	22	12.37(3.25)	6 – 19	22
IRI-EC	25.15(1.87)	23 – 30	22	23.44(3.99)	15 – 31	22	26.82(3.13)	21 – 33	22
IRI-PT	22.61(3.65)	16 – 29	22	21.97(3.98)	12 – 31	22	24.30(4.01)	18 – 33	22
BF			20			22			24
Gender (female)			6			4			6

	Year 10H			Year 11A			Year 11B		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	13.30(0.47)	13 – 14	21	14.92(0.47)	14 – 15	18	15.00(0.56)	14 – 16	20
KM	56.11(7.31)	38 – 68	21	58.05(9.09)	43 – 74	18	58.15(7.20)	46 – 71	20
LOTR_OPT	12.10(4.18)	6 – 19	21	8.83(2.03)	5 – 13	18	9.15(2.08)	5 – 13	20
IRI-EC	25.75(3.82)	18 – 33	21	22.00(1.79)	18 – 26	18	22.25(2.53)	16 – 27	20
IRI-PT	21.15(4.96)	12 – 31	21	20.88(2.13)	16 – 24	18	20.75(2.77)	15 – 26	20
BF			12			31			19
Gender (female)			4			10			10

	Year 11C			Year 11D			Year 11E		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	15.10(0.56)	14 – 16	13	15.35(0.24)	15 – 15.5	6	14.33(0.57)	14 – 15	3
KM	61.50(11.67)	38 – 78	13	57.08(2.96)	51 – 59	6	52.00(1.73)	50 – 54	3
LOTR_OPT	9.38(3.18)	5 – 14	13	7.83(2.89)	3 – 12	6	7.33(2.64)	4 – 10	3
IRI-EC	22.92(2.71)	16 – 28	13	22.16(0.91)	21 – 23	6	22.66(1.00)	22 – 24	3
IRI-PT	18.69(2.67)	14 – 24	13	20.00(1.75)	17 – 22	6	20.00(0.86)	19 – 21	3
BF			17			9			1
Gender (female)			6			7			2

	Year 12A			Year 12B			Year 12C		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	17.20(0.63)	16 – 18	10	16.42(0.51)	16 – 17	14	16.17(0.39)	16 – 17	18
KM	56.30(23.05)	43 – 66	10	52.28(5.45)	44 – 63	14	53.77(7.65)	44 – 73	18
LOTR_OPT	9.22(1.69)	7 – 12	10	7.28(1.83)	4 – 11	14	7.61(2.24)	4 – 13	18
IRI-EC	23.90(6.77)	9 – 34	10	28.07(3.04)	21 – 32	14	25.27(4.41)	13 – 33	18
IRI-PT	20.80(5.57)	12 – 29	10	24.14(4.40)	16 – 35	14	23.16(3.08)	15 – 28	18
BF			7			6			10
Gender (female)			2			14			18
	Year 12D			**Year 12E**			**Year 13A**		
	M (SD)	**Range**	**N**	**M (SD)**	**Range**	**N**	**M (SD)**	**Range**	**N**
Age	17.00(0.47)	16 – 18	18	16.66(0.51)	16 – 17	11	16.85(0.36)	16 – 17	18
KM	57.00(6.74)	45 – 65	18	54.81(8.38)	42 – 68	11	56.57(6.69)	46 – 74	18
LOTR_OPT	13.68(3.72)	5 – 19	18	11.50(3.48)	7 – 19	11	9.57(5.11)	2 – 21	18
IRI-EC	26.41(2.78)	21 – 31	18	26.25(3.17)	21 – 32	11	28.42(4.14)	18 – 34	18
IRI-PT	25.91(4.69)	15 – 35	18	24.12(4.39)	16 – 31	11	24.92(4.52)	16 – 30	18
BF			8			1			9
Gender (female)			9			4			12

Table D2. Non-network descriptives for each classroom.

Network descriptives

	Year 9A			Year 9B			Year 9C		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
DG1	5.50(3.45)	0 – 15	9	5.92(1.41)	0 – 50	64	6.60(1.23)	0. – 50	64
DG2	4.66(2.68)	0 – 10	9	16.82(6.18)	0 – 70	64	5.83(0.92)	0 – 35	64
SNQ-O	3.00(1.23)	0 – 6	9	2.64(0.61)	-3 – 7	64	2.51(0.57)	-3 – 7	64
SNQ-R	1.33(0.55)	0 – 2	9	1.82(0.34)	0 – 6	64	1.60(0.33)	0 – 7	64
Duration	1.16(0.41)	0 – 2	9	2.21(0.55)	1 – 10	64	1.85(0.42)	0 – 9	64
	Year 9D			**Year 9E**			**Year 10A**		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
DG1	3.42(0.46)	0 – 25	529	3.60(0.49)	0 – 40	441	6.11(1.02)	0 – 20	49
DG2	2.53(0.41)	0 – 20	529	2.86(0.51)	0 – 70	441	3.42(1.05)	0 – 12	49
SNQ-O	1.31(0.19)	-3 – 7	529	1.55(0.25)	-3 – 7	441	2.88(0.70)	-2 – 6	49
SNQ-R	0.95(0.17)	0 – 8	529	0.96(0.20)	0 – 7	441	0.90(0.15)	0 – 3	49
Duration	0.93(0.19)	0 – 10	529	1.46(0.21)	0 – 12	441	1.71(0.45)	0.5 – 7	49
	Year 10B			**Year 10C**			**Year 10D**		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
DG1	3.33(1.46)	0 – 5	9	4.99(0.65)	0 – 35	196	5.00(0.91)	0 – 20	64
DG2	2.50(1.49)	0 – 5	9	4.58(0.78)	0 – 40	196	12.57(5.80)	0 – 90	64
SNQ-O	1.16(1.03)	-2 – 4	9	1.17(0.30)	-3 – 7	196	1.25(0.45)	-3 – 7	64
SNQ-R	0.66(0.29)	0 – 1	9	1.04(0.19)	0 – 5	196	1.46(0.40)	0 – 5	64
Duration	1.00(0.00)	1 – 1	9	1.91(0.52)	0.5 – 11	196	0.67(0.21)	0 – 3	64
	Year 10E			**Year 10F**			**Year 10G**		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
DG1	3.11(0.56)	0 – 50	484	3.61(0.54)	0 – 70	484	4.16(0.53)	0 – 75	484
DG2	2.79(0.51)	0 – 40	484	3.09(0.46)	0 – 100	484	3.35(0.59)	0 – 90	484
SNQ-O	1.30(0.22)	-3 – 7	484	1.94(0.26)	-3 – 7	484	1.81(0.19)	-3 – 7	484
SNQ-R	0.64(0.14)	0 – 5	484	1.40(0.16)	0 – 7	484	1.54(0.14)	0 – 7	484
Duration	1.07(0.22)	0.25 – 11	484	1.39(0.23)	0 – 11	484	1.70(0.28)	0.5 – 13	484

	Year 10H			Year 11A			Year 11B		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
DG1	4.75(0.50)	0 – 50	441	4.49(0.52)	0 – 80	324	4.38(0.66)	0 – 100	400
DG2	3.86(0.54)	0 – 50	441	8.42(4.00)	0 – 100	324	4.94(0.80)	0 – 50	400
SNQ-O	1.85(0.20)	-3 – 7	441	2.20(0.27)	-3 – 7	324	1.99(0.20)	-3 – 7	400
SNQ-R	1.71(0.11)	0 – 7	441	1.32(0.16)	0 – 5	324	1.73(0.11)	0 – 7	400
Duration	1.00(0.21)	0 – 13	441	2.30(0.24)	1 – 11	324	2.29(0.19)	1 – 15	400
	Year 11C			**Year 11D**			**Year 11E**		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
DG1	3.94(0.43)	0 – 30	169	5.76(1.81)	0 – 40	36	9.00(1.75)	5 – 12.5	9
DG2	3.30(0.52)	0 – 40	169	4.90(1.12)	0 – 20	36	10.00(1.68)	5 – 15	9
SNQ-O	1.58(0.30)	-3 – 7	169	2.33(0.59)	-2 – 7	36	0.83(0.69)	-1 – 3	9
SNQ-R	1.82(0.29)	0 – 7	169	1.60(0.29)	0 – 3.5	36	2.66(0.58)	2 – 4	9
Duration	1.91(0.36)	1 – 12	169	1.40(0.25)	1 – 3	36	1.33(0.28)	1 – 2	9
	Year 12A			**Year 12B**			**Year 12C**		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
DG1	4.98(1.06)	0 – 40	100	6.34(0.52)	0 – 30	196	5.35(0.38)	0 – 40	324
DG2	5.52(0.88)	0 – 25	100	4.86(0.59)	0 – 40	196	4.22(0.38)	0 – 30	324
SNQ-O	1.63(0.41)	-3 – 7	100	1.49(0.26)	-2 – 7	196	1.70(0.19)	-3 – 7	324
SNQ-R	1.62(0.21)	0 – 5	100	1.13(0.13)	0 – 6	196	1.11(0.09)	0 – 5	324
Duration	1.93(0.33)	0 – 7	100	2.24(0.41)	0 – 6	196	2.51(0.37)	0 – 13	324
	Year 12D			**Year 12E**			**Year 13A**		
	Density M (SEM)	**Range**	**N**	**Density M (SEM)**	**Range**	**N**	**Density M (SEM)**	**Range**	**N**
DG1	3.71(0.72)	0 – 30	324	7.00(1.37)	11.11 – 12.50	121	4.39(0.73)	0 – 100	324
DG2	2.44(0.49)	0 – 30	324	5.44(1.32)	0 – 12.5	121	3.27(0.67)	0 – 100	324
SNQ-O	0.84(0.19)	-3 – 7	324	0.90(0.30)	-3 – 7	121	0.78(0.16)	-3 – 7	324
SNQ-R	0.54(0.13)	0 – 3	324	2.12(0.28)	0 – 7	121	0.76(0.16)	0 – 6	324
Duration	1.25(0.26)	0 – 16	324	1.74(0.44)	1 – 9	121	1.63(0.36)	0 – 14	324

Table D3. Network descriptives for each classroom.

MRQAP models – 1st Person Dictator Game (DG1) Including Relationship Reciprocation

	Unstandardised regression coefficient	P value
Year 9A		
MRQAP final model: R^2_{adj} =.n.s., *p* = n.s.		
Year 9B		
MRQAP final model: R^2_{adj}=.11, p<.01		
Intercept	-0.12	0.94
SNQ-O	0.78	< .001
Year 9C		
MRQAP final model: R^2_{adj}=.28, p<.001		
Intercept	2.29	0.21
SNQ-O	0.88	< .001
SNQ-R	-1.22	.02
BF (Alter)	-0.78	.02
Year 9D		
MRQAP final model: R^2_{adj}=.51, p<.001		
Intercept	3.32	0.29
SNQ-O	1.29	< .001
SNQ-R	-0.22	.04
KM (Ego)	0.09	< .001
IRI-PT (Alter)	-0.37	< .001
BF (Alter)	-0.65	.02
Year 9E		
MRQAP final model: R^2_{adj}=.n.s., p = n.s.		
Year 10A		
MRQAP final model: R^2_{adj}=.34, p<.001		
Intercept	5.35	.002
SNQ-O	0.91	< .001
SNQ-R	-0.30	.006
IRI-EC (Ego)	-0.20	< .001
Gender (Alter)	1.17	.04
Year 10B		
MRQAP final model: R^2_{adj}=.54, p<.001		
Intercept	-1.02	0.42
SNQ-O	0.88	< .001
SNQ-R	-0.96	< .001
Year 10C		
MRQAP final model: R^2_{adj}=.52, p<.001		
Intercept	0.18	0.82
SNQ-O	1.35	< .001
SNQ-R	-0.50	< .001

BF (Ego)	-1.07	.003
Duration	-0.31	.01
Gender (Alter)	-2.58	< .01
Year 10D		
MRQAP final model: R^2_{adj}=n.s., p = n.s.		
Year 10E		
MRQAP final model: R^2_{adj}=.23, p<.001		
Intercept	-0.80	0.43
SNQ-O	1.45	< .001
Year 10F		
MRQAP final model: R^2_{adj}=.36, p<.001		
Intercept	-2.35	< .001
SNQ-O	1.45	< .001
Year 10G		
MRQAP final model: R^2_{adj}=.20, p<.001		
Intercept	-0.86	0.20
SNQ-O	1.33	< .001
Year 10H		
MRQAP final model: R^2_{adj}=.31, p<.001		
Intercept	8.03	.05
SNQ-O	1.28	< .001
KM (Ego)	-0.17	< .01
IRI-PT (Alter)	0.17	.02
Gender (Ego)	-3.49	< .001
Year 11A		
MRQAP final model: R^2_{adj}=.21, p<.001		
Intercept	-10.45	< .001
SNQ-O	0.91	< .001
SNQ-R	-0.43	.006
KM (Alter)	0.08	.02
LOTR (Alter)	0.47	.003
Year 11B		
MRQAP final model: R^2_{adj}=.14, p<.001		
Intercept	-2.65	.06
SNQ-O	1.10	< .001
SNQ-R	-0.47	< .001
Year 11C		
MRQAP final model: R^2_{adj}=.31, p<.001		
Intercept	3.85	.07
SNQ-O	0.79	< .001
SNQ-R	-0.26	< .01
IRI-PT (Alter)	-0.21	.03
Duration	-0.37	.02

Year 11D		
MRQAP final model: R^2_{adj}=.40, p<.001		
Intercept	29.92	.07
SNQ-O	1.32	.002
IRI-EC (Ego)	-1.45	< .05
BF (Ego)	-0.94	.03
Year 11E		
MRQAP final model: R^2_{adj}=.34, p<.001		
Intercept	-8.01	< .01
SNQ-O	1.07	< .001
SNQ-R	-0.79	< .01
IRI-PT (Alter)	0.33	< .01
Year 12A		
MRQAP final model: R^2_{adj}=.27, p<.001		
Intercept	9.33	1.00
SNQ-O	0.79	< .001
SNQ-R	-0.23	< .001
KM (Ego)	-0.06	< .001
KM (Alter)	0.02	< .001
IRI-EC (Ego)	-0.04	< .001
IRI-EC (Alter)	-0.01	< .001
IRI-PT (Ego)	0.01	< .001
IRI-PT (Alter)	-0.02	< .001
BF (Ego)	0.46	< .001
BF (Alter)	-0.17	< .001
LOTR (Ego)	-0.38	< .001
LOTR (Alter)	0.01	< .001
Duration	-0.13	< .001
Year 12B		
MRQAP final model: R^2_{adj}=.33, p<.001		
Intercept	-3.98	1.00
SNQ-O	0.92	< .001
SNQ-R	-0.18	< .001
KM (Ego)	0.03	< .001
KM (Alter)	0.04	< .001
IRI-EC (Ego)	-0.02	< .001
IRI-EC (Alter)	0.01	< .001
IRI-PT (Ego)	-0.10	< .001
IRI-PT (Alter)	0.12	< .001
BF (Ego)	0.55	< .001
BF (Alter)	-0.54	< .001
LOTR (Ego)	0.04	< .001
LOTR (Alter)	-0.12	< .001

Duration	-0.02	< .001
Year 12C		
MRQAP final model: R^2_{adj}=n.s., p = n.s.		
Year 12D		
MRQAP final model: R^2_{adj}=.30, p<.001		
Intercept	9.03	< .001
SNQ-O	1.10	< .001
IRI-PT (Ego)	-0.29	.03
Gender (Ego)	3.12	< .01
Year 12E		
MRQAP final model: R^2_{adj}=.99, p<.001		
Intercept	14.57	< .001
KM (Ego)	-0.07	< .001
IRI-EC (Ego)	-0.01	< .001
IRI-PT (Ego)	0.02	< .001
LOTR (Ego)	0.14	< .001
Gender (Ego)	-0.31	< .001
Year 13A		
MRQAP final model: R^2_{adj}=.29, p<.001		
Intercept	-1.13	.23
SNQ-O	2.18	< .001
SNQ-R	-0.75	.04

Table D4. Single-classroom DG1 MRQAP models predicting cooperation with network and non-network variables including Relationship Reciprocation.

MRQAP models – 1st Person Dictator Game (DG1) Including Alter-rated Social Tie Strength

	Unstandardised regression coefficient	P value
	Year 9A	
MRQAP final model: R^2_{adj}=n.s., p = n.s.		
	Year 9B	
MRQAP final model: R^2_{adj}=.13, p<.01		
Intercept	0.01	1.00
SNQ-O	1.10	< .001
	Year 9C	
MRQAP final model: R^2_{adj}=.23, p<.001		
Intercept	1.33	.36
SNQ-I	1.04	<.001
	Year 9D	
MRQAP final model: R^2_{adj}=.51, p<.001		
Intercept	3.32	.29
SNQ-O	1.02	<.001
SNQ-I	0.27	.03
KM (Ego)	0.09	.004
IRI-PT (Alter)	-0.37	.003
BF (Alter)	-0.65	.02
Gender (Alter)	-2.39	<.001
	Year 9E	
MRQAP final model: R^2_{adj}=.34, p<.001		
Intercept	5.35	.003
SNQ-O	0.61	<.001
SNQ-R	0.30	<.01
IRI-EC (Ego)	-0.20	.002
Gender (Alter)	1.17	<.05
	Year 10A	
MRQAP final model: R^2_{adj}=.79, p<.001		
Intercept	29.20	.02
SNQ-I	0.80	<.001
IRI-EC (Ego)	-0.17	.02
IRI-EC (Alter)	-0.58	.03
IRI-PT (Alter)	-0.58	.02
Duration	0.36	.02
Gender (Alter)	-1.64	.03
	Year 10B	
MRQAP final model: R^2_{adj}= n.s., p = n.s.		
	Year 10C	
MRQAP final model: R^2_{adj}=.13, p<.001		
Intercept	-3.43	.11

SNQ-O	0.82	<.001
LOTR (Alter)	0.47	.02
Year 10D		
MRQAP final model: R^2_{adj}= n.s., p = n.s.		
Year 10E		
MRQAP final model: R^2_{adj}=.23, p<.001		
Intercept	-0.80	.44
SNQ-O	1.45	<.001
Year 10F		
MRQAP final model: R^2_{adj}=.36, p<.001		
Intercept	-2.35	.003
SNQ-O	1.45	<.001
Year 10G		
MRQAP final model: R^2_{adj}=.20, p<.001		
Intercept	-0.86	.21
SNQ-O	1.33	<.001
Year 10H		
MRQAP final model: R^2_{adj}=.31, p<.001		
Intercept	8.03	<.05
SNQ-O	1.28	<.001
KM (Ego)	-0.17	<.001
IRI-PT (Alter)	0.17	.01
Gender (Ego)	-3.49	<.001
Year 11A		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
Year 11B		
MRQAP final model: R^2_{adj}=.14, p<.001		
Intercept	-2.26	.10
SNQ-O	0.84	<.001
SNQ-I	0.61	<.001
Year 11C		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
Year 11D		
MRQAP final model: R^2_{adj}=.33, p<.001		
Intercept	-3.23	.22
SNQ-O	1.74	<.001
Year 11E		
MRQAP final model: R^2_{adj}=.34, p<.001		
Intercept	-7.13	<.01
SNQ-O	0.83	<.01
SNQ-I	0.64	.03
IRI-PT (Alter)	0.30	.003
Year 12A		

MRQAP final model: R^2_{adj}=.23, p<.001		
Intercept	9.97	1.00
SNQ-O	0.58	<.001
SNQ-I	0.36	<.001
KM (Ego)	-0.06	<.001
KM (Alter)	0.01	<.001
IRI-EC (Ego)	-0.02	<.001
IRI-EC (Alter)	-0.01	<.001
IRI-PT (Ego)	-0.01	<.001
IRI-PT (Alter)	-0.02	<.001
BF (Ego)	0.36	<.001
BF (Alter)	-0.15	<.001
LOTR (Ego)	-0.31	<.001
LOTR (Alter)	-0.02	<.001
Duration	-0.07	<.001
	Year 12B	
MRQAP final model: R^2_{adj}=.32, p<.001		
Intercept	-4.31	1.00
SNQ-O	0.93	<.001
SNQ-I	0.26	<.001
KM (Ego)	0.04	<.001
KM (Alter)	0.05	<.001
IRI-EC (Ego)	-0.03	<.001
IRI-EC (Alter)	0.01	<.001
IRI-PT (Ego)	-0.10	<.001
IRI-PT (Alter)	0.13	<.001
BF (Ego)	0.54	<.001
BF (Alter)	-0.52	<.001
LOTR (Ego)	0.03	<.001
LOTR (Alter)	-0.13	<.001
Duration	-0.02	<.001
	Year 12C	
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
	Year 12D	
MRQAP final model: R^2_{adj}=.30, p<.001		
Intercept	9.03	<.01
SNQ-O	1.10	<.001
IRI-PT (Ego)	-0.29	.03
Gender (Ego)	3.12	.003
	Year 12E	
MRQAP final model: R^2_{adj}=.99, p<.001		
Intercept	14.57	<.001
KM (Ego)	-0.07	<.001

IRI-EC (Ego)	-0.01	<.001
IRI-PT (Ego)	0.02	<.001
LOTR (Ego)	0.14	<.001
Gender (Ego)	-0.31	<.001
Year 13A		
MRQAP final model: R^2_{adj}=.29, p<.001		
Intercept	-1.13	.22
SNQ-O	1.42	<.001
SNQ-I	0.75	.03

Table D5. Single-classroom DG1 MRQAP models predicting cooperation with network and non-network variables including Alter-rated Social Tie Strength.

MRQAP models – 2nd Person Dictator Game (DG2) Including Relationship Reciprocation

	Unstandardised regression coefficient	**P value**
Year 9A		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
Year 9B		
MRQAP final model: R^2_{adj}=.71, p<.001		
Intercept	2816.84	< .001
IRI-EC (Ego)	-30.77	< .001
IRI-PT (Ego)	-59.54	< .001
BF (Ego)	-29.02	< .001
LOTR (Ego)	-103.22	< .001
Gender (Ego)	-42.96	< .001
Year 9C		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
Year 9D		
MRQAP final model: R^2_{adj}=.40, p<.001		
Intercept	-4.86	< .001
SNQ-O	0.98	< .001
KM (Ego)	0.07	< .001
Year 9E		
MRQAP final model: R^2_{adj}=.18, p<.001		
Intercept	-5.11	.07
SNQ-O	1.06	< .001
SNQ-R	-0.42	.03
KM (Ego)	0.10	.02
BF (Ego)	-0.88	< .01
Year 10A		
MRQAP final model: R^2_{adj}=.56, p<.001		
Intercept	-1.86	.13
SNQ-O	0.76	< .001
Year 10B		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
Year 10C		
MRQAP final model: R^2_{adj}=.46, p<.001		
Intercept	-12.10	< .001
SNQ-O	1.18	< .001
SNQ-R	-0.39	< .001
LOTR (Ego)	0.52	.02
LOTR (Alter)	0.50	.04
Duration	-0.35	.03
Year 10D		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		

Year 10E		
MRQAP final model: R^2_{adj}=.47, p<.001		
Intercept	-8.92	.28
SNQ-O	1.82	< .001
KM (Ego)	-0.20	.04
IRI-EC (Ego)	1.10	< .01
IRI-PT (Alter)	-0.35	.03
Duration	-1.53	< .001
Year 10F		
MRQAP final model: R^2_{adj}=.45, p<.001		
Intercept	0.12	.92
SNQ-O	1.43	< .001
SNQ-R	-0.41	< .01
IRI-PT (Alter)	-0.22	< .001
BF (Ego)	0.65	.02
Gender (Ego)	2.53	< .001
Year 10G		
MRQAP final model: R^2_{adj}=.40, p<.001		
Intercept	-35.22	< .001
SNQ-O	1.32	< .001
SNQ-R	-0.37	< .01
KM (Ego)	0.33	< .001
IRI-PT (Ego)	0.56	< .001
Duration	0.37	.04
Year 10H		
MRQAP final model: R^2_{adj}=.37, p<.001		
Intercept	12.45	< .001
SNQ-O	1.42	< .001
SNQ-R	-0.54	< .001
KM (Ego)	-0.17	< .001
LOTR (Alter)	-0.15	.04
Gender (Ego)	-3.75	< .001
Gender (Alter)	-1.84	< .01
Year 11A		
MRQAP final model: R^2_{adj}=.34, p<.001		
Intercept	-3.40	< .001
SNQ-O	0.77	< .001
SNQ-R	-0.35	< .001
Duration	0.41	< .01
Year 11B		
MRQAP final model: R^2_{adj}=.49, p<.001		
Intercept	-7.51	.04
SNQ-O	1.50	< .001
SNQ-R	-0.55	< .001

KM (Ego)	-0.16	< .01
IRI-EC (Ego)	0.38	.02
BF (Ego)	-0.77	.02
LOTR (Ego)	0.51	< .01
Year 11C		
MRQAP final model: R^2_{adj}=.28, p<.001		
Intercept	-9.53	.02
SNQ-O	0.80	< .001
SNQ-R	-0.39	< .001
KM (Ego)	0.12	< .001
IRI-EC (Ego)	0.41	.03
LOTR (Ego)	-0.74	< .001
Gender (Ego)	-4.63	< .001
Year 11D		
MRQAP final model: R^2_{adj}=.45, p<.001		
Intercept	39.24	.04
SNQ-O	0.49	.04
IRI-EC (Ego)	-1.64	< .05
BF (Ego)	-0.99	< .05
Year 11E		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
Year 12A		
MRQAP final model: R^2_{adj}=.52, p<.001		
Intercept	-36.91	< .001
SNQ-O	1.13	< .001
KM (Ego)	0.28	< .001
IRI-EC (Ego)	0.26	< .001
LOTR (Ego)	0.98	< .01
Gender (Ego)	8.81	< .001
Year 12B		
MRQAP final model: R^2_{adj}=.32, p<.001		
Intercept	4.54	1.00
SNQ-O	0.78	< .001
SNQ-R	-0.10	< .001
KM (Ego)	-0.12	< .001
KM (Alter)	0.08	< .001
IRI-EC (Ego)	0.02	< .001
IRI-EC (Alter)	-0.16	< .001
IRI-PT (Ego)	0.15	< .001
IRI-PT (Alter)	0.03	< .001
BF (Ego)	-0.20	< .001
BF (Alter)	-0.69	< .001
LOTR (Ego)	-0.57	< .001
LOTR (Alter)	0.17	< .001

Duration	0.15	< .001
Year 12C		
MRQAP final model: R^2_{adj}=.44, p<.001		
Intercept	-6.50	1.00
SNQ-O	0.81	< .001
SNQ-R	-0.26	< .001
KM (Ego)	-0.03	< .001
KM (Alter)	0.06	< .001
IRI-EC (Ego)	-0.01	< .001
IRI-EC (Alter)	0.02	< .001
IRI-PT (Ego)	0.12	< .001
IRI-PT (Alter)	0.12	< .001
BF (Ego)	1.10	< .001
BF (Alter)	-0.40	< .001
LOTR (Ego)	-0.14	< .001
LOTR (Alter)	-0.12	< .001
Duration	0.01	< .001
Year 12D		
MRQAP final model: R^2_{adj}=.44, p<.001		
Intercept	0.99	.06
SNQ-O	1.01	< .001
Year 12E		
MRQAP final model: R^2_{adj}=.92, p<.001		
Intercept	-0.26	.95
SNQ-R	0.32	< .01
IRI-EC (Ego)	1.14	< .001
IRI-PT (Ego)	-0.77	< .001
BF (Ego)	4.98	< .001
LOTR (Ego)	0.39	< .001
Gender (Ego)	-9.48	< .001
Year 13A		
MRQAP final model: R^2_{adj}=.27, p<.001		
Intercept	-2.46	.10
SNQ-O	2.25	<.001
SNQ-R	-1.10	<.001

Table D6. Single-classroom DG2 MRQAP models predicting cooperation with network and non-network variables including Relationship Reciprocation.

MRQAP models – 2nd Person Dictator Game (DG2) Including Alter-rated Social Tie Strength

	Unstandardised regression coefficient	**P value**
Year 9A		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
Year 9B		
MRQAP final model: R^2_{adj}=.71, p<.001		
Intercept	2816.84	<.001
IRI-EC (Ego)	-30.77	<.001
IRI-PT (Ego)	-59.54	<.001
BF (Ego)	-29.02	<.001
LOTR (Ego)	-103.22	<.001
Gender (Ego)	-42.96	<.001
Year 9C		
MRQAP final model: R^2_{adj}=.57, p<.001		
Intercept	23.20	<.01
SNQ-O	0.84	<.001
IRI-PT (Ego)	-0.86	<.01
BF (Ego)	9.38	<.001
Gender (Ego)	-29.48	.002
Year 9D		
MRQAP final model: R^2_{adj}=.40, p<.001		
Intercept	-4.86	<.001
SNQ-I	0.98	<.001
KM (Ego)	0.07	<.001
Year 9E		
MRQAP final model: R^2_{adj}=.18, p<.001		
Intercept	-5.11	.06
SNQ-O	0.63	<.001
SNQ-I	0.42	.04
KM (Ego)	0.10	.01
BF (Ego)	-0.86	.01
Year 10A		
MRQAP final model: R^2_{adj}=.56, p<.001		
Intercept	-1.45	.16
SNQ-O	1.02	<.001
Year 10B		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
Year 10C		
MRQAP final model: R^2_{adj}=.11, p<.001		
Intercept	-4.70	.07
SNQ-I	0.71	<.001

LOTR (Alter)	0.61	.04
Year 10D		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
Year 10E		
MRQAP final model: R^2_{adj}=.47, p<.001		
Intercept	-8.92	.31
SNQ-O	1.82	<.001
KM (Ego)	-0.20	.03
IRI-EC (Ego)	1.10	.002
IRI-PT (Alter)	-0.35	.03
Duration	-1.53	<.001
Year 10F		
MRQAP final model: R^2_{adj}=.45, p<.001		
Intercept	0.12	.95
SNQ-O	1.02	<.001
SNQ-I	0.41	<.01
IRI-PT (Alter)	-0.22	<.001
BF (Ego)	0.65	.03
Gender (Ego)	2.53	.004
Year 10G		
MRQAP final model: R^2_{adj}=.40, p<.001		
Intercept	-35.22	<.001
SNQ-O	0.95	<.001
SNQ-I	0.37	.01
KM (Ego)	0.33	<.001
IRI-PT (Ego)	0.56	<.001
Duration	0.37	.02
Year 10H		
MRQAP final model: R^2_{adj}=.37, p<.001		
Intercept	12.45	<.001
SNQ-O	0.87	<.001
SNQ-I	0.54	<.001
KM (Ego)	-0.17	<.001
LOTR (Alter)	-0.15	.04
Gender (Ego)	-3.75	<.001
Gender (Alter)	-1.84	<.01
Year 11A		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
Year 11B		
MRQAP final model: R^2_{adj}=.47, p<.001		
Intercept	-7.86	.04
SNQ-O	1.21	<.001
SNQ-I	0.71	<.001

KM (Ego)	-0.16	<.001
IRI-EC (Ego)	0.41	.003
BF (Ego)	-0.72	.02
LOTR (Ego)	0.56	<.001
Year 11C		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
Year 11D		
MRQAP final model: R^2_{adj}=.39, p<.001		
Intercept	39.24	.02
SNQ-I	0.64	.02
IRI-EC (Ego)	-1.65	.02
BF (Ego)	-0.65	<.01
Year 11E		
MRQAP final model: R^2_{adj}= n.s., *p* = n.s.		
Year 12A		
MRQAP final model: R^2_{adj}=.50, p<.001		
Intercept	-33.74	<.001
SNQ-I	1.49	<.001
KM (Ego)	0.26	<.001
IRI-EC (Ego)	0.24	<.001
LOTR (Ego)	0.97	<.01
Gender (Ego)	7.91	<.001
Year 12B		
MRQAP final model: R^2_{adj}=.30, p<.001		
Intercept	5.38	1.00
SNQ-O	0.87	<.001
SNQ-I	0.07	<.001
KM (Ego)	-0.13	<.001
KM (Alter)	0.08	<.001
IRI-EC (Ego)	0.04	<.001
IRI-EC (Alter)	-0.16	<.001
IRI-PT (Ego)	0.14	<.001
IRI-PT (Alter)	0.03	<.001
BF (Ego)	-0.20	<.001
BF (Alter)	-0.76	<.001
LOTR (Ego)	-0.56	<.001
LOTR (Alter)	0.17	<.001
Duration	0.19	<.001
Year 12C		
MRQAP final model: R^2_{adj}=.43, p<.001		
Intercept	-6.75	1.00
SNQ-O	0.71	<.001
SNQ-I	0.31	<.001

KM (Ego)	-0.02	<.001
KM (Alter)	0.06	<.001
IRI-EC (Ego)	-0.01	<.001
IRI-EC (Alter)	0.02	<.001
IRI-PT (Ego)	0.12	<.001
IRI-PT (Alter)	0.13	<.001
BF (Ego)	1.10	<.001
BF (Alter)	-0.39	<.001
LOTR (Ego)	-0.15	<.001
LOTR (Alter)	-0.12	<.001
Duration	0.01	<.001
Year 12D		
MRQAP final model: R^2_{adj}=.44, p<.001		
Intercept	1.93	.69
SNQ-O	0.97	<.001
KM (Ego)	-0.14	.02
IRI-EC (Ego)	0.59	<.001
IRI-PT (Ego)	-0.30	<.05
LOTR (Ego)	-0.27	<.01
Gender (Ego)	4.71	<.001
Year 12E		
MRQAP final model: R^2_{adj}=.90, p<.001		
Intercept	-0.79	.88
IRI-EC (Ego)	1.17	<.001
IRI-PT (Ego)	-0.76	<.001
BF (Ego)	5.07	<.001
LOTR (Ego)	0.37	<.001
Gender (Ego)	-10.17	<.001
Year 13A		
MRQAP final model: R^2_{adj}=.27, p<.001		
Intercept	-2.46	.09
SNQ-O	1.14	.004
SNQ-I	1.10	<.001

Table D7. Single-classroom DG2 MRQAP models predicting cooperation with network and non-network variables including Alter-rated Social Tie Strength.

MG- MRQAP models – 1st Person Dictator Game (DG1) Including Relationship Reciprocation

Independent Variable	Unstandardised Regression Coefficient	*p* value
MG-MRQAP model		
$R^2_{adj} = .21, p < .001$		
Ego-rated social tie strength	1.31	< .001
Relationship reciprocation	-0.37	< .001
KM (Ego)	0.02	.003
KM (Alter)	0.05	< .05
Gender (Ego)	-1.00	.01
Ego-rated social tie strength x Year Group	-0.08	.03
KM (Alter) x Year Group	-0.02	.04
Gender (Ego) x Year Group	0.68	< .001

Table D8. Relationship In-link Strength MG-MRQAP model. Class intercepts for the model were: Year 9A (*b* = -3.55, *p* = .001), Year 9B (*b* = 2.29, *p* = .73), Year 9C (*b* = 5.11, *p* = .003), Year 9D (*b* = 2.37, *p* = .005), Year 9E (*b* = 1.90, *p* = .85), Year 10A (*b* = 3.10, *p* = .88), Year 10B (*b* = 3.28, *p* = .001), Year 10C (*b* = 4.08, *p* = .001), Year 10D (*b* = 3.95, *p* = .003), Year 10E (*b* = 5.91, *p* = .19), Year 10F (*b* = 2.81, *p* = .006), Year 10G (*b* = 3.45, *p* = .001), Year 10H (*b* = 4.48, *p* = .001), Year 11A (*b* = 3.64, *p* = .008), Year 11B (*b* = 3.93, *p* = .002), Year 11C (*b* = 3.58, *p* = .003), Year 11D (*b* = 4.46, *p* = .19), Year 11E (*b* = 10.20, *p* = .001), Year 12A (*b* =

6.92, *p* = .002), Year 12B (*b* = 7.51, *p* = .007), Year 12C (*b* = 5.81, *p* = .01), Year 12D (*b* = 1.18, *p* = .46), Year 12E (*b* = 13.85, *p* = .002), Year 13A (*b* = 7.61, *p* = .002). Independent variables eliminated due to non-significance were LOTR (Ego) x Year Group (*b* = 0.01, *p* = .49), IRI-PT (Alter) x Year Group (*b* = -0.01, *p* = .48), IRI-EC (Alter) x Year Group (*b* = 0.02, *p* = .30), Duration x Year Group (*b* = 0.01, *p* = .48), LOTR (*b* = -0.01, *p* = .43), BF (Alter) x Year Group (*b* = 0.14, *p* = .18), Gender (Alter) x Year Group (*b* = 0.19, *p* = .40), IRI-PT (Alter) (*b* = -0.02, *p* = .33), IRI-PT (Ego) x Year Group (*b* = 0.01, *p* = .35), KM (Ego) x Year Group (*b* = 0.02, *p* = .03), BF (Ego) x Year Group (*b* = -0.06, *p* = .28), Relationship reciprocation x Year Group (*b* = -0.04, *p* = .22), IRI-EC (Alter) (*b* = 0.03, *p* = .20), IRI-PT (Ego) (*b* = -0.03, *p* = .16), IRI-EC (Ego) x Year Group (*b* = 0.02, *p* = .16), IRI-EC (Ego) (*b* = -0.02, *p* = .18), Gender (Alter) (*b* = -0.50, *p* = .12), BF (Ego) (*b* = 0.09, *p* = .19), LOTR (Alter) x Year Group (*b* = -0.07, *p* = .04), LOTR (Alter) (*b* = 0.02, *p* = .32).

MG- MRQAP models – 1st Person Dictator Game (DG1) Including Alter-rated Social Tie Strength

Independent Variable	Unstandardised Regression Coefficient	*p* value
MG-MRQAP model		
R^2_{adj} = .21, $p < .001$		
Ego-rated social tie strength	0.81	< .001
Alter-rated social tie strength	0.35	< .001
KM (Ego)	0.03	< .001
Gender (Ego)	-0.82	.01

Gender (Ego) x Year Group	0.59	< .001

Table D9. Relationship In-link Strength MG-MRQAP model. Class intercepts for the model were: Year 9A (*b* = -1.01, *p* = .001), Year 9B (*b* = 2.61, *p* = .77), Year 9C (*b* = 4.92, *p* = .001), Year 9D (*b* = 2.72, *p* = .001), Year 9E (*b* = 2.39, *p* = .02), Year 10A (*b* = 2.13, *p* = .65), Year 10B (*b* = 2.21, *p* = .001), Year 10C (*b* = 3.02, *p* = .001), Year 10D (*b* = 2.96, *p* = .008), Year 10E (*b* = 4.80, *p* = .06), Year 10F (*b* = 1.79, *p* = .04), Year 10G (*b* = 2.56, *p* = .001), Year 10H (*b* = 3.20, *p* = .001), Year 11A (*b* = 1.26, *p* = .25), Year 11B (*b* = 1.56, *p* = .004), Year 11C (*b* = 1.24, *p* = .006), Year 11D (*b* = 2.08, *p* = .34), Year 11E (*b* = 7.84, *p* = .001), Year 12A (*b* = 3.15, *p* = .001), Year 12B (*b* = 3.93, *p* = .08), Year 12C (*b* = 2.17, *p* = .19), Year 12D (*b* = 1.05, *p* = .45), Year 12E (*b* = 10.43, *p* = .001), Year 13A (*b* = 4.03, *p* = .001). Independent variables eliminated due to non-significance were Duration x Year Group (*b* = 0.03, *p* = .48), IRI-EC (Alter) x Year Group (*b* = 0.02, *p* = .28), IRI-PT (Alter) x Year Group (*b* = 0.03, *p* = .48), LOTR (Ego) x Year Group (*b* = 0.01, *p* = .44), LOTR (Ego) (*b* = -0.01, *p* = .42), BF (Alter) x Year Group (*b* = 0.14, *p* = .18), Gender (Alter) x Year Group (*b* = 0.19, *p* = .37), IRI-PT (Ego) x Year Group (*b* = 0.01, *p* = .36), KM (Ego) x Year Group (*b* = 0.02, *p* = .04), IRI-PT (Alter) (*b* = -0.02, *p* = .30), BF (Ego) x Year Group (*b* = -0.06, *p* = .25), IRI-EC (Alter) (*b* = 0.03, *p* = .22), Alter-rated social tie strength x Year Group (*b* = -0.04, *p* = .23), Gender (Alter) (*b* = -0.49, *p* = .14), IRI-PT (Ego) (*b* = -0.03, *p* = .18), BF (Ego) (*b* = 0.11, *p* = .19), Duration (*b* = -0.07, *p* = .13), IRI-EC (Ego) x Year Group (*b* = 0.02, *p* = .10), BF (Alter) (*b* = 0.21, *p* = .09), IRI-EC (Ego) (*b* = -0.03, *p* = .08), LOTR (Alter) x Year Group (*b* = -0.07, *p* = .03), LOTR (Alter) (*b* = 0.02, *p* = .31), KM (Alter) x Year Group (*b* = -0.02, *p* = .06), KM (Alter) (*b* = 0.01, *p* = .17), Ego-rated social tie strength x Year Group (*b* = -0.06, *p* = .06).

MG- MRQAP models – 2nd Person Dictator Game (DG2) Including Relationship Reciprocation

Independent Variable	Unstandardised Regression Coefficient	*p* value
MG-MRQAP model		
$R^2_{adj} = .14, p < .001$		
Ego-rated social tie strength	1.19	< .001
Relationship reciprocation	-0.29	< .001
KM (Alter)	0.05	< .001
KM (Alter) x Year Group	-0.01	< .05

Table D10. Relationship In-link Strength MG-MRQAP model. Class intercepts for the model were: Year 9A (*b* = -1.40, *p* = .001), Year 9B (*b* = 12.68, *p* = .72), Year 9C (*b* = 1.86, *p* = .001), Year 9D (*b* = 0.89, *p* = .001), Year 9E (*b* = 0.22, *p* = .07), Year 10A (*b* = 0.63, *p* = .85), Year 10B (*b* = 1.62, *p* = .001), Year 10C (*b* = 2.61, *p* = .001), Year 10D (*b* = 9.63, *p* = .73), Year 10E (*b* = 3.14, *p* = .03), Year 10F (*b* = 1.14, *p* = .001), Year 10G (*b* = 2.02, *p* = .001), Year 10H (*b* = 2.40, *p* = .001), Year 11A (*b* = 6.67, *p* = .008), Year 11B (*b* = 3.88, *p* = .001), Year 11C (*b* = 2.04, *p* = .001), Year 11D (*b* = 2.86, *p* = .007), Year 11E (*b* = 10.23, *p* = .001), Year 12A (*b* = 5.77, *p* = .002), Year 12B (*b* = 5.33, *p* = .001), Year 12C (*b* = 4.25, *p* = .003), Year 12D (*b* = 0.12, *p* = .33), Year 12E (*b* = 10.39, *p* = .001), Year 13A (*b* = 6.20, *p* = .001). Independent variables eliminated due to non-significance were Duration x Year Group (*b* = -0.08, *p* = .45), IRI-EC (Ego) x Year Group (*b* = 0.01, *p* = .48), LOTR (Alter) x Year Group (*b* = -0.03, *p* = .25), Duration (*b* = -0.02, *p* = .44), Relationship reciprocation x Year Group (*b* = -0.04, *p* = .44), BF (Alter) x Year Group (*b* = 0.03, *p* = .39), BF (Ego) x Year Group (*b* = -0.08, *p* = .41), BF (Ego)

(b = -0.07, p = .43), LOTR (Ego) x Year Group (b = 0.01, p = .50), Gender (Alter) x Year Group (b = -0.01, p = .50), KM (Alter) x Year Group (b = -0.01, p = .45), LOTR (Ego) (b = 0.07, p = .32), IRI-EC (Ego) (b = -0.01, p = .51), IRI-PT (Alter) x Year Group (b = 0.01, p = .46), Gender (Ego) x Year Group (b = 0.54, p = .36), IRI-PT (Ego) x Year Group (b = 0.08, p = .13), IRI-PT (Alter) x Year Group (b = -0.01, p = .37), KM (Ego) x Year Group (b = 0.02, p = .19), BF (Alter) (b = 0.11, p = .24), KM (Ego) (b = 0.07, p = .20), IRI-PT (Ego) (b = 0.07, p = .22), Ego-rated social tie strength x Year Group (b = -0.08, p = .12), IRI-EC (Alter) x Year Group (b = 0.04, p = .05), IRI-EC (Alter) (b = -0.01, p = .13).

MG- MRQAP models – 2nd Person Dictator Game (DG2) Including Alter-rated Social Tie Strength

Independent Variable	Unstandardised Regression Coefficient	p value
MG-MRQAP model		
R^2_{adj} = .15, p < . 001		
Ego-rated social tie strength	0.92	< .001
Alter-rated social tie strength	0.32	< .001
IRI-PT (Alter)	-0.06	.03
Gender (Alter)	-0.65	.02

Table D11. Relationship In-link Strength MG-MRQAP model. Class intercepts for the model were: Year 9A (b = 2.97, p = .03), Year 9B (b = 12.75, p = .68), Year 9C (b = 2.01, p = .78), Year 9D (b = 0.94, p = .001), Year 9E (b = 0.93, p = .01), Year 10A (b = -0.48, p = .31), Year 10B (b = 0.56, p = .001), Year 10C (b = 1.83, p = .04), Year 10D (b = 9.71, p = .70), Year 10E (b = 2.27, p = .80), Year 10F (b = 0.12, p = .88), Year 10G (b = 1.64, p = .001), Year 10H (b =

1.40, p = .001), Year 11A (b = 4.94, p = .81), Year 11B (b = 1.81, p = .001), Year 11C (b = 0.11, p = .001), Year 11D (b = 1.01, p = .73), Year 11E (b = 8.30, p = .001), Year 12A (b = 2.53, p = .001), Year 12B (b = 2.86, p = .001), Year 12C (b = 1.69, p = .001), Year 12D (b = 0.29, p = .87), Year 12E (b = 7.86, p = .001), Year 13A (b = 3.70, p = .001). Independent variables eliminated due to non-significance were Duration x Year Group (b = -0.01, p = .49), IRI-EC (Ego) x Year Group (b = 0.01, p = .48), LOTR (Alter) x Year Group (b = -0.03, p = .27), BF (Alter) x Year Group (b = 0.03, p = .38), Duration (b = -0.02, p = .43), Gender (Ego) x Year Group (b = 0.02, p = .40), Gender (Ego) (b = -0.35, p = .58), BF (Ego) x Year Group (b = -0.06, p = .46), BF (Ego) (b = -0.07, p = .46), Gender (Alter) x Year Group (b = 0.02, p = .49), Alter-rated social tie strength x Year Group (b = 0.01, p = .51), LOTR (Ego) x Year Group (b = 0.01, p = .45), KM (Alter) x Year Group (b = -0.01, p = .43), KM (Ego) x Year Group (b = 0.06, p = .06), IRI-PT (Ego) x Year Group (b = 0.10, p = .04), IRI-PT (Alter) x Year Group (b = 0.01, p = .37), LOTR (Alter) (b = -0.03, p = .28), KM (Ego) (b = 0.07, p = .24), BF (Alter) (b = 0.04, p = .40), IRI-PT (Ego) (b = 0.04, p = .39), KM (Alter) (b = 0.01, p = .15), IRI-EC (Ego) (b = -0.12, p = .08), Ego-rated social tie strength x Year Group (b = -0.09, p = .09), IRI-EC (Alter) x Year Group (b = 0.05, p = .02), IRI-EC (Alter) (b = 0.01, p = .51), LOTR (Ego) (b = 0.18, p = .06).

QAP correlations

Classroom	SNQ-R	SNQ-I
Year 9A	0.44	0.60
Year 9B	0.43	0.61
Year 9C	0.34	0.76
Year 9D	0.41	0.65
Year 9E	0.42	0.63
Year 10A	0.22	0.89
Year 10B	0.17	0.93
Year 10C	0.34	0.75
Year 10D	0.52	0.43
Year 10E	0.36	0.72
Year 10F	0.41	0.65
Year 10G	0.41	0.66
Year 10H	0.42	0.64
Year 11A	0.36	0.72
Year 11B	0.42	0.63
Year 11C	0.53	0.43
Year 11D	0.39	0.68
Year 11E	0.94	0.80
Year 12A	0.37	0.71
Year 12B	0.33	0.77
Year 12C	0.31	0.80
Year 12D	0.29	0.83
Year 12E	0.54	0.40
Year 13A	0.37	0.72

Table D12. Correlations between SNQ-O and SNQ-R/SNQ-I variables.

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