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Cognitive and environmental factors in the development and impact of mathematical resilience in childhood

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Cognitive and environmental factors in the development and impact of mathematical resilience in childhood

By

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Certificate of Ethical Approval

Applicant:

Katie Baker

Project Title:

Development and trial of an intervention to teach parents how to parent for Mathematical Resilience.

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

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Table of Contents

Table of Tables

Table of Figures

Abstract

The aim of this thesis is to understand the nature of mathematical resilience (MR) in the early primary school years and how parenting relates to the development of MR. Although MR has been used successfully to support older learners struggling with mathematics there has been little research into the development and impact of MR in primary aged children. One of the reasons for this is that there is not currently a scale to measure MR in this age group and therefore a scale to measure MR in Year 1 children was developed as part of this research. This thesis uses mixed methods to investigate whether MR can be measured successfully in five and six year olds, whether links between MR and mathematical performance in primary children can be found and whether the concept of MR can be used to develop a successful intervention to help parents support their Year 1 children in mathematics.

Using cognitive interviewing, exploratory and confirmatory factor analysis and reliability analysis the twelve item Baker Children's Mathematical Resilience Scale was developed. The scale was used in two longitudinal studies to show positive quantitative links between MR and performance in Year 1 children. Two experimental studies were run; one showing positive links between MR and performance on a mathematics task in primary school children and the second showing links between a parent and child's MR and between parents' MR and the way in which they support their children during a mathematics activity. An intervention which uses the concept of MR to help parents to support their children in mathematics was developed, piloted and evaluated using process evaluation, qualitative and quantitative methods. Two case studies demonstrate the potential of the intervention to create positive changes in parents' behaviour when working with their children on mathematics.

The significance of this thesis is that it establishes a scale for measuring MR suitable for use with primary school aged children and demonstrates for the first time associations between MR and performance in this age group. It also develops an intervention that shows potential for improving the MR of parents and children and for teaching parents

better ways in which to help their children in mathematics. Finally it demonstrates, for the first time, links between parents' MR and the way they work with their children on mathematics as well as between parent and child MR.

The thesis has implications for future research, suggesting that the development and impact of MR on performance in mathematics should be further investigated, and providing the means to do so in the form of the Baker Children's Mathematical Resilience Scale. The research also has implications for schools suggesting that they should carefully consider the attitudes towards mathematics that they are fostering in their children alongside the skills they are teaching them. Schools should endeavour to engage parents, looking to work with and support them as partners rather than adopting a top down didactic approach. For parents, this thesis suggests that there are positive ways to help their children in mathematics and it is not necessary for them to be strong mathematicians to do so. Finally for anyone who has experienced problems when learning mathematics this thesis offers hope that by building MR the experience of learning mathematics can become more pleasant and successful in future.

Chapter 1 Introduction

This thesis charts an investigation into mathematical resilience (MR: Johnston-Wilder and Lee 2010a and b). It is enhanced by nearly 20 years working as a mathematics educator at all levels of mathematics education and stems from a desire to fully understand and alleviate the experiences and difficulties of learners and those attempting to support them - including the author - both in the classroom and at home. The path to this thesis was marked by a dilemma experienced by many educators, the need to incorporate the individual's mathematical learning needs and feelings towards the subject with the requirement of the educational system for ever improving results. When standing in a classroom does one do what is best for the child or for the data? Is it possible to do both? And what consequences does this decision have in the long term? This tension has been a key thread throughout the thesis since it is not only in the classroom that this dilemma exists. In research the quantitative versus qualitative debate rages. Which is more valid as evidence – statistical significance or a participant's lived experience? And which way of presenting these statistics and data is most valid?

In this thesis, as in the classroom, a pragmatic attitude has been adopted. Ideally every individual's experiences and needs could be catered for in the classroom and heard in the research narrative. But we live in a data driven world and no matter how good a child's experience of mathematics or a participant's experience of an intervention, if no improvement in grades or statistical significance can be found external assessment will find the teaching wanting or the research invalid. Thus this research adopts a mixed methods approach, giving equal weighting to qualitative and quantitative research. The story of the research is told alongside the data in an attempt to provide a fuller picture of the impact and difficulties of the process.

When the researcher first encountered the work of Johnston-Wilder and Lee on MR, she felt a strong pull towards the "rightness" of the theory. It possessed face validity, seeming to embody what she was witnessing in the mathematics learners she encountered. Those who possessed the attributes described in MR were those who thrived in the mathematics classroom over time, whilst those who did not either did not thrive at all or thrived for a while and then stopped being successful in mathematics. The Kooken Mathematical Resilience Scale (MRS: Kooken, Welsh, McCoach, Johnston-Wilder and Lee 2013, 2015) which allowed the measurement of mathematical resilience seemed to offer an opportunity to identify those who were well equipped to encounter the struggles of learning mathematics and those who would need more support. In the intervening years the researcher has tried to approach MR with a more critical and open mind. This thesis is the result of that journey. Whilst the researcher has seen the benefits of teaching for MR in practice, she has attempted to put aside these preconceived preferences during the research process.

Much of the extant research on MR has been conducted from an educational and social science perspective. It has been to a large extent qualitative in nature and conducted by a relatively small pool of researchers. During the course of this PhD those who originally posited MR have subtly changed their definitions and research directions and this has been noted and accommodated where possible.

The current thesis has attempted to study MR from a psychological research perspective, evaluating the ways in which it overlaps with other affective constructs, its links with performance and its usefulness in promoting better outcomes in mathematics. It also considers how mathematical resilience could be developed in young children. The original intention of the thesis was to develop an intervention to be delivered to parents to help to improve children's MR. However, prior to the development it was necessary to further understand MR and to develop a scale to measure it which could be used with young children.

At times, this research story necessarily overlaps with the story of the researcher's own life. The PhD journey is a long one and both the researcher and the research landscape changed over the course of it. It is undeniable that if one could start the PhD again at the point one has reached by the end of the process one would do things differently but as in life itself it is not possible, or desirable, to go back. One can only acknowledge mistakes that have been made and things which did not go to plan and do better in future, much as a mathematically resilient individual would approach the learning of mathematics.

Structure of the Thesis

The remainder of the thesis is split into ten chapters. Chapter 2 is a literature review of the state of mathematics in the UK; MR and its links to affective literature and parental engagement. Chapter 3 is a guide to the studies conducted as part of the thesis, where and how they are used. Chapter 4 describes the development of the Baker Children's Mathematical Resilience Scale (BCMRS). Chapters 5, 6 and 7 describe studies into links between MR and performance in mathematics. Chapter 8 describes a study into the impact of parental MR and mathematics anxiety (MA) on their children's MR and on interactions between parents and children working on a mathematics task. Chapters 9 and 10 describe the development and evaluation of an intervention for parents to help them work with their children on mathematics. In Chapter 11 the findings are discussed and conclusions are drawn.

Chapter 2 Literature Review

2.1 Chapter Summary

In this chapter the current state of mathematics education in England is evaluated. A definition of mathematical resilience (MR) is provided and its links to the affective literature and to children's performance in mathematics are discussed. An ecological model of education is adopted and the influence of parents on a child's mathematical education is discussed.

2.2 Introduction

The original aim of this thesis was to develop an intervention to be delivered to parents to help them improve their children's MR. This chapter considers the current literature and seeks to establish the necessity for improvements in mathematics education in England. It uses the Ecological Systems Theory Model (Bronfenbrenner 1979) to review the current research into mathematics in general and MR in particular and to explore the potential of delivering interventions to parents as catalysts for change in their children.

2.3 The Ecological Model

Ecological systems theory (Bronfenbrenner 1979) suggests that a child's development is influenced by the world around them and their interactions with it. Bronfenbrenner suggests five different systems which impact on an individual as shown in Figure 2-1. In the current context the individual is a child learning mathematics. Their educational development is firstly impacted by their own individual characteristics. These will be discussed further in section 2.5. The ecological model suggests that a child's development is also influenced by their interactions with the wider world in the form of the other systems with which they come into contact. The microsystem is the first external influence on the child. It is made up of the different types of interactions a child has every day, with parents, teachers and peers. The mesosystem represents the interaction of the different microsystems that the child belongs to such as links between home and school, and between family and other community settings. These two systems, micro- and mesosystem, will be discussed in further detail in section 2.6. The exosystem represents factors that do not have a direct effect on the child but which affect them indirectly. In the case of mathematics education examples of these could be government policies or educational initiatives and these aspects will be discussed in section 2.4. The macrosystem for a child learning mathematics would be the cultural beliefs about mathematics held in the country or community in which the child was learning. This is discussed in section 2.4. Finally the chronosystem represents the impact of changes or consistency in the child's systems over time.

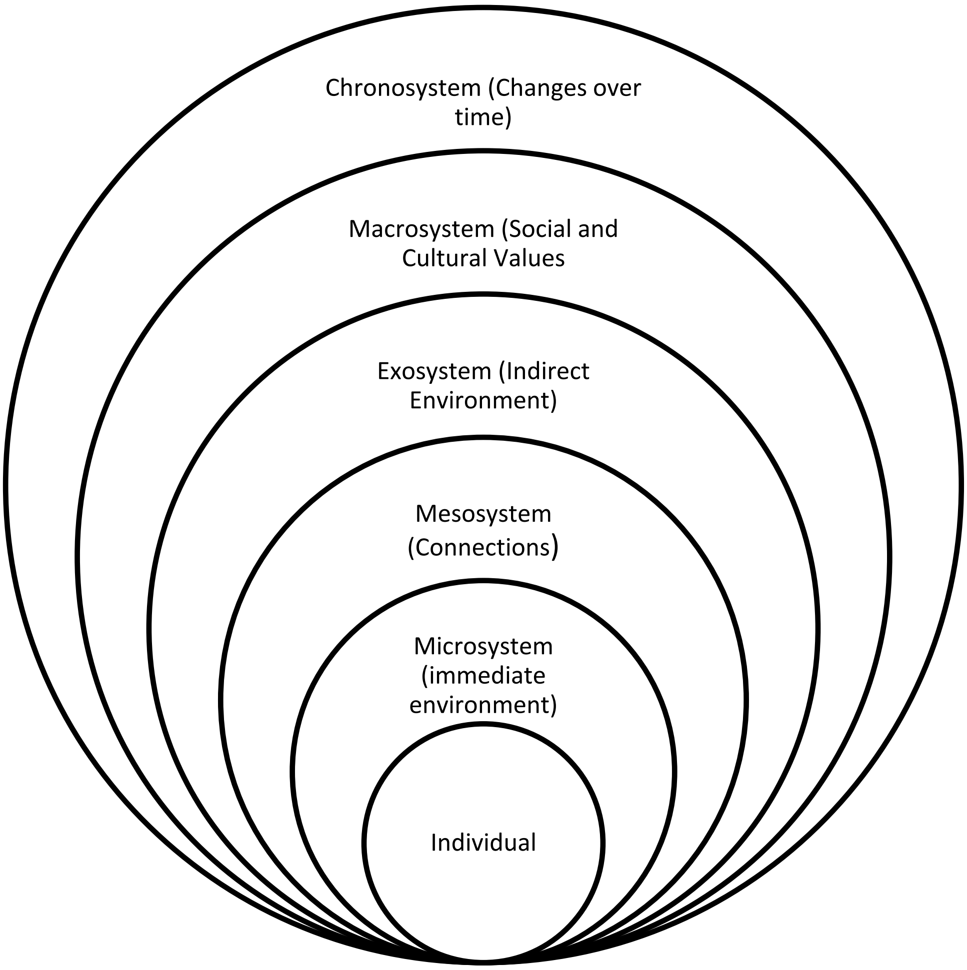

Figure 2-1 Bronfenbrenner's Ecological Systems Theory Model 1979

Applying the ecological model to a child's mathematical development emphasises the importance of interactions with these various systems on the child's development. The effect is bi-directional, that is, the way a child responds to the systems within which they find themselves influences the way these systems react to them and vice versa. Thus an individual child would be seen to develop differently in a different set of systems and one set of systems could affect two different children in different ways.

The importance of this model when considering the learning of mathematics is that when attempting to achieve change within the individual it is necessary to consider the wider environment in which that individual is learning and not focus purely on changing the individual themselves (Jackson 2013). In the case of the current research, if interventions are to be developed to improve mathematical outcomes for individual children it is necessary that the wider context of the child's mathematics education is considered. The following sections will therefore look in turn at each of the systems in the ecological model.

2.4 The State of Mathematics in England

2.4.1 Section Summary

This section looks at the exo- and macrosystems in Bronfenbrenner's model (see section 2.3); considering government policy and social and cultural beliefs about mathematics in England.   During their term in government (2010 to 2015), the Conservative and Liberal Democrat Coalition highlighted the need to improve outcomes for British children in mathematics and one of the aims of the revised National Curriculum in England, which came into operation in September 2014, was to address this issue. This section considers the background and motivation for these changes, wider problems with mathematics in the United Kingdom and the evidence for changes in these areas since 2014.

2.4.2 Issues in Mathematics Education pre-2014

The introduction of the 2014 National Curriculum followed a number of league tables and reports which highlighted the underperformance of British students in mathematics (e.g. OECD 2000, 2014). Schleicher (OECD 2013 quoted in Social Mobility and Child Poverty Commission 2014) concluded that "Good numeracy is the best protection against unemployment, low wages and poor health". However, in 2011, the Skills for Life Survey (BIS 2011) found that the percentage of adult respondents (16-65 year olds normally resident in England) at Entry Level 3, the expected level of a primary child, or above in mathematics had declined from 78.6% to 76.3% since 2003. This decline was found in both the 19-65 age group (79% to 77%) and the 16-18 age group (79% to 72%) although in the 16-18 age group the decline was not statistically significant, which was likely due to the smaller number of respondents of this age range. It was estimated that this left around 8.1 million English adults with numeracy levels at or below the level of a 7-9 year old. The report did not speculate on reasons for this decline.

Reports highlighted the cost of poor mathematical literacy to individuals and to the economy (e.g. KPMG 2009). Martin, Hodgson, Maloney and Rayner, (2014) estimated the annual cost of low mathematical literacy (level 3 or below) to the economy as a whole as £20.2 billion or 1.3% of GDP with £3.2 billion of these costs falling to employers, £8.2 billion to the government and £8.8 billion to individuals. Parsons and Bynner (2005) found that at age 30, those in their cohort study with poor numeracy were over twice as likely to be unemployed as those with competent numeracy. They reported that men with low levels of numeracy received the lowest hourly rates of pay and women's low numeracy meant they were less likely to be in full time employment, regardless of how many children they had. For both men and women, having low levels of numeracy had more of a negative impact than having low levels of literacy making it "difficult for them to function in all areas of modern life" (Parsons and Bynner 2005:7). Parsons and Bynner (2005) warned that without action those with the lowest levels of numeracy, particularly women, were at risk of social exclusion. Those with low levels of numeracy were also found to be more likely to be absent from the workplace through illness (Carpentieri, Litser and Frumkin 2009) echoing Parsons and Bynner's (2005) findings which linked poor numeracy in men to depression and in women to higher reported levels of poor physical health.

2.4.3 Introduction of the 2014 National Curriculum

With this background, the 2014 National Curriculum in England was introduced with the aim of providing children with "the essential knowledge they need to be educated citizens" (Department for Education 2014a:6). The importance of mathematics was particularly highlighted as "a precondition of success across the national curriculum"

(Department for Education: 9). The 2014 mathematics curriculum has a strong emphasis on learning basic skills such as times tables and mental methods of arithmetic in an attempt to replicate the teaching methods of countries such as Singapore and Hong Kong, whose students were seen to be performing more strongly in international tests, such as Programme for International Student Assessments (PISA), than those from the UK (e.g. OECD 2014).

The new mathematics curriculum received some criticism which mainly centred on the fact that it requires children to learn some concepts at a younger age than they were required to previously and that the curriculum content was too narrow. Some educators claimed that it introduces abstract concepts to children before they are ready for them (e.g. Hanson 2013, Wrigley 2014) and that this would actually damage children's prospects in mathematics, rather than promoting them. In 2013, in advance of the introduction of the new curriculum, 100 academics wrote to the Independent newspaper warning of "the dangers posed by Michael Gove's new curriculum which would seriously erode educational standards" and claiming that the inappropriate demands of the new curriculum would lead to "failure and demoralisation" for learners (Various 2013). Despite these concerns, the new curriculum came into force in England in September 2014 with the Secretary of State for Education, Michael Gove, stating that it had been developed "with regard to the views of subject experts and teachers and to the findings of international best practice comparisons" to effectively prepare children for the modern world (Gove 2013). All maintained schools (i.e. schools which are not private or academies) are currently required to follow the National Curriculum.

2.4.4 Other Issues Pertinent to Mathematics Education

One aspect not explicitly highlighted in the development of the National Curriculum but which is increasingly recognised as having an impact on mathematical outcomes are attitudes in wider society towards mathematics, Bronfenbrenner's macrosystem in the ecological model (see section 2.3). Attitudes in the United Kingdom towards mathematics and mathematicians are often negative (Epstein, Mendick and Moreau 2010). Mathematicians are widely viewed in the popular media as "isolated, obsessed, possibly autistic but certainly socially inept" (Epstein et al. 2010:52). It is socially acceptable to be unable to do mathematics in a way that it is not acceptable to be unable to read and many people claim to dislike the subject (KPMG and National Numeracy 2017). Dowker (British Psychological Society 2018) found that older children were more upset by failure in mathematics and tended to rate their own performance less positively than younger children. Although this study was not longitudinal and as such does not track changes in individuals' attitudes over time, it does provide evidence to support the theory that as the mathematics they are encountering gets harder, children become less enthusiastic about it. However, a longitudinal study to test this premise has not yet been carried out so such conclusions are at present tenuous.

The fear of mathematics is increasingly being recognised as a distinct and verifiable problem in the learning of mathematics. The construct mathematics anxiety (MA); "a feeling of tension, apprehension or fear that interferes with mathematics performance" (Ashcraft 2002:181) was first identified in the 1950s and first psychometrically measured by Richardson and Suinn (1972). MA impacts on mathematics education in several ways. The most apparent is through what was termed "global avoidance" by Ashcraft and Faust (1994). This is the phenomenon that those who are mathematics-anxious avoid situations in which they will be expected to do mathematics. Thus they avoid educational opportunities and careers that depend on mathematics. The impact of MA on performance is less clear (Ashcraft and Ridley 2005) although the nature of learning would suggest that those who avoid doing a subject are not going to attain mastery at it. It has been proposed that high levels of MA affect working memory and attention and are thereby detrimental to performance in mathematics (e.g. Hopko, Ashcraft, Gute, Ruggiero and Lewis 1998, Ramirez, Gunderson, Levine and Beilock 2013).

In 2012, researchers studied the effects of MA on the brains of 7-9 year old children (Young, Wu and Menon 2012). The study found that children classified as having high MA had distinct brain patterns in the amygdala when considering mathematical tasks in comparison to those who were classified as having low MA. Specifically, the children with high MA showed increased activity in the right amygdala, particularly the basolateral nucleus which has been found to be linked to learned fear (Young et al. 2012). The connections between the right amygdala and other areas of the brain also differed in the two groups. For the children with low MA, the amygdala was coupled with areas of the brain linked to efficient task processing whilst they were considering the mathematics problems, whereas in children with high MA it was connected to areas linked with processing and regulating emotions. This supports the theory that children in the high MA group were disadvantaged in their ability to work on the tasks by reduced information processing efficiency and were also experiencing higher levels of anxiety whilst engaged on the tasks. Young et al. (2012) suggest that, since these results indicate MA is parallel but not equivalent to other anxiety disorders, it could be possible to treat it, and thus potentially reverse these effects, with treatments based on those used on other anxiety disorders. However, such treatments are not currently in use in English schools.

Chinn (2009) estimated levels of high MA as between 2% and 6% in the secondary school population but other studies have found a higher prevalence. Ashcraft and Moore (2009) defined those who scored at least one standard deviation above the grand mean on the MA test they carried out as highly mathematics anxious. This statistical definition led to 17% being classified as having low MA, and 17% high MA. Although there is not a consensus on the prevalence of MA in the general population it can be hypothesised that it is affecting a significant number of individuals and needs to be addressed in any mathematics education setting.

A further identified issue in learning mathematics is that it involves what Liebeck (1990) termed a “hierarchy of abstractions” and Skemp (1987) termed “concept development”. When learning mathematics, early concepts lead on to later ones and mastery of each stage is necessary before moving on to the next. In a curriculum such as that in operation in England, which teaches by age rather than by current achievement, it is likely that a significant number of children will be moved from a concept they have not fully grasped to a new one before they are ready. For example, in 2016, 21% of Reception children had not reached the expected level in number

(Ofsted 2017) and thus had not mastered the early stages of number learning by the time they entered Year 1. According to Skemp (1987), if not addressed, this may lead them to have an incomplete understanding of Year 1 number concepts and a failure to retain them over extended periods. This effect would continue the following year and thus would accumulate throughout their school mathematics career. It could also be hypothesised that this constant working at a level above that they have currently mastered could be contributory to the development of MA.

There is another issue even amongst individuals who leave school with the required level in mathematics; if mathematics knowledge is not used regularly it is easily forgotten, particularly for those who have the lowest level of skills to start with and who have periods out of employment (e.g. Bynner and Parsons 1998). Thus, for a mathematically literate population, individuals need both to attain well whilst in education but also continue to engage with the subject once they have left. In a culture which does not value mathematics and where large numbers of individuals are MA, voluntary on-going engagement is unlikely to be occurring and thus figures for attainment upon leaving school are likely to be an overestimate of those who will remain functionally numerically literate throughout their life.

2.4.5 Mathematics in England Since 2014

Despite the introduction of the new National Curriculum, GCSE passes at grade C/4 or above (the government minimum required standard) have fallen since 2014 from 62.4% to 59.4% in 2018 (FFT Education DataLab 2018). There is also concern about the low levels of accuracy required to obtain a pass on the higher paper, for example in 2019 on the AQA mathematics paper the lower boundary for a level 4 was 43 out of 240 (AQA 2019). The picture is more promising at Key Stage 2 where the percentage of children achieving the required standard has increased since 2016 from 70% to 76% (Robertson 2018). However, these children spent the early part of their school careers on the old curriculum and therefore conclusions cannot be drawn from these figures on the curriculum's effectiveness. There has been a rise in the number of children reaching the expected level at the end of Key Stage 1 from 73% in 2016 to 75% in 2017

(Schoolsweek 2017) but it is too soon to say whether these improvements will be reflected in higher levels of mathematical literacy throughout the lifespan.

Large numbers of individuals in the wider UK population still have low levels of numerical literacy. In 2017, 30.1% of 16 year olds in the UK achieved lower than a level 4, the required level for that age, in their mathematics GCSE (Joint Council for Qualifications CIC 2018). Numbers who go on to improve their qualification in post-16 education are traditionally small; for example only 7% of students who re-sat the exam in 2013 improved their grade (Department for Education 2014b). Recently published figures show that in 2019, the 71,067 students who had previously achieved Level 1 qualifications (below Grade 3 or D for GCSE or equivalent) had actually made negative progress when required to continue with their mathematics education post-16 (Department for Education 2019). Amongst children from disadvantaged backgrounds these figures are significantly worse. According to the 2017 State of the Nation report, 39.2% of children on free school meals attain the equivalent of levels A* to C in both English and mathematics compared to 67% of all other children. Thus a significant number of young people are still leaving compulsory education without the level of mathematics qualification that the government believe they need for future life. Business leaders are also concerned that the UK workforce does not possess the numerical skills to make them competitive in the job market (Tu, Colahan, Hale, D'Souza, McCallum, Mallows, Carpentieri and Litser 2016).

The proportion of students going on to study mathematics once it is no longer compulsory is also low. In 2010, a report from Hodgen, Pepper, Sturman and Ruddock found that England, Wales and Northern Ireland had the lowest level of participation in post-16 mathematics education of the countries surveyed, at only 20% or fewer (Hodgen et al. 2010). Smith (2017) reported that in 2015/16 nearly three quarters of 16 year olds who got an A* to C grade did not continue with mathematics. Girls were less likely than boys with equivalent grades to continue to A-level e.g. 50% of A grade girls compared to 70% A grade boys went on to study A-level mathematics in 2014/15. Smith cited stereotypical images of mathematicians as one reason for not wanting to pursue the subject. However, other factors such as lower "mathematics self-concept" and higher achievement in other subjects were also given as possible reasons for girls not to continue mathematics beyond GCSE level (Smith 2017). This indicates that mathematics is still not a subject that the majority of young people connect with and wish to pursue once it is no longer compulsory. Having said this, since 2014 the importance of continuing mathematics learning has been recognised by the government. The requirement for the current academic year (2019-2020) is that all full time 16 to 18 year old students who do not hold a standard GCSE pass grade must continue to study mathematics as a condition of their funding (Education and Skills Funding Agency 2019).

2.4.6 Conclusions

The introduction of the National Curriculum in 2014 has been followed by improvements in standards at primary school level and falls in outcomes at GCSE level although it is too soon to attribute these changes directly to the new curriculum. Worryingly, between a quarter and a third of students are still failing to attain the required levels, leaving large numbers of young people, particularly amongst the socially disadvantaged, unprepared for the numerical demands they will meet in later life. Those individuals scoring the lowest levels are at risk of social exclusion due to their poor levels of numeracy and there is a negative financial impact on the economy and employers.

Academic outcomes are only one part of the story of mathematics education. Culturally it is seen as acceptable to be poor at mathematics and those who go on to voluntarily study it to high levels are often viewed as social outsiders. Large numbers of students who have been very successful at mathematics at GCSE level do not go on to study the subject at A-level, despite the recognised advantages of having such a qualification and the skills that go with it. Many students leave school disliking mathematics and it is socially acceptable, possibly even desirable, to admit to being unable to do mathematics. A significant number of individuals are also experiencing MA, which not only means that they find it difficult to engage with mathematics and are struggling to achieve good outcomes in the subject but that the process of learning mathematics itself is causing them high levels of emotional distress. These factors can lead to avoidance of mathematics amongst large sections of the population resulting in deterioration in mathematical skills among individuals once they leave school. Whilst these problems persist, improvements in academic outcomes alone are not enough to provide the country with the numerically literate population that it needs. Attitudes towards mathematics need to be addressed, both as a means to potentially improve outcomes during the school years and also to improve engagement with mathematics; which in turn will preserve mathematical literacy throughout life.

The evidence presented here has shown several issues in mathematics education in England at the present time and highlights problems that need to be addressed at the exo- and macro- system levels of the ecological model (Bronfenbrenner 1979). However, it is beyond the scope of the current research to address issues at these levels and therefore solutions will be considered at levels of the model where an individual teacher, school or parent has the potential to change outcomes. Therefore the next section considers the effect of MR at the individual level and considers implications for the improvement of outcomes in mathematics.

2.5 Mathematical Resilience and its Role in Mathematics Education

2.5.1 Section Summary

This section considers the construct Mathematical Resilience (MR: Johnston-Wilder and Lee 2010a and b), its theoretical role in the learning of mathematics and evidence for its usefulness as a predictor of, and tool to improve, individual performance in mathematics. In particular it considers whether MR is useful for addressing the impact of the cultural and affective problems identified in section 2.4 on the individual and whether using MR to do so has the potential to improve mathematical engagement and outcomes. MR is described and its place within the literature on affect, motivation and attribution is discussed.

2.5.2 What is Mathematical Resilience?

MR is “a positive approach to mathematics that allows people to overcome any affective barriers presented when learning mathematics” (Johnston-Wilder and Lee 2010b:1). Those who possess MR are said to possess specific attitudes towards three aspects of learning mathematics: *growth, struggle and value*, and to have access to resources to turn to when encountering difficulties. Mathematically resilient beliefs are: the belief that it is possible to get better at mathematics (*growth);* the understanding that it is necessary to struggle in order to learn mathematics and the knowledge of how to do so (*struggle*); and the belief that mathematics is important in the learner's own life (*value*). Mathematically resilient learners also possess resources in the form of relationships (or microsystems) with individuals such as parents, teachers or peers who they are happy to ask for help with mathematics and who are equipped to provide it, as well as access to physical resources such as textbooks, the internet, calculators etc. and the knowledge about how to use them effectively to solve difficulties they encounter in learning mathematics.

Johnston-Wilder and Lee (2010a and b) adopted the term MR to describe a phenomenon which they had noticed in individuals who had received effective mathematics teaching, and which was more than just the ability to pass mathematics exams. The origins of MR research were in supporting teachers to teach mathematics in a more productive way, by picking activities and responding in ways which would encourage the formation of the beliefs that lead to MR. Since its conception, MR has been used by Johnston-Wilder and Lee to address poor performance in and negativity towards mathematics by helping learners to recognise that learning mathematics often leads to anxiety and aiming to give them tools to overcome the anxiety they experience. It has also been used to combat avoidance of mathematics by helping students to understand their inclination to avoid it and giving them ways to view and deal with their own struggles in the subject more positively (Lee and Johnston-Wilder 2017). Lee and Johnston-Wilder claim that once learners develop MR they are more willing to engage with the subject and thus will achieve better outcomes in mathematics.

An important aspect of MR literature which is used to allow learners to talk and think about the emotions they are experiencing whilst working on mathematics is the growth zone model (Figure 2-2: Lee and Johnston-Wilder 2013).

Figure 2-2 Growth Zone Model (Lee and Johnston-Wilder 2013)

This model consists of three zones. The first is the *green* or *comfort zone* where mathematics learners are not presented with any significant level of challenge. They possess the knowledge to complete the work and can do so happily. In this zone, they feel a sense of security but little learning is taking place. The second zone, known as the *amber* or *growth zone*, is the optimal zone for the learning of mathematics. This zone provides challenge to learners but they feel comfortable with the level of challenge and are equipped to ultimately overcome it. In contrast, the third zone, known as the *red* or *danger zone*, provides a level of challenge that is too great for the learner. When working in this zone the learner feels an unacceptable level of stress and is incapable of interacting with the learning in any meaningful way.

Since the term MR was first used, several articles and a book chapter have been published about the construct, many from Johnston-Wilder and Lee but also from others (e.g. Johnston-Wilder, Lee, Garton, Goodlad and Brindley 2013, Goodall, Johnston-Wilder and Russell 2017, Goodall and Johnston-Wilder 2015, Kooken et al. 2013), and international conferences on MR have taken place incorporating research from academics, teachers and parents. MR has also been suggested as a strategy for overcoming MA (e.g. Marshall, Mann, Wilson and Staddon 2017, Johnston-Wilder et al. 2013). Most of the research to date has been on the MR of secondary and post-16 students and on how activities designed to promote MR can be used to overcome difficulties that students have encountered in learning mathematics (e.g. Johnston-Wilder et al. 2013, Goodall & Johnston-Wilder 2015). The legitimacy of the construct throughout the mathematical learner's life span has not been proven. In particular there has been no research on how MR develops and whether it correlates with performance throughout a learner's mathematical career. This thesis investigates the development of MR in Year 1 children and its links with performance in primary aged children.

2.5.3 Mathematical Resilience and the Affective Literature

It has been hypothesised that affective aspects of mathematics education may have an effect on performance in the subject as well as on willingness to participate in mathematical activities, which in turn impacts the maintenance of mathematical performance over an individual's lifespan (e.g. Fennema and Sherman 1978, Wilkins and Ma 2003). Lee and Johnston-Wilder stated that MR has its origins in concepts such as mindset, optimism, self-efficacy and motivation (Lee and Johnston-Wilder 2017) which are amongst the most prevalent constructs in the affective literature. The following section considers what elements MR has in common with other dominant affective concepts, reviews the evidence for the importance of affective concepts on performance and considers where MR has advantages over other constructs that may make it a more useful starting point to improve the teaching and learning of mathematics.

As discussed in Section 2.5.2, MR theory developed out of studies of the teaching and learning of mathematics. Thus it has its basis in the way that mathematical knowledge develops. Mathematics is a cumulative subject (Skemp 1987, Liebeck 1990). Learners develop skills in mathematics over time with each stage building on the one before. Initial skills may be straightforward acquisition of facts and understanding of number but mathematics soon requires problem-solving skills. Skemp (1987) discussed how this type of mathematical learning requires a goal, a plan to achieve that goal and the ability to adapt the plan if it proves inadequate. This type of learning cannot be communicated to the learner by a teacher but needs to be experienced and developed by the learner actively engaging in the process of problem solving. Therefore, learners can encounter difficulties in mathematics in three distinct ways or a combination of the three: lack of basic skills and knowledge; lack of ability to form a plan to help them solve a mathematics problem; or lack of ability to change their plan in response to it not working. Possessing MR encourages learners to engage with problem solving, since they believe that struggling will help them to grow (improve) in an area they value. Engaging with problems enables them to practise forming and adapting plans and thus become better at it. The possession of resources enables learners to compensate for basic skills that they may lack. Thus the possession of MR helps combat the problems described by Skemp (1987).

Lee and Johnston-Wilder (2017) state that to possess MR learners have to have a *growth* mindset; believing that they can improve their own mathematical skills by working on them. *Growth* mindset was defined by Dweck (2008). Dweck identified the importance of mindset in academic performance, defining two distinct mindsets towards learning: *growth mindset*, in which an individual believes that it is possible for them to improve through the effort they apply and *fixed mindset,* in which an individual believes that ability is not related to effort but is an inbuilt quality or failing of the individual themselves. According to mindset theory, individuals with a growth mindset evaluate setbacks in learning, such as failing a test or getting lower on an assignment than usual, and use the feedback from their evaluation to make changes to improve next time. They see successes as indicative of the effort they have put into their work. According to mindset theory those with a growth mindset to a particular task will be more successful at that task than those with a fixed mindset, and this conclusion is supported in mathematics by Skemp's (1987) description of the attributes necessary for the acquisition of mathematics skills. When studying mathematics, those with a growth mindset to the subject will possess the ability to pursue a policy of evaluating and refining their plans that Skemp claimed is necessary for learning. Mindset theory has become popular in educational circles and is widely used to try and improve educational outcomes (Busch 2018).

Theoretically therefore a growth mindset is important for learning but evidence for its effect on outcomes is more mixed. In 2018, an Education Endowment Foundation review of sixty-six meta-analyses incorporating over three thousand studies into evidence on strategies for teaching mathematics to 9 to 14 year olds (Education Endowment Foundation 2018) concluded that "Encouraging a growth mindset rather than a fixed mindset is unlikely to have a negative impact on learning and may have a small positive impact." (2018:159). There has, however, been some controversy about mindset theory and its use by schools as a panacea for attitude and achievement problems. Sisk, Burgoyne, Sun, Butler and MacNamara (2018) undertook two meta-analyses considering the evidence for the impact of growth mindset on achievement and the effectiveness of growth mindset interventions in improving achievement. They found only a weak relationship between mindset and achievement in the studies they considered, indicating that mindset may not be as closely linked to academic performance as Dweck and other mindset advocates claim. They also concluded that the interventions were not having the transformative effects on academic outcomes that the proponents of mindset theory suggested they would. However, there was a lack of information on whether the interventions had actually changed mindsets in the studies (many did not measure children's mindset at the start of the intervention). Thus it could not be assessed whether the failure to improve achievement occurred despite a change in mindset or whether the intervention had been ineffective at changing mindsets and this was why achievement had not been affected.

Research conducted amongst K-12 teachers (Yettick, Lloyd, Harwin, Riemer and Swanson 2016) may shed some light on the ineffectiveness of mindset interventions. When K-12 teachers were surveyed, only 20% believed that they were good at fostering growth mindset in their classrooms despite having received training on how to do so. Similarly, only 20% believed that they had deeply integrated growth mindset into their teaching practice. Thus the lack of impact of the interventions could have been down to a failure to implement them correctly rather than a problem with the interventions themselves. Rigorous analysis of the implementation of interventions would be necessary to draw stronger conclusions.

There has also been resistance to the emphasis in mindset theory on praising effort rather than achievement. This practice is adopted by mindset theorists in an attempt to encourage a growth rather than a fixed mindset. Wood (2017) challenged the practice, claiming that it was important that those, such as young black men, who had never been told they had intelligence or ability before be praised for intelligence and achievement at school.

Dweck (2015) argues that these problems are a result of the way mindset theory is being implemented rather than a problem with the theory itself. She claims that educators and parents are sometimes claiming a growth mindset while responding in ways that promote a fixed mindset. She also makes clear that the emphasis on effort should be on productive effort, on identifying whether effort is actually helping an individual to improve or whether they need to change their strategy. This issue is addressed in MR, which emphasises that learners should not only be aware of the need to struggle but they should know how to do so. Dweck (2015) is also concerned that mindset theory can be used to blame learners for their fixed mindset rather than supporting them to think more positively about their learning. She stated that individuals are not uniquely fixed or growth mindset. This means that an individual may hold a fixed mindset in certain areas of their life but not in others. It also implies that an individual's mindset in a certain area can change over time as a result of their experiences or of a conscious effort to change. Thus mindset is not a characteristic of an individual which can be used to excuse their lack of performance but rather a tool to aid them in improving their learning. This is the way growth mindset is used in MR.

Like Lee and Johnston-Wilder, Boaler (2016) applied the idea of mindset theory specifically to mathematics education. She claimed that mindsets to mathematics could be different to mindsets to other subjects because mathematics engenders strong negative responses which, as discussed in section 2.4, are society wide and this can lead to learners developing growth mindsets about everything else in their life while remaining convinced that they will never be able to do mathematics. If this is the case, even learners who generally perform well academically would have a different experience in the mathematics classroom and be unequipped to overcome setbacks that they would overcome with ease in other subjects. She states that general mindset interventions can be undermined in mathematics by learners returning to traditional ways of thinking and learning during mathematics lessons and that a specific focus needs to be kept on mindset during mathematics lessons and activities in order for growth mindsets to mathematics to be developed (Boaler 2016).

The evidence on growth mindset discussed here suggests that the concept has potential for helping learners to work more effectively. Learners with a growth mindset to mathematics would possess the ability to logically and unemotionally evaluate their learning and problem solving strategies and refine them as necessary in order to improve their learning outcomes. However, despite this strong theoretical link there is insufficient evidence to conclude that having a growth mindset alone leads to better performance in mathematics. In fact, Dweck's own comments (2015) suggest that this is not the case. Although learners need to have the ability to change their plans and believe they can get better in order to attempt to do so, they also have to have effective strategies of working which will enable their plan to work in the end, and these strategies do not necessarily result from a growth mindset alone. Believing you can improve is necessary but not sufficient to do so. MR, which combines growth mindset with other approaches to mathematics, may therefore provide a more effective approach than mindset theory alone.

Another theory which considers how individuals evaluate their successes and failures is *achievement attribution* (Weiner 1985). Achievement is perceived to be attributable to internal factors (things inside the person themselves) and external factors (those which are outside the person). Internal and external factors are then further split into factors which are fixed and thus unchangeable and factors which can be changed. A final consideration is how much control the individual has, or perceives themselves to have, over these factors. When considering achievement, causality is most often attributed to ability and effort (Weiner 1985). The importance of attribution for learners is that if they perceive themselves to be able to influence outcomes, this encourages them to continue to try to learn.

As discussed in Section 2.4, cultural norms in England lead many to believe that mathematics ability is a fixed internal factor, i.e. it is generally seen as a characteristic of an individual rather than something that can be developed. For an individual possessing this attitude the incentive to put effort into learning mathematics is reduced because, no matter how hard they try, they feel that if they are not a 'maths person' their effort is wasted. This belief may be experienced to a far greater extent than for other subjects because the emphasis in society on being a 'maths person' or not is far greater than for other subjects (see section 2.4). These cultural stereotypes may lead individuals to believe that their outcomes in mathematics are attributable to a combination of an internal unchangeable factor (whether they are a 'maths person') and external factors, such as the quality of their teacher or the questions that come up on the exam, rather than to something they themselves can influence. However, learners who possess MR believe in growth and struggle and therefore attribute achievement to factors that they can influence themselves. The learner with these beliefs will feel more control over their learning in mathematics and thus will attribute their achievements in a way that Weiner (1985) claims leads to greater desire to continue learning.

Bandura (1977) adopted the term *self-efficacy beliefs* to describe the beliefs an individual has about whether they are able to influence the events in their lives. Individuals who have high self-efficacy beliefs about mathematics believe that they can influence how well they do in the subject, those with low self-efficacy beliefs believe they cannot. Those who possess MR and attribute their mathematical achievements to factors over which they have control, such as the amount of effort they put in and the extent to which they struggle, believe that they can influence their mathematics achievements and therefore have high self-efficacy beliefs about mathematics. After reviewing nine meta-analyses, Bandura and Locke (2003) concluded that self-efficacy beliefs are linked to motivation and performance such that those who have higher self-efficacy beliefs are more motivated and perform better in a wide variety of spheres. Thus by possessing MR learners have higher levels of self-efficacy and are likely to be more motivated and perform better in mathematics.

Bandura listed four ways that self-efficacy beliefs could be developed: *mastery experiences* when a learner has the experience of success in a subject, *vicarious experiences* when the individual has a role model, someone whom they can observe doing well in a subject, *verbal persuasion* where learners are told that they can do well in the subject and *emotional and psychological states* such that the individual possesses the ability to regard a negative event in a more positive light. For example, an individual may fail a test but rather than despairing about this they are able to feel self-compassion and understanding of the reasons that led to this failure. Some individuals, such as those who are depressed, find it difficult to experience self-compassion and thus are not in the emotional or psychological state to develop self-efficacy. Interventions that have been developed to promote MR in young people (e.g. Johnston-Wilder, Lee, Garton, Goodlad and Brindley 2013) centre around giving individuals mastery experiences, providing coaches or role models who present them with vicarious experiences and talking to learners about how they can do well in mathematics and the feelings they have around the subject in an attempt to help them achieve more positive experiences. Thus these interventions to promote MR are providing the means by which Bandura claims individuals develop self-efficacy in mathematics.

Research into self-efficacy and achievement in mathematics provides evidence that they are related but there is a lack of data across time and insufficient evidence to conclude the direction of any causal relationship between the two (Pantziara 2016). Hannula, Bofah, Tuohilampi and Metsamuurronen (2014) studied 3502 Finnish children between third and ninth grade and concluded that the relationship potentially changed over a child's lifespan with achievement affecting self-efficacy early on, then a reciprocal relationship and finally self-efficacy affecting achievement amongst older children. Skaalvik and Skaalvik (2006) found that self-efficacy beliefs predicted achievement to a greater extent than prior achievement alone in 246 middle school and 484 high school students. Williams and Williams (2010) used PISA 2003 data to conclude a reciprocal determinism between self-efficacy and performance in 24 out of 33 countries.

The evidence on achievement attribution theory and self-efficacy beliefs suggests that if an individual believes that they are in control of their mathematics education and attributes their successes and failures to internal and changeable sources they will be more inclined to persevere in mathematics and in turn this may lead to them being more successful in the subject. Individuals who possess MR fall into this category.

Optimism is another term that has been used to express a desirable way for individuals to attribute the causes of events (Seligman 1990). According to Seligman, individuals consider outcomes according to their *permanence*, *pervasiveness* and *personalization*. Those individuals who are optimistic believe that setbacks are *temporary* i.e. they will not last forever; *specific* to a situation rather than global, i.e. they have failed at one task, they are not unable to do any mathematics; and responsibility for failure is *external* i.e. it is not a failing in them personally and could be linked to factors beyond their control. They see success as *permanent* i.e. it can be reproduced, *pervasive* i.e. if they can succeed at one thing they can succeed at another and *personal* i.e. success is down to their own effort. Seligman (1990) found that optimistic learners were more likely to persevere at tasks and thus were more likely to be successful. Yates (2002) found that the less optimistic learners were, the lower their achievement in mathematics over time. However, other studies were not so positive about the effects of optimism. Tenney, Logg and Moore (2015) found that although optimism did improve persistence on a task, it did not improve performance as much as their participants thought it would. Ruthig, Perry, Hall and Hladkyj (2004) found that optimism was actually an academic risk factor for learners unless they received attributional retraining, that is an intervention that aims to enhance motivation and change how learners think about their learning experiences.

Work on confidence may suggest a reason for this. Williams (2013) discusses the overlaps between confidence and optimism. Confidence has been defined as the extent to which an individual feels they are able to learn or perform well and confidence in mathematics has a significant positive correlation with achievement (Hart 1989). However, some studies (e.g. Pajares and Miller 1997) have found that links between confidence and performance have been stronger on multiple choice mathematics tasks than open ended tasks. Williams (2013) suggested that confident individuals all possess two aspects of optimism, namely seeing success as permanent and pervasive, but differences can be found in the way their confidence has been developed and thus in how they view failure. She identified two distinct types of confidence which she termed *disabling confidence* and *enabling confidence.* These two types of confidence were identified by watching individuals work on tasks and then interviewing them afterwards and analysing what they said about the mathematics that they were working on. *Disabling confidence* was found in learners who had developed their confidence through praise for their successful following of mathematical rules. Whilst they possessed two aspects of optimism (success as permanent and pervasive) they did not perceive failure as temporary and their successes as having arisen from their own personal effort. Thus, when faced with problems they had not previously encountered, they gave up and had low levels of performance. Those learners who possessed *enabling confidence* had developed their confidence through previous success in problem solving and they possessed the additional optimistic characteristic of seeing failure as specific to the situation they were currently in, not pervasive. Thus, when they were faced with problems they had not previously encountered, they attempted to adapt their previous skills to the new situation and performed at a higher level on tasks.

Using these definitions, those who possess enabling confidence can be seen to have a well-founded confidence based in reality, where the individual possesses the skills that they attribute to themselves. Disabling confidence in contrast is when an individual feels confidence in their abilities that is not well placed: once they are faced with the unknown in mathematics they are unable to deal with it. Individuals with disabling confidence are often unable or unwilling to go outside their comfort zone and risk showing their confidence to be misplaced, so they will be unable to try new things in mathematics and thus to progress in the subject. This is very similar to a subset of those who Dweck (2008) classed as having a fixed mindset; those who are performing well in mathematics but believe that this is an aspect of themselves rather than an outcome of their effort. Such learners identify very closely with the vision of themselves as a good mathematician and are unwilling to try new things in mathematics for fear that they will not do as well as they have done before. Thus despite, or perhaps because of their prior success, they are unwilling to risk failure in the future. Disabling confidence in mathematics is often caused by over-helping, where learners believe they are doing the work themselves but are actually being helped to a large extent by others (Williams 2013).

The distinction that Williams (2013) has identified in confidence may be equally applied to optimism. If an individual does not link their successes to their own efforts they may become over optimistic and think they will always do well without having to work. When they do not work, their performance levels will fall, leading to the negative link between optimism and performance which Ruthig et al. (2004) found.

It therefore appears that optimism and confidence alone are not enough. Both need to be based in a realistic view of events and combined with an approach to working on tasks that is likely to succeed, by knowing how to solve problems and being willing to put in the effort to do so. Those with MR possess the belief that they can get better in mathematics (growth) but also acknowledge that they need to work to do so (struggle) and are equipped with the resources and motivation (value) to enable them to do so.

It has been shown that there are strong links between MR, mindset theory, achievement attribution, self-efficacy, optimism and confidence. These theories consider how an individual thinks about their own successes and failures. Although the literature suggests that there are more beneficial ways to view achievement such as a growth mindset, attributing achievements to changeable factors, feeling high levels of self-efficacy or possessing optimism or confidence grounded in reality, there is doubt over whether these things alone are enough to affect achievement. It seems that along with these beliefs, how an individual works on mathematics is equally important. Different theories about what is necessary to work effectively on mathematics and how these theories tie in with MR will now be considered.

Once learners possess the belief that they can do better in mathematics and can influence their own outcomes, they need to know how to do so. In Skemp's (1987) theory this is having knowledge of how to plan and how to adapt the plan. Understanding in mathematics is often linked to *persistence* and *perseverance*. The two terms are often used interchangeably to describe the ability to keep working on a task despite encountering difficulties in doing so. However, a distinction should be drawn between persistence: continuing to work on the task in exactly the same way once difficulties have been encountered and perseverance: adapting the way of working to a more suitable one but continuing towards the same long term goal. Conroy (1998) discussed this distinction in a speech to graduating high school students. He also claimed that persistence is important but it is perseverance, the ability to adapt and make adjustments when your original strategy is not working, that is essential for success.

This distinction between persistence and perseverance is not always recognised in the literature and this makes conclusions on their impact on performance more difficult. Some studies, such as Mokrova, O'Brien, Calkins, Leerkes and Marcovitch (2013), use time spent working on a task to define persistence, not considering whether participants were refining and adopting appropriate strategies. Despite this they found positive links between increased persistence and greater mathematics skills (Mokrova et al. 2013). Millman, Bieger, Klag and Pine (1983) found that there was a limit on the effectiveness of perseverance. They conducted four studies that showed when a learner was already willing to persevere, increasing their perseverance did not lead to any more or any quicker learning (Millman et al. 1983). However, their measure of perseverance was also the time spent working on a task and did not consider adaptation strategies. Once again perseverance and persistence are concepts that are widely spoken of in the literature as important to performance but evidence on the truth of this statement is not conclusive.

Two further theories that consider the way learners respond to encountering difficulties and whether they persevere in learning in the face of them are *academic resilience* (Martin and Marsh 2003) and *academic buoyancy* (Martin and Marsh 2009). *Academic resilience* is the ability to continue to do well when the difficulties encountered are severe and sustained, such as issues at home and physical or mental issues. Martin and Marsh (2003) proposed a five factor model of academic resilience called the 5Cs. They found that confidence (self-efficacy), coordination (planning), control, composure (low anxiety) and commitment predict *academic resilience*. *Academic buoyancy* is the ability to do well when faced with more common place, everyday difficulties in learning such as finding a particular topic or activity difficult or failing to make a connection with the teacher. In general the difficulties encountered by learners of mathematics are the everyday ones covered by academic buoyancy, although some learners may find the experience so difficult that it requires academic resilience. For many individuals even though learning mathematics is not truly traumatic it can be a very uncomfortable experience, particularly if they are frequently working in the danger or comfort zones, thus experiencing high levels of anxiety or boredom respectively. MR learners, who are defined as having the ability to deal with these experiences and the skills to move themselves back in to the growth zone, are academically buoyant.

Research has shown that academic buoyancy and academic achievement are linked but that the effect is small (e.g. Martin 2014). Some academics have suggested that this is because the relationship works through an indirect mechanism. Collie, Martin, Malmber, Hall and Ginns (2015) found that they were linked by control (i.e. belief in the ability to influence events as in self-efficacy) but hypothesised that this might not be the only mechanism by which they were linked. Evidence for academic buoyancy having a direct effect on academic outcomes is again inconclusive.

Grit (Duckworth, Peterson, Matthews and Kelly 2007) is defined as a combination of perseverance and passion for long term goals. In their 2007 study, Duckworth et al. found that grit accounted for 4% of the variance in the success outcomes they measured. Since then, grit and its development has been an increasing focus amongst US educationalists and Duckworth's book on the subject has become a best seller. This is despite the fact that even if the 4% figure is accurate there could still be more important factors affecting the other 96% of variance. Initially, studies for the impact of grit on performance looked promising, although the effects of grit were mediated by other things in these early studies. Duckworth, Kirby, Tsukayama, Berstein and Ericsson (2010) found that grit predicted final performance in a spelling bee when mediated by deliberate practice. Lee and Sohn (2017) found that grit was associated with higher grades in college students in Korea, again mediated by deliberate practice. However, other studies began to cast doubt on the universal impact of grit. Bazelais, Lemay and Doleck (2016) found that grit was not a significant predictor of academic performance in science and Grohman, Ivcevic, Silvia and Kaufman (2017) replicated this finding for creative subjects. The literature on grit again seems to suggest that it is only part of the story since the practice that is being undertaken may be equally important. Thus the belief that helping children to develop grit will help to improve their performance is again an oversimplification, the reality of the situation appears, even from Duckworth's own work, to be more complicated than this.

The evidence on the impact of the way learners work on mathematics has been unclear. Learners who continue working on tasks do appear to have more success but the relationship is not direct and certain task dependent ways of working seem to be more successful than others. The benefit of MR in this area is that as well as believing that they need to struggle with mathematics; those who possess MR have resources to help them to struggle successfully, adapting their approach to the problem at hand.

As previously discussed self-efficacy beliefs were linked by Bandura (1977) to both performance and motivation and Skemp (1987) stated that individuals had to have a goal in order to be successful on a mathematics task. Psychological theories of motivation consider what makes a person engage in specific behaviours. Most theories of motivation recognise two distinct types of motivation; *intrinsic motivation* where an individual is motivated to engage in a task because they find the task itself interesting and enjoyable and *extrinsic motivation* where an individual is motivated to engage in a task because they foresee some reward for them in undertaking it or a negative effect if they do not do so. Traditional theories of motivation generally focus on the amount of motivation that individuals possess and suggest that those who are motivated by external factors will participate in tasks unwillingly, with poorer performance outcomes than those motivated by intrinsic motivation. Studies such as Marayama, Pekrun, Lichtenfeld and von Hofe (2013) have found positive links between intrinsic motivation for mathematics and growth in academic achievement over time.

Research by academics such as Wigfield and Eccles (2000) and Ryan and Deci (2000) has investigated different types of and influences on motivation and the resulting impacts on behaviour. They have theorised that individuals can engage willing and enthusiastically in tasks for which they have little or no interest but in which they see value and this has led to an adaptation of motivation theory research to incorporate understanding of **what** is motivating an individual as well as the **amount** of motivation they have for a task.

Self-Determination Theory (Ryan and Deci 2017) is concerned with what causes humans to thrive. It considers motivation in the light of biological, social and cultural factors and looks at the underlying attitudes and goals which influence individual actions. Ryan and Deci (2017) identify individuals as having three basic psychological needs, competence (the need to feel capable), autonomy (the need to possess independence to act) and relatedness (the need to feel connected to others). They hypothesise that an individual's decisions about what actions to take are influenced by the impact any decision has on these needs. They define three types of motivation: *intrinsic motivation* which is when actions are performed due to an individual's personal interest in them and to which the reward is internal satisfaction; *external motivation* which is when actions are performed to attain an external reward or avoid a punishment and *autonomous extrinsic motivation* which is when the individual has no personal interest in the action but has voluntarily accepted its importance to them. Intrinsic and autonomous external motivation is seen as the most beneficial. Self-determination theory is based on the premise that all individuals are naturally curious and inspired to learn and grow (i.e. they naturally have intrinsic motivation to learn new things) but contends that social and cultural factors can either increase or reduce these natural inclinations.   In education, self-determination theory has been used to evaluate the impact of classroom practices on these natural inclinations and on the three basic psychological needs, and to consider which methods of teaching support and which undermine them (e.g. Niemiec and Ryan 2009). Research has found that where these needs are met intrinsic motivation and autonomous extrinsic motivation increase (see Niemiec and Ryan 2009).

Therefore by inference, individuals who possess MR have the three basic psychological needs of self-determination theory met in the mathematics classroom since they feel capable of doing well in mathematics (belief in growth), they possess autonomy in mathematics (a knowledge of how to struggle and an understanding of mathematics in their own life that comes from valuing mathematics) and feel relatedness in mathematics (they know other people to turn to as resources when they are stuck). Thus according to self-determination theory their intrinsic and autonomous extrinsic motivation for mathematics will be higher. Research (e.g. Broussard and Garrison 2004, Awan, Noureen and Naz 2011), has shown that possession of intrinsic and autonomous extrinsic motivation is linked to improved academic outcomes, further evidence that the possession of MR may be linked to improved performance in mathematics.

The expectancy-value theory of achievement motivation (Wigfield and Eccles 2000) states that an individual's decisions about whether to work on a task and how long they will continue to work on it are influenced by their beliefs about how well they will do in that task and how much they value it. Thus to apply maximum effort to a mathematics task, and hopefully thereby to achieve highly, the expectancy-value theory implies that a learner needs to believe that they will be able to complete that task and feel that they personally will accrue some benefit by doing so. Wigfield and Eccles (2000) found that an individual's beliefs about how well they would do in mathematics and how much they valued it were a stronger predictor of achievement than prior achievement or how much they valued achieving well. As described in section 2.5.2., the *growth* aspect of MR inclines learners to believe that they will eventually be able to complete tasks and it is the *value* aspect of MR which addresses the issue of personal benefit. Mathematically resilient individuals are aware of the value of mathematics in their own lives (Johnston-Wilder and Lee 2010a and b) and thus can readily recognise the personal benefit from completing mathematics tasks. Therefore by Wigfield and Eccles' theory (2000) those who possess MR are best placed to apply maximum effort to a mathematics task, they are likely to be most motivated and they are most likely to perform highly in mathematics.

Findings about the impact of motivation on performance are mixed. As discussed, Wigfield and Eccles (2000) found positive effects of motivation on performance, as did

Bobis, Anderson, Martin and Way (2011). Broussard and Garrison (2004) found that higher levels of mastery motivation were related to higher performance in mathematics in first and third grade children. Stipek, Salmon, Givvin, Kazemi, Save and MacGyvers (1998) analysed the impact of classroom practices designed to improve motivation and found that the practices were effective in improving motivation and that improved motivation improved the learners' skills with relation to fractions, the mathematical activity they were studying. However, some studies (e.g. Gagne and St Pere 2001) found only a small impact of motivation on performance.

One reason for these differing findings may be the variety of definitions of motivation used in the literature. It may also be true that, as previously discussed, continuing to work on a task is not necessarily a predictor of success at that task. Being motivated to do a task may be necessary for learners to work on that task, but knowing how to work on it is also necessary for success.

Another way in which the term motivation has been used is to describe an individual's ability to stay focussed on a task once it becomes hard (e.g. Richardson and Abraham 2009). These definitions have strong links to definitions of academic buoyancy or resilience. Martin (2003) developed the Student Motivation and Engagement Wheel which identifies factors necessary for a student to be engaged with their work and those which would cause them to be disengaged. Factors identified by Martin as necessary for motivation were self-belief (or self-efficacy), learning focus, value for schooling, persistence, planning and study management (2003). In this definition the belief that the individual will eventually succeed is not considered, purely whether they are willing to keep trying. Bobis et al. (2011) concluded that classroom practices which were designed to improve this type of motivation also improved performance in the mathematics classroom. They suggested that the Student Motivation and Engagement Wheel was a useful model for teachers when considering how to improve the motivation of their students.

Mathematically resilient individuals possess many factors included on the wheel because they believe that everyone can get better in mathematics (growth), value the learning of mathematics (value) and possess persistence and the ability to focus on and plan their study (struggle). Thus encouraging MR fits in with the models of improving motivation endorsed by Bobis et al. (2011).

Although definitions of motivation vary, clear links between motivation and performance have been found. MR theory does not suggest that all learners can develop intrinsic motivation or a love of mathematics but mathematically resilient learners do see the value of mathematics and thus could be expected to have at least positive, autonomous extrinsic motivation for the subject. As discussed in section 2.5.2, MR theory developed from observations of good classroom practice and thus it could be contended that it is a result of a classroom that is supporting the development of intrinsic and autonomous extrinsic motivation, as advocated by self-determination theory.

As previously argued, motivation alone is not enough for high performance if an individual does not know how to work on tasks. Mathematically resilient learners understand the need to struggle in mathematics and how to do so and thus combine motivation with an approach to working on mathematics that is more likely to be successful.

As discussed, a wide variety of terms are used to try and describe learners' attitudes to learning in general and mathematics in particular. The major problem with research into the effect of attitudes on mathematics learning is the lack of clarity around the definitions of the terms with academics using the same term for subtly different concepts and different terms being used to describe very similar concepts. A second problem is that it is increasingly being recognised that performance in mathematics is not just affected by one such concept; it is a result of the interplay of several different concepts. Thus many of the definitions in the affective literature are oversimplifications. Di Martino and Zan (2011) describe how definitions for attitudes towards mathematics in mathematics education are increasingly based on a tripartite model; namely that attitude is made up of cognitive, affective and behavioural elements. They (2011) proposed the *three-dimensional model for attitude toward* *mathematics (TMA).* In this model, attitudes towards mathematics are seen as being formed from interplay between three elements: emotional disposition towards mathematics, vision of mathematics and perceived competence in mathematics.

A further issue is the bidirectional nature of affective beliefs and achievement. As well as affect influencing performance, performing at different levels will have an effect on a learner's affective beliefs. For example if a learner is continually performing at a high level they may have higher confidence than a learner who is continually performing at a low level. As previously discussed this may be disabling confidence, but until they face major problems in mathematics their confidence will continue to be high. Their confidence may then be knocked by some work that they find difficult or believe they have performed poorly on and the poor performance will cause a drop in confidence rather than a lack of confidence having affected the performance.

Thus the future for affective research is in clarifying what is meant by affective terms and considering the interplay between the different affective elements and between performance and affective beliefs.

2.5.4 Conclusions

With their theory of MR, Johnston-Wilder and Lee (2010a and b) have identified a specific approach to mathematics possessed by learners that has grown out of good teaching and learning and which they see as being beneficial to learners. The concept of MR has been widely used to support learners who struggle with mathematics and thus has a solid base in the reality of mathematics education. This is an approach which fits with the tenets of Self-Determination Theory and looks to support the development of individuals' three basic psychological needs for autonomy, competence and relatedness. MR theory draws on many aspects of the affective literature discussed in this thesis but it goes further than each of them in its attempts to combine them together to define an effective mathematics learner. The definition of a mathematically resilient learner considers cognitive, affective and behavioural elements and as such fits in with the TMA.

Considering the direct link to the experience of teachers and learners and the theoretical links to so much of the affective literature, it seems possible that there is a direct link between MR and performance in and attitudes to mathematics. It also seems possible that this link may be stronger and less susceptible to change than the affective constructs discussed in this thesis because it prepares learners for challenges in mathematics and thus is less affected by them. However, this link is not yet proven. Many questions remain to be answered about MR. Although Lee and Johnston-Wilder identified it as an outcome of good mathematics teaching which allows learners to go on to do more with mathematics than simply pass exams (2017) there has been little research on how MR develops and what kind of teaching and learning allows it to do so. Most of the research that has currently been done on MR uses it as a tool to remedy problems with mathematics amongst older learners rather than to prevent them occurring in the first place. Theoretically, the literature review suggests that, since MR theory is advocating the promotion of elements of the affective domain that have been found to correlate with better academic outcomes, it should correlate with better performance in learners of all ages. However, to date there have been no reported studies of this among primary school children. It also seems possible that if MR could be developed in young people they would be less likely to encounter problems in mathematics in the future, but again this has not been studied. Finally, with its emphasis on valuing mathematics and understanding the struggles that are involved in learning it, it seems possible that encouraging MR will overcome the dislike of and anxiety about mathematics and the unwillingness to take part in mathematical activities that were identified as problems in Section 2.4. Again there is currently not sufficient evidence of this link. This thesis attempts to address some of these gaps in the research and conclude whether developing MR in children could be a way of improving future outcomes in mathematics. The following section considers the potential role of parents, as a child's primary microsystem, in developing MR.

2:6 The Role of the Parent in Mathematics Education

2.6.1. Section Summary

This section considers the role of the parent in a child's mathematical learning. In Bronfenbrenner's model the parent forms part of the child's micro- and meso-systems. Interactions between parents and child form the child's primary microsystem and interactions between parents and schools form a mesosystem. Thus parents play an important role in the individual child's ability to learn mathematics. Section 2.5 suggested that improving MR might be a means by which the problems identified in mathematics education in Section 2.4 might be overcome and individual performance in mathematics might be improved. If this proves to be the case it would be necessary to have a means by which improvements in MR could be achieved. Whilst working as a teacher and tutor the researcher noticed that parents often undermined their children's MR, for example by saying that they themselves were not 'maths people' so their child probably would not be either or that they had never had to use algebra for example. For these reasons it is hypothesised that an intervention for parents to help them develop rather than undermine MR in their children may be a route to improve children's MR. In order to explore the validity of this claim the literature on the role of the parent in mathematics education is now considered.

2.6.2 What is Parental Involvement?

According to Bakker and Denneson (2007), the concept of parental involvement originally arose to try and describe the advantage that middle-class children had over less well-off children due to the support that they and the school received from their parents. Higher levels of academic success were put down in part to this input and thus other parents were encouraged to emulate the behaviour of white middle class parents. The original definitions of parental involvement include traditional middle class activities such as attending meetings with teachers, coming into school to help out with activities and trips (known as school-based activities) and activities such as spending time reading stories to children, ensuring they complete homework and taking them on trips to museums and other cultural events (known as home-based activities). School-based activities are more easily and thus more often measured in surveys into how parents interact with their children around mathematics. Such activities are directed almost entirely by the school and teachers and take place in the school setting. Home-based activities, which are generally directed by the parent although, like homework, they may have been inspired by the school, are less easy to quantify and may take place at home or in other settings. In such traditional interactions all parties generally view the school and teachers as the authority on and main agent in the provision of the child's education and the parents as supplementing the education provided by the school.

One problem with this model of parental involvement is that some parents are not able to participate fully in it. Parents' ability to become involved in their child's education in these ways has been defined according to their possession of two types of capital: cultural capital and social capital (Murray, McFarland-Piazza & Harrison 2015). Cultural capital (Bourdieu 1973) refers to skills and knowledge possessed by individuals which allow them to fit into the culture in which they are based and thus to thrive it in. In terms of parental involvement those who have gone through the education system themselves are likely to have better knowledge of it than those who were educated in a different system or who left education early (Murray, et al. 2015). Thus it is easier for parents with experience of the system to understand the educational environment that their children are educated in and to promote their children's success. It is also easier for parents who possess cultural capital around education to talk to teachers and help out in schools as they share a common understanding of what education is. On the other hand, parents who have not been educated in the same education system as their children or have left education early will find it more difficult to understand that system, to help their children work within the system or to become involved with school themselves.

Social capital centres on social networks and the advantages that such networks can bring (McNeal 2001). In terms of education, parents who are in social networks with other parents and sometimes even with teachers can gain knowledge of what is going on in school, how other children are performing and how they might help their own child, as well as teachers' expectations for children. Those who do not belong to such networks do not have access to this information.

The traditional concept of parental involvement is only possible for a subset of parents who possess cultural and social capital. In practice, opportunity for parental involvement, as promoted by this definition, privileges those who have time during the day and early evening to attend events in school and help with homework, those who have resources to provide trips and excursions, those who are aware of what their child should be doing at school and increasingly those who pick their children up at the end of the school day when they can talk directly to teachers, rather than from childcare. Many parents do not fulfil these criteria. In the United Kingdom, 59.2% of children live in households where all adults work and 34.5% of mothers work full time (Office for National Statistics 2018) making it difficult for them to pick up children at the end of the school day and be involved during the school day. Parents may struggle to understand the English curriculum and communicate with the school; as 7.5 million people were registered as born outside of the UK in the last reported census and 4.2 million have a main language other than English, 726,000 of whom could not speak English well (Office for National Statistics 2015 and 2013). Statistics for 2016/17 show that 11% of children live in low income households and material deprivation (Department for Work and Pensions 2018) meaning there is a lack of money for trips and school equipment. Finally, mathematics methods currently taught in schools vary vastly from those taught twenty years ago meaning many parents do not understand what their children are learning. Consequently, a potentially large number of parents do not possess the necessary social and cultural capital to engage in the traditional forms of parental involvement.

Borgovoni and Montt (2012) reviewed data on parental involvement in education in 13 countries and reported that most parents understand the need to be involved in their children's education (p52). They noted, however, that is it less likely for disadvantaged parents to be involved, a finding echoed in Speight, Maisey, Chanfreau and Haywood (2015). Borgovoni and Montt (2012) also found that not all of the parents who engaged with their children's education did so in the most effective ways. However, Borgovoni and Montt (2012) used data that recorded traditional forms of involvement such as writing words and numbers with children, asking about their day and telling stories and did not look at other forms of involvement such as those identified by Russell (2002).

In her PhD thesis, Russell, (2002) investigated unrecorded forms of parental involvement and concluded that parents are involved in their children's mathematics education at home. However, she found that they are involved in some ways which do not necessarily fall into the traditional categories. These included setting mathematics questions for their children, teaching children their own methods (which may be different to the schools) and monitoring books to see that the curriculum is being covered. Thus rather than supporting the school in supporting their child as in traditional definitions of parental involvement, here parents were acting directly with their child in ways that may sometimes have been contradicting the school's own methods. Russell also reported that parents frequently did not understand the information that schools were sending home about the curriculum and the mathematics their children were doing and were acting as advocates to help the children 'survive' school mathematics rather than as partners with the school.

Russell's (2002) thesis is not the only evidence for a lack of clarity in how parents are actually involved. Studies on parental involvement frequently differ on their definition of the concept. Activities as diverse as talking to teachers, being actively involved in school activities, being involved in the running of the school and helping with homework have all been described by the same term: parental involvement. Measures of parental involvement can also vary from self-report to researcher observations (Desforges and Aboucher 2003). Due to this divergence in definitions there is now a lack of clarity about the meaning of the term parental involvement, which Georgiou (1997) described as "a generic term with so many meanings that soon it will have no meaning at all" (p206). This lack of clarity is problematic because it means that parental involvement is "not uniformly defined or measured by researchers" (Bakker and Denneson 2007:193). In fact, as has been suggested above, some types of home-based involvement may not have been measured at all. This weakens the power of research on parental involvement and it is therefore important for any study into the effect of parents on their children's education to clearly define terms and to identify exactly what interactions are causing any effect found.

A more useful definition for parental involvement may focus less on the specific activities that parent and child are involved in and more on what educational interactions between parent, child and school should look like in order to be effective. Pomerantz, Moorman and Litwack (2007) suggested four key aspects of parental involvement:

- It should promote autonomy rather than be controlling.
- It should focus on the process of learning rather than the person (this can also be described as focussing on mastery rather than performance).
- Parental support should promote positive affect.
- Parents should hold positive beliefs about their children's abilities.

Goodall's six point model for parental engagement (2013) has many overlaps with that of Pomerantz et al. It specifies authoritative parenting, early parental interest in education, learning taking place in the home not just at school, parents showing an active interest in their child's education and encouraging high aspirations and parents staying engaged in education throughout childhood as essentials of parental engagement. Both of these models move the emphasis away from parents supporting the school and towards parents independently supporting their children, a model which is more closely aligned to the type of interactions Russell (2002) identified.

Russell found that parents were keen to have the support of schools in supporting their child. However, due to the factors discussed earlier they were finding it hard to understand the communications they were receiving and interpret what the school wanted. Conjoint Behavioral Consultation (CBC) (Sheridan and Kratochwill 2007) attempts to find a solution to this problem. CBC recognises the bidirectional nature of the relationship between parent and teacher in supporting a child where "parents, teachers, and other caregivers or service providers work as partners and share responsibility for promoting positive and consistent outcomes related to a child's academic, behavioural, and social-emotional development" (Sheridan and Kratochwill 25). CBC aims to take into account and make use of parents' knowledge of their children and of cultural differences and to strengthen home-school partnerships in such a way that they truly become partnerships. Power in this relationship, unlike the traditional model of parental involvement, lies equally with parent, school and child. The barriers of lack of social and cultural capital are reduced since the input of all parties is equally valued and they work together to break these barriers down.

These models all move away from the roles assigned in the traditional model of parents as assistants in the teacher's job of educating the child. They recognise the role of parents and school as co-educators and as such equal in importance to a child's education. However, many of the activities defined and measured in studies as parental involvement are still managed and instigated by schools and this creates a conflict.

2.6.3 Categorising Parental Interactions

This thesis looks explicitly at parents' mathematical interactions with their children, which normally, but not exclusively, take place outside school. These interactions will be described using two distinct terms: parental involvement and parental engagement. The definitions are based on those proposed by Goodall and Montgomery (2014). Parental involvement is defined in line with the dictionary definition of involvement. As such, a parent is demonstrating parental involvement with mathematics learning if they are taking part in a mathematical activity with their child. The outcomes of this involvement may be either positive or negative. Parental engagement goes further and involves "a greater commitment, a greater ownership of action, than will parental involvement" (Goodall & Montgomery 2014:2). Thus parental engagement with mathematics learning is defined in this thesis as: activities that parents engage in with or for the benefit of their child which are not directed by the school. Such activities originate with the parent and are a response to the parent's knowledge of their own child and that child's mathematical learning needs. According to Goodall and Montgomery (2014), parental support of learning that involves parental engagement is the most beneficial for the child. Using these definitions, parental involvement with children is not necessarily seen as having a positive effect on the child involved. The ambiguity raised by this issue can be understood by viewing parents who take part in such activities as attempting to carry out the type of involvement they assume is expected by the school or believe will be beneficial when, in reality, they are misapplying the principles. Using the learning zone model (Lee and Johnston-Wilder 2013, see section 2.5.2) they are causing their child to work in the red or danger zone. Hence the interactions result in negative rather than positive effects. Parental engagement is defined as a positive form of interaction that takes account of a child's needs and ensures they are working in the growth zone. When looking at interactions between parents and children parental engagement rather than involvement is the desired goal.

Support which takes account of a learner's needs, which in the context of parental interactions in this thesis is categorised as parental engagement, was described by Wood, Wood and Middleton (1978) as *contingent support*. When an individual provides *contingent support* they adapt the nature of support they provide in line with the amount of success that the person they are helping is currently experiencing. By doing so, they provide the optimum level of support at any given time. When working on a specific task, Wood et al. (1978) described the ideal situation of the *contingent shift principle* in which when an individual fails at the task, the person helping them increases their level of involvement with and control over the task, and when they succeed involvement and control are decreased. Working in such a way as to provide contingent support to a learner is often described as *scaffolding*. The term *scaffolding* was inspired by Vgotsky (1962) and adapted for use in the classroom by Bruner (1985). It refers to the practice of providing support for a learner only to the level that it is required at their particular stage of learning. If a child starts to struggle support is increased and as they start to master a task support is gradually removed, in line with the *contingent shift principle*.

Studies such as Pratt, Green, MacVicar and Bountrogianni (1992) and Mattanah, Pratt, Cowan and Cowan (2005) have considered parental interactions with their children during mathematics tasks, using Wood's levels of contingent support as the basis for their coding schemes. Both studies consider the construct in the light of authoritative parenting. An authoritative parent is one who has high expectations of their child but is responsive to their needs and encourages autonomy in appropriate situations – in other words their support is contingent. It has been shown that an authoritative parenting style has a positive effect on educational outcomes (Barber and Olsen 1997, Grolnick and Ryan 1989, Mattanah 2001). Pratt et al. (1992) found that variations in children's learning during a task in which they were supported by their parent could be predicted by the type of support their parent gave, and that authoritative parenting styles were positively related to more effective scaffolding and better mathematical outcomes. Mattanah et al. (2005) found that parents' level of contingent support was a predictor of academic performance. In Mattanah et al.'s study the autonomy-supportive aspect of authoritative parenting was closely linked to scaffolding behaviour.

Shumow (1998) used a coding scheme similar to Wood's when measuring the effectiveness of an intervention to improve the nature of parental assistance with mathematics homework. The intervention aimed to encourage parents to provide assistance that encouraged self-regulation and kept children involved in problem solving tasks. Shumow regarded individuals who provided higher levels of contingent support according to this coding scheme as providing more helpful assistance.

Figure 2-3 , created by the author and based on Goodall's six point model (2013), demonstrates how, in theory, parenting for MR supports parental engagement and contingent support including being an authoritative parent as defined in the literature discussed above. Autonomy supportive parenting behaviour is closely linked to the struggle aspect of MR, since a parent who is supportive of autonomy does not immediately provide answers but allows children to work on tasks themselves.

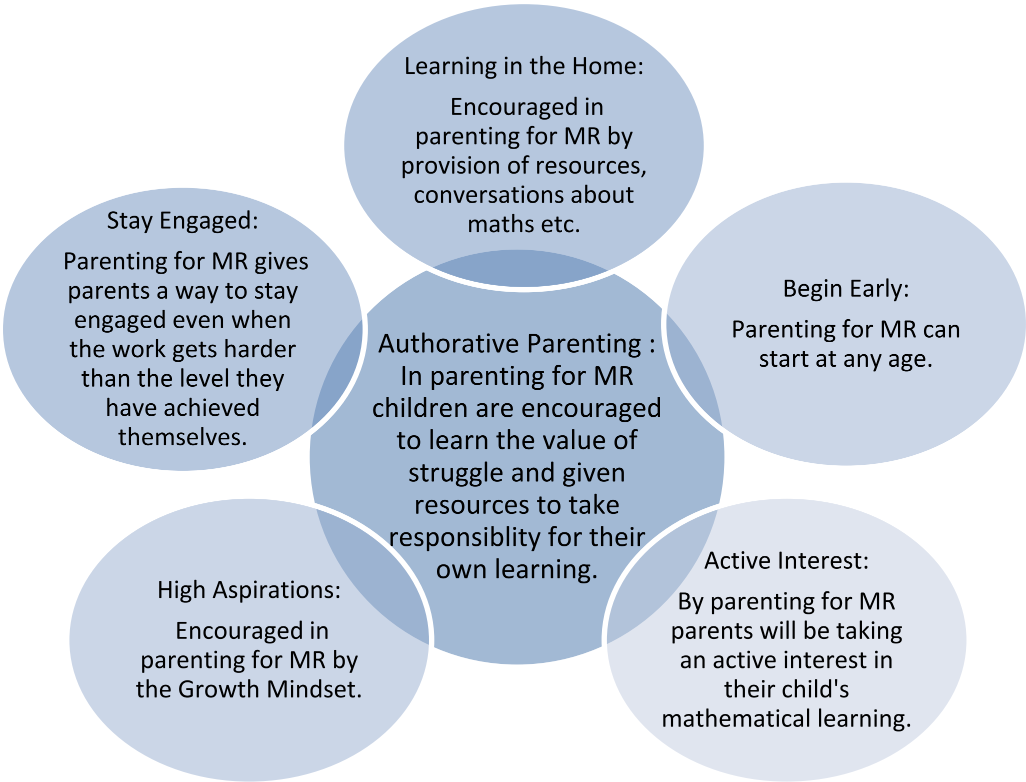

Figure 2-3 Figure Showing How Parenting for MR Supports Being an Authoritative Parent

Parents are not generally teachers and have not been formally taught how to help their children in mathematics and this has been put forward as one of the barriers to them doing so. However, it is clear from work such as Pratt et al. (1992) and Mattanah et al. (2005) on parental support with mathematics homework that some parents do know how to help with mathematics. Where they get this knowledge is not clear but one factor that might have an influence on how they help their children is their own experience of and feelings about mathematics, in particular their MR. Goodall and Johnston-Wilder's case-study (2015) showed that by working on improving a parent's MR they were able to support the parent in helping their child more successfully. However, to date there has been no other research on whether a parent's MR influences the type of interactions they have with their child when working on mathematics.

There is also little research on whether a child's MR is influenced by their parent(s) and if so how this process occurs. Studies such as Goodall and Johnston-Wilder's (2015) and Berkowitz, Schaeffer, Maloney, Peterson, Gregor, Levine and Beilock (2015) would suggest that a parent who is not confident in mathematics themselves can support their child to be confident in the subject if shown a successful way to communicate with them. In a pilot study that the author ran during 2014 (Unpublished) one parent who was highly mathematics anxious and had low MR had two children who were highly MR. Therefore it may be that the interactions that the parent has with their child around mathematics are not just important for the task they are undertaking but also in the development of MR.

2.6.4 The Evidence for Parental Impact on Mathematics Performance

Parental involvement in children's education has traditionally been recognised as positive, with higher levels of involvement leading to higher levels of academic achievement. This has led to a number of policies (e.g. Department for Education 2007, 2014a) and reports (e.g. National Numeracy and Mayor's Fund for London 2016, Gay 2014) advocating parents becoming involved in their children's learning with the aim of improving child outcomes. Indeed, a school's interactions with parents are now included by Ofsted when assessing the effectiveness of the school (Ofsted 2019). The literature on the effectiveness of parental involvement in education is less convincing than these policies would suggest, however, particularly in mathematics.

Borgovoni and Montt (2012) concluded that parental involvement helped improve children's cognitive and non-cognitive skills and motivation. A 2011 Cabinet Office policy paper for improving social mobility concluded that children were more likely to succeed when their parents were involved in their education (Deputy Prime Minister's Office 2011). However, Patall, Cooper and Robinson (2008) conducted a synthesis of the evidence on the impact of parental involvement with homework and concluded that, apart from among very young children; such support produced only negligible effects if any. A study into the effect of mathematically anxious parents working with their children on maths found that the children actually performed worse when their parents worked with them (Maloney, Ramirez, Gunderson, Levine, & Beilock 2015) and other studies into parents working with children on homework have shown negative outcomes (e.g. Hill & Tyson 2009 and Jeynes 2005). Thus it can be seen that parental involvement in education has the potential to be positive but is not always proving so.

Patall et al. (2008) attempted to explain why the relationship between parental involvement and achievement is not a straightforward one. They claim that many factors including the child's age and ability as well as the parent's own skills will influence how effective involvement is. Parents may be trying their best to help but they do not possess the necessary skills to do so. (Wilder 2014, Pomerantz et al. 2007). These skills include both mathematical knowledge, which parents may not have due to lack of education or lack of experience of new methods, and knowledge of how best to support their children's learning. This lack of knowledge may mean that, with the best of intentions, parents are causing their children to work in the danger or comfort zones and thus are participating in negative parental involvement rather than parental engagement.

The issue is also clouded by the fact that parental involvement is often, although not exclusively, triggered by a request from a child for help. Thus some parents who are more involved with their child's mathematics education are responding to a child who is struggling with mathematics. Thus poor outcomes in mathematics may be the cause, not the outcome of parental involvement (Patall et al. 2008, Georgiou 1997). These two issues, parents being untrained in supporting their children and being more likely to be helping those who are already struggling, are also cited as reasons for negative correlations between homework support and academic outcome in a recent Education Endowment Foundation report (Education Endowment Foundation 2018).

A further reason that is not so widely discussed in the literature may be that while parents are outwardly supportive of mathematics education their underlying thoughts and feelings about the subject may lead to different messages being passed on to their children. Lane (2012) describes how adults attempt to be encouraging and vocalise positive feelings about mathematics whilst evidencing any negative feelings they may have through their non-verbal behaviour. Since, as discussed in section 2.4, many people have a negative view of mathematics it is possible that these feelings are what is being passed to children, regardless of parents' outward support of the subject. This may be particularly true of parents who do not themselves possess MR. Such parents have low levels of belief in growth, low value for mathematics and do not understand that it is necessary to struggle in mathematics, much less know how to do so. Therefore when working with their children they may be inadvertently passing on these negative feelings, possibly even their own lack of MR, as they attempt to help them.

These findings suggest that parents need support in helping their children with mathematics. Such support should include information about the mathematics their children are using, information about how best to support their child and the space to consider and possibly amend their own negative thoughts and feelings about mathematics.

2.6.5 The Evidence for Interventions to Support Parents

There have been several reviews of interventions to help parents support their children. A review into parental interventions to support disadvantaged children found few effective interventions (Gorard and See 2013) and thus concluded that it was hard to say what worked. It concluded that successful interventions need to involve initial training of parents as well as on-going support and cooperation between teachers and parents. The review found that interventions that simply encouraged parents to work with their children without teaching them how to do so were not effective. Gorard and See (2013) also identified the problem of getting parents to be involved in such interventions and the high dropout rate as contributory to their lack of success. Brief, flexible interventions would therefore seem more promising.

A Department for Education review of best practice in parental engagement (Goodall, Vorhaus, Carpentieri, Brooks, Akerman and Harris 2011) found that interventions that reviewed and targeted the needs of parents were most effective. The authors also concluded that those interventions that included training in parenting skills were more effective than those which did not. The review's authors found that parents needed clear guidance on what they should be doing in order to support their child. Thus the best interventions were ones which assessed the needs of parent and child and gave the parent specific strategies to address these needs.

There are few evidence based studies of interventions for parents on how to help with mathematics. Of those that do exist, the interventions frequently focus solely on teaching the mathematical techniques that children need to learn and encouraging parents to do more mathematics with their children not on how they are working together (e.g. Balli, Wedman and Demo 1997, Muir 2009 and 2012). Balli et al. (1997) studied the effect of prompting parents to support with mathematics homework on levels of involvement and achievement and found that although parents became more involved after prompting there was no effect on achievement Muir's (2009) intervention encouraged parents to participate in structured numeracy activities with their children. No analysis of the effects on achievement was undertaken. In Muir (2012) this project was extended to support parents by teaching them about the mathematics their children would be doing but again there was no focus on how they helped or how this affected achievement. Muir (2012) did conclude that it was important that the affective domain was considered for the parents as their own experiences were influencing how they worked with their children.

The most well-known large scale projects that encourage parents to work with their children on mathematics are the IMPACT and Ocean Mathematics projects. The IMPACT Project (Merttens and Vass 1993) is based around supporting schools in providing materials for parents to take part in mathematical homework activities with their children. These are then brought back into the classroom to feed back into the children's work. The project reports success in engaging parents with the activities with the assumption that this engagement is necessarily helpful but there is little direct evidence on its impact on achievement. The Ocean Mathematics Project (Bernie & Lall 2008) also provides mathematical homework activities for parent and child to work on but in addition parents attend workshops with their children to learn about the activities and the mathematics their children are doing. This project did report links between the sessions and increased achievement although they reported that other initiatives may also have had an impact on raising achievement. Both of these projects emphasised the bi-directional nature of their initiatives, emphasising that they helped the parents to become partners in their children's education and encouraged feedback between home and school.

2.6.6 Conclusions

The evidence on parental involvement suggests that simply asking parents to become more involved with their children's mathematics education may actually be empowering them to help in the wrong ways and may be detrimental to outcomes. Interventions need to be run to support parents in helping their children in mathematics. Such interventions need to ensure parents possess the skills to help their children effectively. Thus an intervention needs to assess the parents' own mathematical knowledge and how they currently work with their child and demonstrate the positive ways that they need to be involved with their children's education. Interventions also need to consider the parents' prior experiences of and feelings towards mathematics.

It may even be that different parents need different approaches. Some parents will be unaware of particular mathematics techniques but if they were taught them they would know how to correctly support their children. Others may be aware of all the techniques but when trying to convey them to their children, may be doing so in negative ways and they need to be made aware of this. Some parents will know neither the techniques nor the way to convey them. Finally some parents will know both and they will not need interventions to help them. In developing interventions to support parents in helping their children in mathematics, educationalists either need to create a wide range of support products for the different experiences of parents that may access them or more realistically develop an intervention that is more readily adaptable to a wider range of parental backgrounds and skills.

Mathematical resilience (MR) may be particularly useful for supporting a wide range of parents in helping with mathematics. The concept is easy to understand with no technical psychological terms and has a focus on the needs of the individual learner which can be used to promote parental engagement rather than simply involvement. Along with the concept of the growth zone diagram (Lee and Johnston-Wilder 2013) it could be used to enable a parent to think about the experience their child is having whilst learning mathematics and how this could be improved, and also allow a parent to reflect upon their own mathematical experiences and how these could be impacting their child. Parenting for MR is also linked to optimal parenting styles. Thus it seems possible that if an intervention were designed to help parents promote MR in their children, such an intervention would possess the attributes of successful interventions; namely adaptability to different groups of parents, easy to understand, brief and aimed at promoting the right kind of support. This project looks at whether it is possible to design such an intervention.

2.7 Overall Conclusions and Thesis Aims

This chapter has considered the problems with mathematics education in England and some potential solutions. Despite changes brought in with the National Curriculum in 2014, there are still large numbers of students leaving school without the level of mathematics that they need, and attitudes to mathematics are widely negative. This means that individuals are avoiding mathematics once they have left school and therefore levels of numeracy in the general population are low. The promotion of Mathematical Resilience (MR) has been proposed by the author as a solution to these problems. MR is an approach to mathematics that leads to more positive attitudes towards mathematics and is likely to lead to success in the subject. The theory has its roots in the affect literature but it is also strongly rooted in practical experience of teaching and learning and studies of learners who perform at different levels in mathematics. MR goes further than many other affective constructs because it combines different attitudes towards mathematics in such a way as to enable learners to respond positively to difficulties and successes in the subject. MR has shown great promise with secondary and college students who are struggling with mathematics and as such it is likely that if young children could be taught to be mathematically resilient they could to some extent be immunised against the problems that they will encounter as they continue to learn mathematics. However, this has not been proven and, since it would require a lifespan longitudinal study to do so, it is beyond the scope of this study. This thesis will consider the immediate evidence for the effect of MR on performance and for how MR develops among young children.

In line with the ecological model of development, it has been proposed that an individual's mathematical development is impacted by the systems surrounding that individual. In the current study the impact of the micro- and mesosystems in the form of interactions with parents will be investigated. The impact of parents on the formation of early attitudes to mathematics has been discussed and suggestions for an intervention based upon MR to support parents in working with their children have been made. The second aim of this thesis will be to develop and evaluate such an intervention.

The decision has been taken to carry out this research with Year 1 children. This is because Year 1 is the first year in which children formally study mathematics and thus it may be supposed that their attitudes towards the subject may be developing around this time. Furthermore, at this age the children are studying relatively simple mathematics which will be accessible to most parents and therefore it may be easier to get parents engaged with their children's mathematics education while they are at this stage of their education.

Chapter 3 Methodology

3.1 Chapter Summary

This chapter discusses the methodology underpinning the research. It details the methods and procedures providing a guide to the separate studies conducted in the thesis including recruitment procedures, samples, scales and measures used, and indicates where the data collected in each study has been used.

3.2 Introduction

In the previous chapter two major problems with mathematics education were identified; large numbers of students are leaving education without the required qualifications and attitudes towards mathematics in the wider population are widely negative. Chapter 2 provided a theoretical argument for the promotion of MR in young children in an attempt to improve mathematical outcomes and attitudes. The studies detailed in the remainder of this thesis consider data-based evidence for this argument and study the following research questions:

1. Can MR be effectively measured in children as young as 5 and 6?

As discussed in Chapter 2, it was decided to carry out the research with Year 1 children. It was initially necessary to consider whether MR could be measured in this age group as there was no extant means of measuring it. Although there has been an increase in research into attitudes towards mathematics in younger children in recent years this is still an area where further research is necessary (Dowker, Ashcraft and Krinzinger, 2012) and as such it was important to establish that the concept of MR made sense in the context of such young children.

2. Are there links between MR and performance in primary aged children, particularly those in Year 1?

Chapter 2 suggested that higher levels of MR would be linked with higher levels of performance. This thesis aims to investigate whether this is true in practise in primary aged children, particularly those in Year 1.

3. What affects the development of MR?

There has been little research on how MR initially develops in students. The ecological model (see Section 2.3) suggests that children's attitudes will be affected by five different systems as well as their own individual characteristics. This thesis looks to investigate potential influences on MR in children's individual, micro- and mesosystems including the child's own experience of mathematics (measured by their performance level and changes in that performance level), the school they attend, their teachers opinion of them and the attitudes of their parents.

4. Can an intervention for parents which introduces MR positively change how they work together on mathematics and improve parent and child MR and child performance?

Prior to beginning this course of study the researcher was conducting classes for parents aiming to help them to support their children in mathematics and introducing them to the concept of MR. Therefore the final question considered in this thesis was whether such classes were effective in achieving the desired outcomes.

The studies that were conducted as part of this thesis were developed iteratively in response to research need and opportunity and driven by the research questions. Studies were initially carried out to develop a scale to measure MR in Year 1 children (Studies A, B, C). These studies looked to establish the reliability and validity of the scale through cognitive interviewing, piloting of the delivery format of the scale and the use of exploratory factor analysis. Data from a later study (Study G) was used to perform confirmatory factor analysis on the scale. One study (Study D) validated the use of the MRS scale (see Section 3.7.1) with parents to enable parents' MR to be measured in subsequent studies. Three studies (Studies E, F and G) looked at links between mathematical performance and MR. One of these (Study E) also considered the question of links between parental and child attitudes to mathematics and between parental and child attitudes and the way they worked together. The final three studies (Studies H, I and J) were concerned with the development and trialling of the parental MR intervention. This chapter gives an overall description of the recruitment, sample, scales and measures for each study and where they are used within the thesis.

3.3 Research Approach

This thesis uses a mixed methods approach, with a combination of quantitative and qualitative techniques. Mixed methods were chosen to reflect the tension in mathematics education where results are usually measured quantitatively, e.g. in tests or exams, but each individual's experience of learning mathematics is different. Changes in a person's attitude or approach to mathematics may not be immediately reflected in an improvement in their test scores but over time new ways of working may well lead to better outcomes. The advantage of mixed methods research in this situation is that it allows both quantitative and qualitative changes to be measured, allowing changes in attitude or approach which may affect future performance to be identified. A second advantage of the mixed methods approach to the thesis was the ability to triangulate results, improving the validity of findings.

The methods used in this thesis were chosen to be the most appropriate for each study. They were generally directed by the research questions although in certain circumstances time considerations also played a part in the choice of method. When developing the scale for measuring children's MR, the qualitative technique of cognitive interviewing was used to refine the scale and ensure it was in a form which would be understood by Year 1 children. Undertaking this step before going to a large scale quantitative trial meant that the children in the main trial were more able to complete the scale and thus the data collected was more accurate and data collection was more efficient. Quantitative methods were then used to further assess the reliability and validity of the scale, in line with recommendations for the development of a psychometric scale (e.g. Streiner and Norman 2008). Even though the scale had been adapted from an existing scale, exploratory factor analysis was chosen as the most appropriate form of initial analysis since the intended population was so different from that of the original scale and it was necessary to ensure that the concept of MR made sense in this population. Confirmatory factor analysis was then used to confirm the factor structure in a different sample.

In the remaining sections of the thesis the following methods were used:

Correlational analysis – This was chosen to identify possible links between different attitudes to mathematics and between attitudes and performance. Partial correlations were used to look at whether initial attitudes and performance in mathematics were affecting later outcomes.

Regression analysis – This method was chosen to look at which particular attitude was having most impact on performance.

Trends – Trends in data were considered to see how children's attitudes were developing over time. Trends must always be considered with caution and were used here in conjunction with other methods (see Section 3.8).

Anovas –These were used to assess whether there were differences in the way the MR of different groups of children changed over time.

Coding of performance – Coding protocols were used to consider the complexity of mathematics a child had used in a particular task. Rather than just allowing performance to be assessed as right or wrong this enabled the type of mathematical thought behind the performance to be evaluated. This was then compared with the child's level of MR.

Coding of parental interactions – A coding protocol for parental interactions was developed based on Wood's contingent levels of support (Wood et al. 1978). This was used to calculate the contingent shift ratio. These methods were based on those used in previous studies of parental interactions with children around mathematics found in the literature.

Analysis of transcripts – Ideally conversational analysis would have been carried out on the transcripts of parental engagement with their children on a maths task. However due to the time consuming nature of such analysis and the scale of the other research questions under consideration it was decided to perform a less time consuming analysis which looked for similarities and differences between transcripts at different levels of performance and MR. This analysis was used in conjunction with the quantitative analysis to draw conclusions.

Process Evaluation – This was used to assess the effectiveness of the intervention and how well it was delivered and was chosen because of the likelihood of problems with the delivery of parental interventions identified in Chapter 2, in order that such problems could be taken into consideration in the overall analysis.

Case Studies – Case studies were used to capture changes brought about by the intervention that were not picked up by the quantitative data due to small sample sizes. The case studies that were chosen exemplify the most positive changes that took place and show the potential for the intervention although it is not intended to claim that such changes are possible in all cases.

Further details of the analyses undertaken and the reasons for their use can be found in the relevant chapters.

3.4 Brief Descriptions of the Studies

In total ten studies were conducted. Brief descriptions are provided for reference in Table 3-1 and more complete descriptions are provided in the remainder of the chapter.

Table 3-1 Description of Studies Conducted in Chronological Order

Study	Brief Description	Sample
A	Cognitive interviewing of Year 1 children to determine items for scale pilot	n = 7 Year 1 children
B	Pilot of BCMRS	n = 42 Year 1 children
C	Trial of BCMRS	n = 322 Year 1 children
D	Online trial of MRS with parents used to validate MRS with sample	n = 48 parents
E	Experiment run at Coventry University Young Researchers event in which MRS data was collected from parents and BCMRS data from children, and parents and children completed a mathematical task together	n = 42 parent and child dyads
F	Experiment run at Coventry University Young Researchers event in which BCMRS data was collected and children completed a mathematical task	n = 74 children ranging from age 5 years 11 months to 12 years 8 months
G	Longitudinal study in which children's performance and MR was measured over an academic year	n = 74 Year 1 children
H	Piloting of the intervention, different ways of collecting data and running the intervention were trialled	n = 8 parents
I	Online survey of parents about what format of intervention would be most useful	n = 55 parents
J	Trialling and evaluation of the final intervention for parents to support their children in mathematics, data on parents were collected pre and post intervention and children's performance and MR was measured over an academic year.	n = 6 parents, n = 29 Year 1 children

Note: MRS is the Kooken Mathematical Resilience Scale (see Section 3.7.1)
BCMRS is the Baker Children's Mathematical Resilience Scale developed as part of this thesis

3.5 Recruitment

Recruitment of schools for studies A, B, C, G, H and J was achieved by sending gatekeeper letters to schools in the local area or on the university's schools database, including those who had taken part in previous studies. In studies B and C opt out letters were sent to all parents of children in Year 1 in schools that had agreed to take part, as was the policy of the university at that time. Those children whose parents had not returned the opt-out form and were present on the day testing took place were asked if they were happy to fill in the instrument. Only those children who indicated they were happy to do so completed it. In studies A, G, H and J opt in consent letters were sent to all children in Year 1 in those schools that agreed to take part, in line with changes to university policy. These letters also collected some background data on the children. Only children whose parents had returned opt in consent forms were asked to take part and if they declined to do so they were allowed to return to their normal classes.

In studies H and J once parents had returned letters indicating they would like to take part they were contacted by the researcher who tried to arrange sessions at a mutual agreeable time and place. Where it was not possible to accommodate everyone who had replied, the option which meant most participants could attend was adopted.

Study D was an online form of the Kooken Mathematical Resilience Scale (MRS: Kooken et al, 2013) hosted on the BOS tool. It was distributed using social media via the researcher's Facebook page for parents. All participants were anonymous and agreed to their participation in the research by checking a tick box.

Studies E and F were carried out as part of events run in two consecutive summers at Coventry University by the Psychology, Behaviour and Achievement Research Centre. These events were designed to promote psychology to young people and allow researchers to carry out psychological experiments. Parents pre-booked and brought their children along to a morning or afternoon session during which the children took part in experiments and fun activities. Background data were collected about the children when sessions were booked and confirmed on the day of attendance when children were randomly allocated to experiments.

Study I was an online survey consisting of three questions developed using the BOS tool. It was distributed using social media via the researcher's Facebook Page and Twitter account. The survey was also shared on the social media sites Netmums and Mumsnet. Email consent was obtained from the sites before the survey was posted. All participants were anonymous. Participant consent was through a check box in which participants agreed to their data being used for the purposes of the research. Three participants did not tick this check box and their responses were excluded from the research.

3.6 Participants

3.6.1 Study A

Cognitive interviews were carried out with seven children (three girls and four boys) in Year One at a small rural Church of England voluntary controlled primary school in Warwickshire. The school achieved a status of outstanding at its last Ofsted inspection in 2008, a status which was unchanged after an Ofsted monitoring inspection in November 2015. The school provided current mathematics assessment levels for all children who were interviewed. Four of the children had been assessed as working at expectations, two were working at greater depth and one was working towards expectations (see section 3.7.3).

3.6.2 Study B

Details of the two schools that took part in the pilot of the Baker Children's Mathematical Resilience Scale (BCMRS: current thesis) can be found in Table 3-2. School 1 was the same school that took part in Study A.

Table 3-2 Information on Study B Schools (GoodSchoolsGuide.co.uk 30/10/16 and Telegraph Education 15/12/16)

School	Percentage Achieving Level 4 or above in Reading, Writing and Mathematics in 2015	Average Scaled Mathematics Score 2016 SATS
1 (n = 19)	*	101
2 (n = 23)	80%	102

* School 1 didn't report Key Stage 2 levels in 2015 as all mathematics levels were disallowed due to problems with administration.

3.6.3 Study C

Five schools were recruited to the trial of the BCMRS. Table 3-3 shows details of the schools. All schools were state funded non-selective, mixed schools.

Table 3-3 Information on Study C Schools (GoodSchoolsGuide.co.uk 30/10/16 and Telegraph Education 15/12/16)

School	Percentage Achieving Level 4 or above in Reading, Mathematics and Writing in 2015	Average Scaled Mathematics Score 2016 SATs
3 (n = 83)	**	**
4 (n = 30)	71%	102
5 (n = 54)	70%	99
6 (n = 31)	87%	104
7 (n = 89)	98%	106

**School 3 was an infant school and had no children at Key Stage 2.

The data from studies B and C were combined in the factor analysis of the BCMRS (see Chapter 4 where further details of the children can be found).

3.6.4 Study D

The MRS was trialled online for use with the parent population. All participants (n = 48) were parents. No other data was collected as it was an exploratory study.

3.6.5 Study E

A study was conducted at Coventry Young Researchers which involved parents and children working together on a mathematics problem. The participants were forty-two parent and child dyads. Thirty-four of the parents were female, seven were male and one did not specify a gender. Forty of the parents reported that they regularly helped their children with mathematics homework. Table 3-4 shows the highest mathematics qualification that the parents had attained.

Table 3-4 Study E Parent's Highest Mathematics Qualification

Highest Mathematics Qualification	Frequency
Below GCSE	2
GCSE	24
A-level	11
Qualified Teacher Status	1
Foundation Degree	1
Degree	3

Twenty-four of the children were male and eighteen were female. Two of the children had high functioning autism, one had movement difficulties and a fourth had been registered as having SEN at school. The mean age of the children was nine years two months (SD = one year six months, Range = six years to twelve years nine months).

3.6.6 Study F

A study was conducted at Coventry Young Researchers where children completed a mathematics task. The participants were seventy-four children, thirty-four girls and forty boys. Their mean age was nine years one month (SD = one year nine months, Range = five years eleven months to twelve years eight months). Seven of the children had special needs: one was being assessed for dyslexia, one had cerebral palsy, one had SEN support at school for mathematics, one had focus and attention difficulties and two had autism spectrum conditions whilst a third was being assessed for autism. Three had issues with their hearing: one had frequent bouts of mild glue ear, one had mild hearing problems in one ear for mid-sounds and the third had an unspecified hearing problem. Three children did not speak English as their first language.

3.6.7 Study G

A longitudinal study of MR and performance was conducted over the course of an academic year. Six schools indicated they would like to take part, five primary schools and an infant school.

Table 3-5 gives details of the six schools. School 2 took part in the initial assessment of MR but then did not provide teacher assessed levels or respond to any further requests to take part in the study. This school was therefore removed from the study. All children who had only completed one administration of the study or who had missing data were removed leaving seventy-four children.

School 5 took part in all three assessments of MR but refused to provide teacher assessed levels after the autumn term. The children from this school were retained in the study but removed from any analysis that required teacher assessed levels in the spring and summer terms.

Table 3-5 Information on Study G Schools

School	Number of participants present when testing took place	Average Scaled Mathematics Score 2016 SATs
1	9	104
2	6	103
3	8	103
4	15	107
5	33	NA*
6	9	101

Of the seventy-four children from whom MR data was collected there were thirty-eight boys, thirty-one girls and five children where no details of gender were provided. The mean age of the children at the start of the trial was five years four months. Seven parents did not provide a date of birth for their children. Forty-five of the children were white British, twelve provided no details of ethnicity and the others classified their children as non-White British, European, African or Asian. Ten of the children had English as a second language. There was one child with a hearing difficulty and thirteen with visual difficulties corrected with glasses. Two parents said their children had special educational needs. At the first administration seven of the children were recorded as being below in mathematics, thirteen as working towards, forty-six as working at expectations and eight as working at greater depth (see section 3.7.3).

3.6.8 Study H

An intervention was developed and tested with groups of parents. The participants were eight parents from three schools. They were allocated to groups based on school. Table 3-6 gives details of the participants and schools that formed each group. Further details can be found in Chapter 9.

Table 3-6 Details of Study H Participants

Group	Number of participants	Gender of parents	Gender of children	Type of School
1	3	3 Female	2 Female,	Rural,

			1 Male	Outstanding Ofsted Rating
2	2	2 Female	1 Female, 1 Male	Small town, Outstanding Ofsted Rating
3	3	2 Female, 1 Male	2 Male	Suburban, Good Ofsted Rating

3.6.9 Study I

An online study was conducted into parents needs from a course to help their children with mathematics. All participants (n = 55) were parents. No personal data was sought as it was an exploratory survey to indicate directions for future research.

3.6.10 Study J

A randomised control trial was planned. Eight schools initially indicated that they would be happy to take part in the study but only four schools had participants in the final study. Participants were allocated to one of three groups. Table 3-7 shows detail of the schools, group allocated and number of participants and Table 3-8 gives details of the participants in each group.

Table 3-7 Details of Number of Participants in Study J by School

School	Description	Group Allocated	Number of parents who attended at least 1 session	Number of children from whom data was collected
1	Small village C of E Primary, rated Outstanding by Ofsted	MR Only	2	2
2	Suburban village C of E Primary rated Good by Ofsted	Maths and MR	4	4
4	Village C of E Primary School rated Outstanding by Ofsted	Control	NA	9
7	Suburban Primary School rated Good by Ofsted	Control	NA	14

Table 3-8 Details of the Groups for the RCT

Control Group Participants in the control group came from two schools (see Table 3-7). Although twenty-nine children were originally given permission to take part in the study only twenty-three provided data for at least two of the time points. Of these seven were boys, twelve girls and four parents did not provide details of gender. Eleven of the children were entitled to free school meals. One child had a problem with their hearing and five children had vision problems corrected with glasses. Four of the children had English as a second language. None of the children had special educational needs according to their parents.
MR Only Group Two children and their parents from one school took part in the study in this group. The children were both White British girls, one left handed and one right handed. Neither had free school meals nor was described as having special needs. The parents were both White British mothers with GCSE mathematics as their highest mathematics qualification. One was qualified to NVQ Level 3 and the other had a Master's Degree. Both were employed, one full time and one part time.
MR and Maths Group Four children and their parents from one school were initially assigned to this group. A further parent from the school came along with one of the other mothers but only attended the first session. The data was still collected from this parent's child. One of the original parents pulled out part way through and requested that their data not be used. This left three parents who attended all sessions and four children from whom data was collected. The children whose parents agreed for their data to be used were two boys and two girls. Three were left handed and one right handed. All children and parents were White British. Two of the children had free school meals and one had hearing and visual difficulties. The parents were all mothers. Three had GCSE as their highest mathematics qualification and one did not list a mathematics qualification. Two of the parents had degrees and the others were qualified to GCSE and NVQ Level 3 standard. All parents were employed.

3.7 Scales and Measures

With the exception of Study A in which cognitive interviews were conducted and Study I which was an online survey of parents' preferences about attending sessions to help their children with mathematics, the other studies used scales to measure Mathematical Resilience (MR), mathematical anxiety (MA) and performance in mathematics.

3.7.1 Measures of Mathematical Resilience used in the Research

Kooken Mathematical Resilience Scale (MRS) (Kooken et al, 2013)

For the adults who took part in the studies the MRS (Kooken et al, 2013) was used. The scale is a twenty-three item Likert type scale with three subscales, growth, struggle and value which is self-completed by participants. The items are scored from 1 (completely disagree) to 7 (completely agree). The total possible scores on the three subscales are 56, growth and struggle and 49, value. This leads to a total possible score of 161. Kooken et al (2013) cite Cronbach alphas of .83 (growth), .73 (struggle) and .94 (value) for the scale. Further discussion of the scale can be found in Chapter 2 and Appendices 1 and 2.

The scale was validated for use in this study using data from the parents in Studies D and J combined. Ninety-one participants in total completed the scale. The sample was approximately seventy-nine percent female. Five parents failed to complete at least one item on the scale. No response was recorded and the analysis was run including these participants. The number of participants was not ideal for a factor analysis being less than the recommended ten per item (Nunnally, 1978) but it was felt that there were enough participants to assess if there was a problem with the scale so an exploratory factor analysis was run (full details can be found in Appendix 2). Cronbach alphas were calculated and found to be strong for each subscale (Value = .889, Growth = .803, Struggle = .734). Cronbach's alpha for the sample was .850. All items loaded on the expected factor apart from Item 9 which loaded on both Growth and Struggle but since it loaded more strongly on Struggle, the factor to which it was originally assigned, this grouping was retained.

Baker Children's Mathematical Resilience Scale (BCMRS)

For the children taking part in the research a new instrument was developed. Full details of the development can be found in Chapter 4. The final form is a twelve item Likert type scale with three subscales, growth, struggle and value. In most of the studies the scale items were read to the children in classes, small groups or individually and they circled their response on a pictorial scale (see Chapter 4, Figure 4-3).

Participants were asked to colour in a smiley face if they consented to take part in the research and a sad face if they did not. When older children completed the scale (e.g. in Studies D and E) they were allowed to read the scale items themselves once it was clear they could do so successfully. Cronbach alphas for the scale were growth, .62; struggle, .65; value, .50; and scale total, .70 (n = 322). The Cronbach alpha for value subscale is lower than ideal but there are only three items on this subscale. Confirmatory factor analysis confirmed the scale structure.

Each item is scored from -2 to 2 with an answer indicative of MR being scored positively. Therefore the three subscales have scores ranging as follows: growth (-8 to 8), struggle (-10 to 10) and value (-6 to 6). The MR total is calculated by scaling the subscales scores before adding them using the following formula:

$$MR\ Total = \frac{Growth\ Total}{4} + \frac{Struggle\ Total}{5} + \frac{Value\ Total}{3}$$

This gives equal weighting to the three elements of MR and a possible range for total MR from -6 to 6 with positive scores indicative of higher levels of mathematical resilience.

3.7.2 Measures of Attitudes to Mathematics

Mathematical Anxiety Scale (MAS: Betz, 1978)

The *MAS* was used to collect data on the parents' mathematical anxiety. This is a ten-item Likert type scale where participants circle to indicate how strongly they agree with statements about their feelings when doing mathematics. Items were scored from 1 to 7 with responses indicating high anxiety scored with a 7. The highest possible score was 70 and the lowest 10.

Mathematics Attitudes and Anxiety Questionnaire (MAAQ: Thomas & Dowker, 2000)

This scale was used to measure MA and attitude in children. The questionnaire consists of seven categories: mathematics in general, written sums, mental sums, difficult mathematics, easy mathematics, mathematics tests and understanding the teacher. For each category children were asked to point to a picture on a five item pictorial Likert type scale indicating how good they thought they were (Self-Rated Competence), how much they enjoyed it (Enjoyment), what it felt like to fail (Failure Response) and how worried it made them feel (MA). The researchers read the items to the children. Thus children completed 28 separate items. The scales consisted of ticks and crosses for Self Related Competence, sweets and wasps for Enjoyment, and Mr Men style faces for Failure Response and MA. Items were scored from 1 to 5 with 5 representing the most positive attitude. Four scores were obtained for Self-Rated Competence, Enjoyment, Failure Response and MA with the highest possible score for each being 35 and the lowest 7. Note that a high score on the MA scale means a low level of MA.

3.7.3 Measures of Performance

Teacher Assessed Levels

Schools provided data about children's performance in the form of teacher assessed levels. These levels were the judgement a teacher had made about how the child was performing against the expected standard for a child of their school year (generally Year 1), as defined by the National Curriculum (Department for Education, 2014a). The abbreviations used throughout this thesis are shown in Table 3-9.

As a subjective measure, teacher assessed levels differ in interpretation from teacher to teacher and school to school. For example, performance against the National Curriculum targets could be measured against where a child should be at that point in the year or against the end of year target. Using the first measure, children would be likely to remain fairly constant in the level they were awarded across the year whereas using the second, they would be expected to rise from below or working towards to at expectations or greater depth as the year progressed. Despite this disadvantage, they are used in this thesis as they are the most common way of measuring performance in primary schools and as such are the measure of performance that teachers, parents and schools recognise.

Table 3-9 Meanings of Abbreviations used for Teacher Assessed Levels

Abbreviation Used	Assessment with Respect to the National Curriculum
Below	Working Below the Expected Standard – these children were working at a level significantly below the standard expected of their age
Working Towards	Working Towards the Expected Standard – these children were working at a level just below the standard expected of their age
At Expectations	Working At the Expected Standard – these children were working as expected for a child of their age
Greater Depth	Working At Greater Depth – these children were completing work above the level expected for a child of their age

Wechsler Individual Achievement Test – Second UK Edition (WIAT-II: Wechsler, 2005)

The *numerical operations* and *mathematical reasoning* subscales of *WIAT-II* were used as a standardised performance measure in several studies. The numerical operations subscale requires children to complete arithmetic style questions. The mathematical reasoning subscale requires them to understand the context of the question before applying arithmetic. The numerical operations subscale allowed an assessment of whether the children had gained the mathematical skills required of a child their age while the mathematical reasoning subscale enabled an assessment to be made of how they applied these skills to mathematical problems, a skill which comes under the struggle strand of MR. The test was administered and scored as described in the handbook. Where scores are standardised for age, 100 is the expected score on both subscales.

3.8 The Interpretation of Statistical Analyses

When carrying out statistical analysis two types of errors can be made (Field, 2014). Type 1 errors occur when a statistically significant effect is identified where there is not one. When a significance level of .05 is used, an error would be expected to be made 5 out of every 100 times that data collection was replicated. However if more than one test was carried out on the same data the chances of making an error would increase. This increased risk is known as the familywise error rate and can be calculated using the following formula: $1-(0.95)^n$. Therefore if many tests are carried out on the same data, the chance of making a Type 1 error is very high. The second type of error, the Type 2 error, occurs when no statistically significant effect is identified when one is present. Calculations of statistical power give the probability of a test finding a statistically significant effect when one is present. When statistical power is low it is very likely that a test will fail to find an effect which is present. Therefore statistical power of >.8 is recommended (Field, 2014).

Throughout this thesis attempts have been made to control for these errors in the following ways:

- The amount of statistical tests conducted has been kept to the minimum level necessary to investigate the research questions under consideration whilst minimising Type 1 errors.
- Where possible studies have been designed to use both qualitative and quantitative methods which allow statistically significant results to be triangulated.
- More than one study has been used to investigate the same research question. If the same result is found in more than one study and with more than one method this adds weight to the validity of the finding.
- Statistical power is reported to allow the potential for Type 2 errors to be evaluated.
- When interpreting the results of these studies a conservative approach has been taken to statistically significant findings which should be seen as suggestions for links and directions for future research rather than definitive outcomes. This is particularly true of the intervention data where participant numbers were very small.

3.9 The Data Lifecycle

This chapter has detailed the methods and procedures used during this thesis. Ten studies were carried out with the aims of developing a scale to measure mathematical resilience in Year 1 children, exploring links between performance and MR in primary aged children and developing an intervention to help parents promote MR in their children. In order to make the most effective use of time, data from studies were used for several purposes. Table 3-10 shows in which chapter data from each study is used. Data were used in the current chapter to validate the scales used in the thesis. In Chapter 4 data were used to develop a scale to measure MR in Year 1 children. Chapter 5 details a study into links between MR and performance. Chapters 6 and 7 are longitudinal studies into MR and performance. Chapter 8 is a study into parental impact on MR. Chapters 9 and 10 detail the development and trialling of a parental intervention to improve MR in children.

Table 3-10 Details of Where Data is Used in the Thesis

	Ch. 3	Ch. 4	Ch. 5	Ch. 6	Ch. 7	Ch. 8	Ch. 9	Ch. 10
Study A		X						
Study B		X						
Study C		X						
Study D	X							
Study E						X		
Study F			X					
Study G	X	X		X				
Study H							X	X
Study I							X	
Study J					X		X	

Chapter 4 Development and Validation of a Scale to Measure MR in Year 1 Children

4.1 Chapter Summary

This chapter initially considers existing instruments to measure MR in children, and concludes that none were suitable for exploring the current research. The remainder of the chapter contains details of the adaptation of the MRS (Kooken 2013, 2015) for this purpose, and the procedures by which validity and reliability were established.

4.2 Review of Existing Measures of Mathematical Resilience

In order to assess the effect of MR on performance it is necessary to measure MR. In this section existing instruments are considered.

Since MR is a relatively new concept, all measures of attitudes to mathematics were initially included. Chamberlin's (2010) review of the most influential instruments to measure affect in mathematics was used to draw up an initial list of scales for consideration. A search of the literature was then conducted to identify possible instruments developed after 2010; the terms and number of results returned are shown in Table 4-1.

Table 4-1 Number of Papers which may Contain Instruments to Measure MR by Search Term

Search Term	Number of Papers
"Mathematical Resilience"	24
"Academic Resilience in Mathematics"	4
"Attitude Mathematics"	23,654

Since the search term "attitude mathematics" returned 23,654 articles, these were restricted to peer-reviewed articles, subject mathematics and then by date to 2010-2018 leaving 1961 articles. The abstracts for these 1961 articles were read and any that mentioned the use of measures, instruments or scales for mathematics attitudes were retained. Studies which stated they had developed their own surveys or questionnaires without psychometric testing were not retained. This left 124 articles in addition to the 28 returned by the other search terms. These articles were reviewed. Any new instruments were added to the list, which can be found in Appendix 1. There was no cited instrument to measure MR in 5 and 6 year olds, since they had either not been validated for use with this age group or they did not measure MR as defined in this thesis or both. It was therefore necessary to adapt one of the scales or create an instrument which was suitable to measure MR with the target audience.

A shortlist of potential scales for adaptation was drawn up using the following inclusion criteria:

1. Validity and reliability data were available for the scale.
2. The scale measured at least one concept analogous to value, struggle or growth.
3. The scale was short enough for administration to Year 1 children, ideally taking no longer than 15 minutes to complete, or had a subscale which could be completed rather than the whole scale.

Scales which only measured mathematics anxiety (MA) were excluded as it was decided to administer an MA scale alongside the MR one when necessary. The remaining options are listed in Table 4-2 and discussed in detail in Appendix 2.

Table 4-2 Potential Scales for Adaptation to Measure MR in Young Children

Fennema-Sherman Mathematics Attitude Scale (Fennema & Sherman, 1976)
Mathematics Attitude Scale (Aiken & Dreger, 1961)
Attitudes Towards Mathematics Inventory (Tapia & Marsh, 2004)
Grit Scale (Duckworth, Peterson, Matthews & Kelly, 2007)
How I Feel About Maths Scale (Chapman, 2003)
Zsoldos-Marchis Questionnaire (Zsoldos-Marchis,2014)
Kooken Mathematics Resilience Scale (Kooken, Welsh, McCoach, Johnston-Wilder & Lee, 2013)
Academic Resilience in Maths Scale (Ricketts, Engelhard & Chang, 2015)

The consideration of scales described in Appendices 1 and 2 suggested that the Kooken Mathematics Resilience Scale (MRS: Kooken et al. 2013, 2015) and the Academic

Resilience in Maths Scale (ARM: Ricketts et al. 2015) were the most suitable for adaptation. Of the two, the ARM scale is less clearly linked to the concept of MR. It measures the participant's self-perception of resilience and was developed with 7th and 8th grade middle school children. It was developed using Item Response Theory which has the advantage of increasing its generalizability to other populations. However, it is unclear whether self-perception of resilience is the same as actual resilience and thus it may not be measuring the required concept.

The MRS which was developed directly from MR theory with Lee and Johnston-Wilder as co-authors on the paper fits more closely to the construct of MR defined in Chapter 2. For this reason the MRS was considered more suitable for the current research. The MRS enables participants' scores on the three strands of MR (value, growth and struggle) to be extracted. An overall MR score was not validated during the development of the scale. The scale was developed with actuaries, college and university students and successfully underwent content validity testing, exploratory and confirmatory factor analysis with this population. It was therefore decided to adapt and validate a version of the MRS for use with a Year 1 population. This version would include an overall score for MR as well as individual subscale scores for the three strands.

4.3 Development of the Baker Children's Mathematical Resilience Scale

In order for a scale to be accepted, validity and reliability must be demonstrated (Streiner and Norman 2008). Validity is a measure of how accurate the scale is at measuring the construct under investigation. Reliability is a measure of consistency and two types of consistency are considered: internal consistency, that is consistency within the scale, and test retest reliability, that is whether the scale records the same responses for the same individual on different occasions (Steiner et al. 2008). The following sections describe the different stages of the development of the BCMRS. First, scale development was carried out, including rewriting the items, cognitive interviewing to ensure validity and piloting of the format. A second study assessed the internal reliability of the revised scale. A third set of analyses examined whether the test followed the anticipated internal structure. Finally, test retest reliability was examined.

4.3.1 Adaptation of the Scale and Cognitive Interviewing

Since the original MRS (Kooken et al. 2013) had not demonstrated validity for use with young children, the scale was adapted to make it more suitable to this age group. The scale items were rewritten by the author in consultation with two literacy colleagues, to make the language suitable for Year One (5 and 6 year old) children. Longer sentences were shortened. Some phrases which were difficult for children to interpret or would be irrelevant to them were changed to reflect expected life and mathematics experiences. Table 4-3 shows the changes that were made to the scale.

Table 4-3 Adaptations Made to the MRS to Make Items Suitable for Children

Item on BCMRS	Item on MRS*	Item from Adult Scale	Amended item on children's scale
1	V3	Math courses are very helpful no matter what I decide to study.	Maths will help me when I grow up.
2	S6	Struggle is a normal part of working on math.	It is OK to find maths hard.
3	G4	If someone is not good at math, there is nothing that can be done to change that.	If you can't do maths now you will never be able to.
4	G2	Math can be learned by anyone.	Anyone can learn maths.
5	S1	Everyone struggles with math at some point.	Everyone finds maths hard sometimes.
6	V1	Math is essential for my future.	I will need maths when I grow up.
7	G3	If someone is not a math person, they won't be able to learn much maths.	If someone is not in a good maths group they won't be able to learn much maths.
8	S3	Good mathematicians experience difficulties when solving problems.	Children who are good at maths find some of the questions hard.
9	S4	People who work in math related fields sometime find math challenging.	People who have jobs that use maths sometimes find maths hard.
10	S5	Everyone makes mistakes at times when doing math.	Everyone gets things wrong sometimes when they are doing maths.
11	V2	Math will be useful to me in my life's work.	Maths will help me.

12	S8	People who are good at math might fail a hard math test.	People who are good at maths might not get all the answers right.
13	G6	Everyone's math ability is determined at birth.	You are born good or bad at maths.
14	V4	Knowing math contributes greatly to achieving my goals.	I need to do maths to help me to do what I want.
15	V6	Having a solid knowledge of math helps me understand more complex topics in my field of study.	Knowing lots of maths helps me do things at school when I am not in a maths lesson.
16	V9	Math develops good thinking skills that are necessary to succeed in any career.	When you do maths you learn ways to think that help you be good at other things.
17	G7	Some people cannot learn math.	Some people can't learn maths.
18	S11	Making mistakes is necessary to get good at math.	You have to get things wrong to be good at maths.
19	G8	Only smart people can do math.	Only clever people can do maths.
20	S7	People in my peer group struggle sometimes with math.	People in my class sometimes find maths hard.
21	V7	Thinking mathematically can help me with things that matter to me.	Thinking the way I do in maths helps me with things I like to do.
22	V8	It would be difficult to succeed in life without math.	It will be hard to do well when I grow up if I am not good at maths.
23	G5	People are either good at math or they aren't.	People are either good or bad at maths.

* Note G = growth, S = struggle, V = value refer to the subscale the item belonged to on the original scale.

The MRS records responses on a 7-point Likert type scale and it was decided to retain the Likert format in the children's scale. However, it was decided to reduce the number of options, making the choice simpler. Thus a 5-point scale was adopted. Both 5- and 7- point Likert scales are suitable for and commonly used in attitude measurement scales (Kline 2013). It was also decided to use pictures rather than descriptions to represent the categories in order to make the scale accessible to children with low levels of literacy. The use of pictures has been found to be valid in measurement scales (Streiner et al. 2008) and their use with children aged 5 and 6 has been validated in studies such as Hunter, McDowell, Hennessey and Cassey (2000). Figure 4-1 shows the pictures that were used ranging from two thumbs down (completely disagree) to two thumbs up (completely agree).

Figure 4-1 Example of Pictorial Scale Used in the BCMRS

Given that Kooken recommended qualitative research to improve items on the original scale (Kooken 2015: 22) and that significant changes had been made to the scale items from those originally conceived; cognitive interviewing was used to further ensure validity. Cognitive interviewing involves interviewing participants about the thought processes they have gone through to arrive at the answer they gave (Willis, Caspar and Lessler 1999). It is commonly used within the health sector for scale development (Dietrich and Ehrlenspiel 2010) and enables the researcher to establish if statements, questions and individual words are being understood as intended by all participants and to identify particular words, phrases or items that need to be amended or deleted from the scale. In this case it was used to establish whether items were age appropriate, whether children were able to complete the scale successfully and whether any amendments could be made to make the scale easier to complete.

There are two main sub-methods of cognitive interviewing – *think aloud,* where participants explain their thinking to the interviewer as they answer the question and *verbal probing*, where the interviewer asks questions about why the participants have arrived at the answer they have given. It was decided to use *verbal probing* in this case as it does not require training of the participant and there is less effect on responses if the participant has an introvert character (Willis et al. 1999). Thus it is felt to be more appropriate for young children.

Concurrent rather than retrospective probing was used for the interview. In this type of probing the interviewer reads out the question or statement, the participant answers and the interviewer immediately uses probes to find out more information about the answer given or the participant's understanding of the item. Using this technique the participants' thoughts are fresh in their mind, reducing the chance of them making up an explanation which can be a criticism of retrospective probing, that is probing done after completion of the whole scale (Willis et al. 1999).

Sample

The sample was taken from Study A. Details of the recruitment process and participants can be found in section 3.6.1. All participants (four boys and three girls) were in Year 1.

Method

A schedule of questions and probes was written prior to the interviews (see Appendix 4). Each participant was initially asked some general questions about their views on mathematics. The meanings of the pictures on the scale were explained to them and then the interviewer read out a scale item before asking the participant to circle the picture that showed how much they agreed with it. The interviewer then asked the probe question/s and the participant responded. This continued for each subsequent item in the scale.

The following types of scripted probes were used, in line with guidelines from Willis et al. (1999):

1. Comprehension/interpretation probes – e.g. What do the words 'in a good maths group' mean to you?

2. Paraphrasing – Participants were asked to put the item into their own words.
3. General Probes a) Why did you choose that answer?
   b) Was that easy or difficult to answer?
   c) Did you understand what that meant?

Non-scripted probes were also used where the researcher wanted to clarify what the child was thinking. During the course of the interviews several of the children began to use the *think aloud* method without prompting and in these cases some probes were omitted.

Interviews were conducted in a quiet room next to the school office by the author. Six of the interviews were audio recorded and later transcribed. Some handwritten notes were also taken. The parents of the seventh child refused consent for recording so handwritten notes were taken at the time and written up later. Interviews took around twenty minutes to keep the children engaged although one child asked, and was permitted, to leave early. It was made clear to participants that the interview was to assess how well the scale worked, not how well they performed on the scale. All participants were given a sticker and a pencil for their participation, whether they completed the whole scale or not.

The interviews were conducted on two separate afternoons with four children being interviewed on the first occasion and three being interviewed on the second. During the first round of interviews it became clear that two of the items were difficult for all of the children to answer. Thus these items were changed for the second round of interviews.

Results

The following changes were made to items as a result of the cognitive interviews.

Replacement of the word ‘hard’ with the word ‘tricky’

Several of the items included the word ‘hard’ to describe the experience of doing mathematics. Probes were asked around this word to make sure that the children understood its meaning, including asking the children if they understood/would prefer the word 'difficult' and if they could suggest a more suitable word. There was no agreement around whether hard or difficult was preferable or understood but when asked to suggest a more suitable word 'tricky' was the most commonly suggested. It was therefore decided to adopt 'tricky' for all items describing struggle in mathematics, particularly as it is a word many Year One children are familiar with because it is used to describe common exception words in literacy (for example in the Jolly Learning scheme (Jolly Learning 2018).

Item 7: If someone is not in a good maths group they won't be able to learn much maths.

Understanding of the phrase "a good maths group" proved problematic with some children comprehending it as a group where children were good at mathematics while others assumed it meant a group that worked well together. For these reasons the item was omitted from the scale.

Item 10: People are either good or bad at maths.

There were some problems with children assuming this question meant at a single point in time and therefore their answers were not accurately reflecting the children's opinions about mathematics ability over time. Some children agreed with the statement when filling in the scale but when questioned further made comments such as:

Participant	Unless you like learn more
Researcher	And could you do that?
Participant	Yeah

Participant	Yeah. You are either good or bad. Doesn't matter how good you are in maths but you can be good or bad.
Researcher	OK can you change from one to the other? Could you be good and then become bad or be bad and get good?
Participant	Yeah.
Researcher	So

Participant	So you might … when if you are good and then you keep forgetting things in maths and then you might get worse and worse at maths when you keep getting it wrong and then…

which indicated that in fact they believed that people were able to change whether they were good or bad and therefore should have been indicating on the scale that they disagreed. Thus the item was changed to read: *You can't change whether you are good or bad at maths.*

Item 13: You are born good or bad at maths.

There was confusion about the meaning of this question with many of the children saying babies could not do maths but then they would learn. One child said she had chosen the option she had at random and another child became completely distracted from the task, talking about a Paddington Bear figure he could see on the wall. For these reasons it was concluded that the item was too difficult for the children to answer and it was removed from the scale.

Item 16: Knowing lots of maths help me do things at school when I am not in a maths lesson.

During the first afternoon of interviews it became clear that this item was difficult for the children to respond to. The length of time taken to respond was significantly longer than their average times (Item 16 mean = 6.7 seconds, Overall mean for these children = 4.4 seconds) and when asked to explain the question in their own words the children could not explain it or gave explanations which spoke about mathematics experiences outside school rather than other uses of mathematics within school:

Researcher	Can you tell me what it means in your own words? Could you say it a different way?
Participant	If you know lots of maths it helps you do things when you are not at school.

The item was therefore changed to *Knowing lots of maths helps me do other things at school* for the second session of interviews. This change reduced the response times (Amended Item 16 mean = 0 seconds (note this indicated an immediate response from all participants). The amended wording was therefore retained.

Item 18: When you do maths you learn ways to think that help you be good at other things.

This item proved problematic for children to explain in their own words and response times were slow (Item 18 mean = 8.3 seconds). It was changed after the first round of interviews in line with participant comments on other questions to read *If you know lots of maths it helps you do things when you are not in school*. This rewording reduced response times (Amended Item 18 mean = 3 seconds) and most children could clearly explain their thinking around the question. However, it was still felt to be problematic and was changed to *Knowing lots of maths helps me do things when I am not at school* in line with the wording of Item 16.

Item 21: It will be hard to do well when I grow up if I am not good at maths.

Although this item was understood by most children some of the children's responses indicated it might be problematic:

Participant	Because if you like if someone like (sic) asks you a question that's like a really hard maths question and you don't get it right you might get a little bit embarrassed.
Researcher	You ... you disagree with that. OK so why did you decide that?
Participant	Because because (sic) erm well because um at you (sic) everyone could do maths when they were well even if when they were erm younger and then they can s (sic) they can do it when they are old.
Researcher	But if they couldn't do it do you think they wouldn't get on very well or would they be OK?
Participant	They would be OK.

The item also included the word hard but it was not felt appropriate to replace it with tricky in this context. Thus the item was reworded to read *I won't do well when I grow up if I am not good at maths.*

Item 23: Thinking the way I do in maths helps me with things I like to do.

This item proved difficult for the children to reword and some children spoke only in terms of school subjects rather than things they enjoyed doing. Response times were slow (Item 23 mean = 6.6 seconds) and as other similar, easier to understand items were already present on the scale it was decided to omit this item.

Use of pictures for the scale responses

The thumbs up/down scale that was used for the children to make their responses on was found to be effective. The children frequently put their own thumbs up or down before making a response showing that they understood the context and use of the scale for agreement or disagreement. All the children were asked at the end of the interview if they would have been happier with a different scale and shown the options given in Figure 4-2.

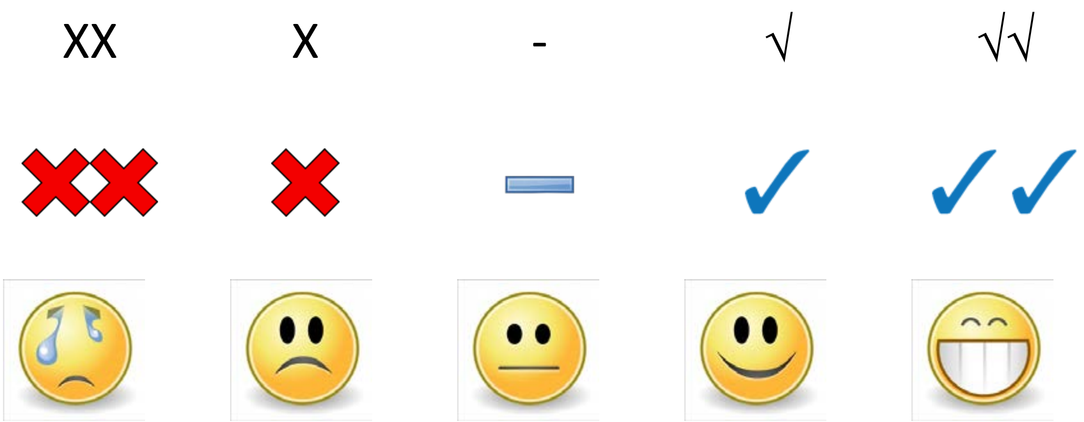

Figure 4-2 Pictorial Scale Options Shown to Children During Cognitive Interviewing

All children choose the scale showing the faces. However, it was decided that the faces did not accurately represent the agree/disagree nature of the scale and since all had managed to complete the thumb up/down scale successfully it was retained.

Conclusions

Cognitive interviewing illustrated that in the main the measure was easy for the children to complete and they could do so accurately. Most items were found to be measuring what they were intended to measure. The removal of three items which were not doing so was found to be necessary and minor modifications were made to four more to clarify their meaning. The Flesch Reading Ease of the items on the amended scale was 98.4 which indicates they are Very Easy to read and therefore suitable for children in Year One.

The adaptation of the MRS (Kooken et al. 2013), followed up by cognitive interviewing, validated a twenty item scale. Since items had been removed and reworded it was now necessary to assess the reliability of the new scale by considering its psychometric properties.

4.3.2 Initial Piloting of the Scale in Schools

In order to assess the psychometric properties of the scale it was necessary for it to be completed by at least 200 children in line with guidelines of a minimum sample of 10 children per scale item (Streiner and Norman 2008). For reasons of practicality it was therefore necessary for the scale to be completed by whole classes of children simultaneously. It was decided to read the scale items out to the children so that children who had difficulty reading would still be able to complete the scale. A pilot was undertaken to see if this method of administration was effective.

Sample

Details of recruitment and participants for the pilot (Study B) can be found in Section 3.6.2. Forty-two Year 1 children from two schools took part in the pilot.

Procedure and Findings

Each child was issued with a scale sheet (see Appendix 5). They were shown a large version of the thumbs up/thumbs down scale with a demonstration of how to correctly circle the answer. The children then completed a practice item with the statement *I like maths*. At this point the researcher went round to all the children and checked that they had completed the item correctly. Once this had been done the researcher read each item in turn out to the children and asked them to circle a picture to indicate how much they agreed with the statement and then repeated the item a second time before moving on to the next. During the administration the researcher noticed that some of the children were putting more than one circle on some of the scales. When this was observed the child was gently guided to make their second circle on the correct scale. However, when the scales were collected and the data collated it was observed that a number of scales (three in School 1 and ten in School 2) had been completed incorrectly with multiple circles on some items and none on others. As a result it was decided to change the layout of the scale for further administrations, leaving more blank space in between items, enlarging the text on the items and putting the numbers for the items immediately to the left of the scale rather than above. The amended scale presentation is shown in Figure 4-3.

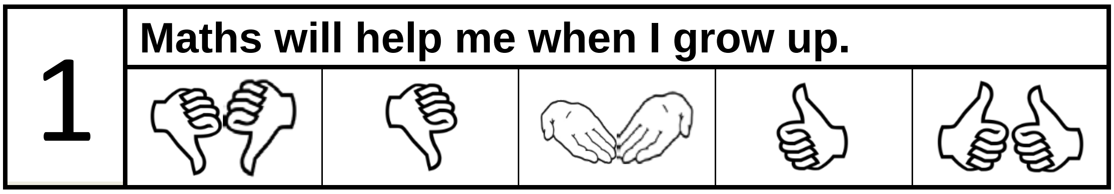

Figure 4-3 Scale Presentation Amended After Piloting

The scale was administered in the two schools a second time in July 2016 to ensure that the changes made to the scale had made it easier to complete. Seventeen of the nineteen children from School 1 and eighteen of the original twenty-three children from School 2 who had completed the scale were present for the second administration. The scale was administered to the children in the same way as before apart from the fact that the administrator held up the scale and pointed to the item that was being completed as she read it out. The children were also asked to check that they had exactly one circle on each item before the scale was collected in. As a result of these changes fewer scales were completed incorrectly (two from School 1 and three from School 2) and the new format was retained. At the end of the two administrations, twenty-one children from the two schools had completed both administrations of the scale successfully.

4.3.3 Reliability Analysis of the Children's Mathematical Resilience Scale

The data collected in Studies B and C (see Sections 3.6.2 and 3.6.3) were used to carry out Exploratory Factor Analysis on the scale (n=322 Year 1 children).

Observations

As data collection took place over the course of the autumn term, some children completed the scale very soon after moving into Year 1. Prior to this, their education in Foundation Stage was predominantly play based and the researcher noticed that in some cases the children's ability to sit and complete the scale had improved markedly between the first and second administration.

The researcher also noticed that when the children were completing the items that related to growth they were agreeing with these items despite them being negatively worded (if they had growth beliefs and were filling in the scale correctly they would have been disagreeing). Initially the researcher considered whether they were filling in the scale incorrectly or struggling with the negative wording but on listening to the comments that they made to each other she concluded that the children's belief in growth (i.e. the ability to get better at mathematics) was weak in a lot of cases and they were accurately filling in the scale. For example children were heard to say they were clever so were good at mathematics and that there were people who could not do mathematics, indicating that they did not believe in growth.

Participants

322 Year 1 children in total completed the scale at least once. Table 4-4 shows details about the participants.

Table 4-4 Details of Participants in the Reliability Analysis for the BCMRS

School	Number of Completions	% Female	% Working Below or Towards	% Greater Depth
1	17	59	47	12
2	18	44	6	17
3	83	39	16	0
4	30	DNP	DNP	DNP
5	54	61	76	0
6	31	73	DNP	DNP
7	89	55	21	20

DNP = School did not provide data

Exploratory Factor Analysis

Exploratory factor analysis is a technique which assesses the internal consistency of a scale (Pett, Lackey and Sullivan 2003). Exploratory factor analysis was carried out on the twenty item scale. The means, standard deviations, skewness and kurtosis for the items are presented in Table 4-5. The 5 point scale was scored so that -2 = two thumbs down and 2 = two thumbs up on the positively worded items and -2 = two thumbs up and 2= two thumbs down on the negatively worded items. The means ranged from -.48 (Item 18 *Only clever people can do maths*) to 1.28 (Item 11 *Maths will help me*).

An initial factor analysis was run using principal axis factoring with no rotation. The scree plot indicated three factors which backed up the proposed three factor structure seen in the MRS (2013) where items fell into one of the three subscales: growth, struggle and value (see Figure 4-4).

Table 4-5 Descriptive Statistics from Administration of the 20 item BCMRS (n = 322)

	N	Mean (SD)	Skewness*	Kurtosis!
I1	319	1.22 (1.10)	-1.467	1.437
I2	319	.82 (1.38)	-.907	-.483
I3	319	-.24 (1.68)	.258	-1.603
I4	321	1.15 (1.26)	-1.313	.502
I5	320	.85 (1.48)	-.945	-.627
I6	317	.99 (1.44)	-1.137	-.214
I7	319	.69 (1.49)	-.744	-.925
I8	319	.60 (1.41)	-.615	-.882
I9	321	-.46 (1.65)	.465	-1.452
I10	322	.67 (1.49)	-.698	-.993
I11	320	1.28 (1.23)	-1.677	1.624
I12	319	.81 (1.45)	-.882	-.662
I13	322	.65 (1.48)	-.725	-.896
I14	318	1.02 (1.30)	-1.150	.164
I15	317	-.21 (1.65)	.182	-1.616
I16	320	.79 (1.47)	-.837	-.762
I17	320	.07 (1.76)	-.058	-1.758
I18	322	-.48 (1.68)	.497	-1.464
I19	321	.21 (1.58)	-.176	-1.511
I20	322	.98 (1.44)	-1.152	-.168

*All standard errors for skewness = .14 ! All standard errors for kurtosis - .27

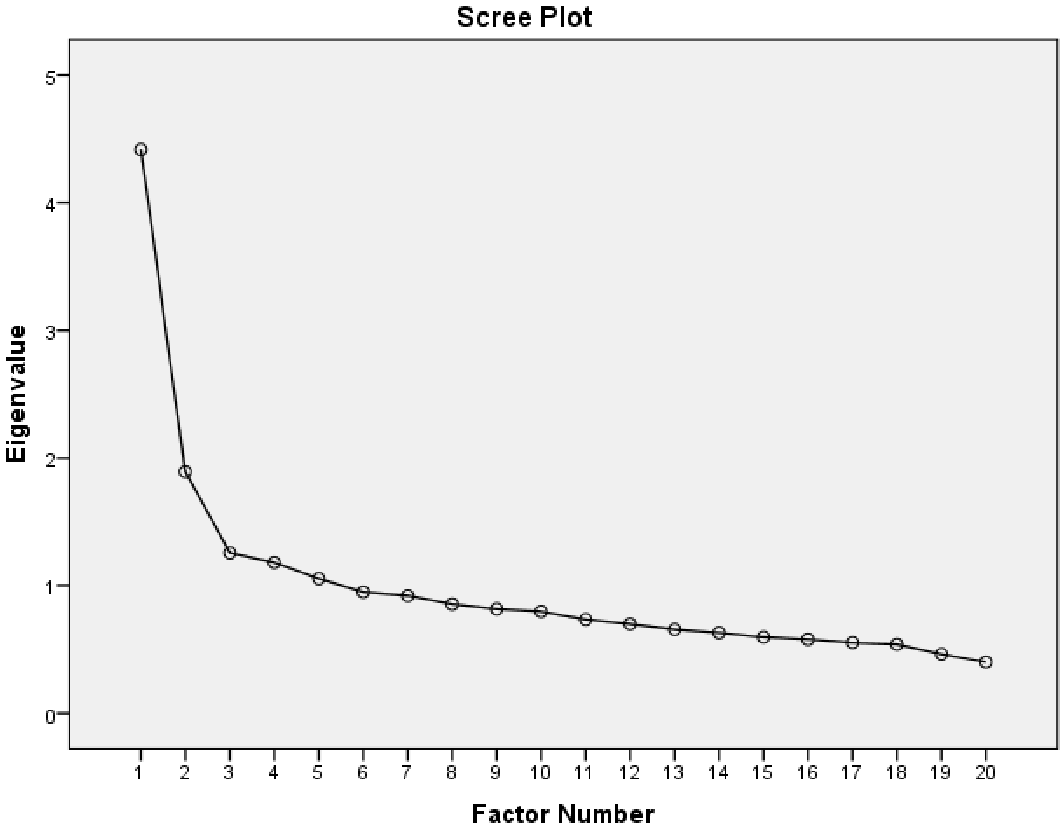

Figure 4-4 Scree Plot from Piloting of the 20 Item BCMRS Indicating Three Factors

The factor matrix was then rotated using oblimin rotation and a three factor solution was obtained. Table 4-6 shows the factor loadings obtained. The items are grouped into the subscales it was proposed that they belonged to and items in bold are those which are loading on the proposed factor. As can be seen (Table 4-6) not all items loaded on the proposed factor and there were also several items which loaded on more than one factor. There is no clear consensus on how to deal with items that load on more than one factor or definitive criteria for the removal of items (Pett et al. 2003). In this study, decisions were made to remove items based on both the statistical data and conceptual considerations as suggested by Pett et al. (2003).

Table 4-6 Pattern Matrix Obtained for 20 Item BCMRS (n = 322)

	Struggle	Growth	Value
I2	**0.465**	0.179	0.103
I5	**0.563**	0.004	-0.046
I7	**0.424**	-0.137	-0.055
I8	**0.478**	-0.080	0.208
I10	**0.493**	-0.107	-0.028
I12	**0.361**	-0.078	0.118
I17	0.203	**-0.375**	0.051
I20	**0.496**	-0.065	-0.059
I1	0.173	0.042	**0.227**
I6	0.150	-0.028	**0.525**
I11	0.225	-0.119	**0.317**
I13	-0.108	-0.386	**0.411**
I14	**0.380**	-0.022	0.193
I16	**0.292**	-0.070	0.250
I19	0.213	**-0.539**	-0.159
I3	0.018	**0.537**	-0.028
I4	**0.399**	-0.008	0.011
I9	-0.095	**0.591**	0.053
I15	-0.091	**0.529**	-0.020
I18	0.222	**0.467**	-0.227

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 15 iterations.

The decision was made to remove four items at this point (Item 14 *Knowing lots of maths helps me do other things at school*, Item *16 Knowing lots of maths helps me do things when I am not at school*, Item 17 *You have to get things wrong to be good at maths* and Item 19 *I won't do well when I grow up if I am not good at maths*) because they loaded strongly on more than one factor (criteria for strong loading was taken to be loadings of >.5 times the highest loading on one or more other factors) whilst also relying on an understanding of context that the children may not have. For example children need to be aware of using mathematics in other situations in items 14 and 16 and they may not be aware of this at age five and six. Similarly they may not be able to imagine *when I grow up*. It was also hypothesised that in a school setting getting things right in mathematics was prized and therefore at this age children may not have experienced getting things wrong on the path to learning mathematics. Items 1 and 11 which strongly loaded on more than one factor but did not have this contextual problem were retained.

A further factor analysis was then run on the remaining 16 items which again indicated 3 factors (see Table 4-7). As before items which load on the proposed factor are in bold.

Table 4-7 Pattern Matrix Obtained for 16 Item BCMRS (n = 322)

	Struggle	Growth	Value
I2	**0.325**	0.174	0.267
I5	**0.616**	0.068	-0.010
I7	**0.458**	-0.049	0.001
I8	**0.388**	-0.090	0.260
I10	**0.553**	-0.058	-0.058
I12	**0.457**	-0.129	-0.033
I20	**0.490**	0.002	0.011
I1	-0.040	0.001	**0.471**
I6	0.067	-0.222	**0.445**
I11	0.212	-0.223	**0.244**
I13	-0.067	**-0.543**	0.194
I3	-0.077	**0.506**	0.080
I4	**0.282**	0.057	0.252
I9	-0.122	**0.494**	-0.014
I15	-0.177	**0.515**	0.057
I18	0.133	**0.569**	-0.030

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 6 iterations.

Items largely loaded on the predicted factors but there were still some items that loaded strongly on more than one factor. It was decided to remove Item 4 *Anyone can learn maths* because this relied on a common understanding of the concept of "anyone", Item 13 *I need to do maths to help me to do what I want* because it depends on the understanding of "what I want" and Item 8 *People who have jobs that use maths sometimes find maths tricky* because this relies on the understanding of jobs that use mathematics. All these concepts may have been unclear to the five and six year olds and the items were loading strongly on more than one factor. This left two items (Item 2 *It is ok to find maths tricky* and Item 11 *Maths will help me*) which loaded strongly on two factors. Item 2 was removed. Item 11 was one of only three value items remaining on the scale and as such the removal of it from the scale would potentially invalidate the value subscale. Therefore at this point the analysis was run with and without Item 11. Without the other items previously removed in this step, Item 11's loadings were now at an acceptable level so it was retain leading to a 12 item scale in which all items loaded on the proposed factors. The pattern matrix can be seen in Table 4-8. Table 4-9 shows the variance explained by the three factor structure and other statistics for the twelve item scale. A copy of the scale can be found in Appendix 6. Table 4-10 shows the factors and their items.

Table 4-8 Pattern Matrix Obtained for 12 Item BCMRS (n = 322)

	Struggle	Growth	Value
I5	**0.638**	0.122	0.064
I7	**0.445**	-0.038	0.018
I10	**0.533**	-0.049	-0.023
I12	**0.435**	-0.067	0.062
I20	**0.511**	0.001	-0.018
I1	-0.022	0.029	**0.329**
I6	0.060	-0.031	**0.585**
I11	0.137	-0.139	**0.394**
I3	-0.034	**0.491**	0.010
I9	-0.080	**0.570**	0.029
I15	-0.111	**0.590**	0.014
I18	0.140	**0.489**	-0.074

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 5 iterations.

Table 4-9 Statistics for 12 Item BCMRS (n = 322)

Factor	Mean (SD)	Cronbach Alpha	Eigenvalues	Cumulative % of Variance
Struggle (n = 5)	4.038 (4.77)	.651	2.88	24.012
Growth (n = 4)	-1.36 (4.55)	.616	1.53	36.722
Value (n = 3)	3.52 (2.67)	.499	1.13	46.174
Total (n =12)	6.361 (6.43)	.702		

Table 4-10 Factors and Corresponding Items for the Final BCMRS

Factor	Items
1. Value	1, 6, 11
2. Growth	3, 9, 15, 18
3. Struggle	5, 7, 10, 12, 20

As can be seen in Table 4-8, the Cronbach's alpha, a measure commonly used to assess the reliability of a scale, for the whole scale was .702. This is greater than the acceptable level of >.7 for reliability of a scale (Field, 2014). The Cronbach alphas for the subscales were lower than ideal.

Confirmatory Factor Analysis

In order to further assess the reliability of the scale, confirmatory factor analysis was carried out on the time 1 data collected in Study G (see Chapter 3) and the control group for Study J (see Chapter 9). A confirmatory factor analysis uses structural equation modelling to assess if data collected from a different sample to that used in the scale development has the same factor structure. If the new data has the same structure the reliability of the scale is increased (Pett et al. 2003.)

Participants

Details of the schools and participants who took part in the study can be found in Sections 3.5, 3.6.7 and 3.6.10. All individuals who had missing data were removed. This left ninety-two Year 1 participants from seven schools.

Method

Confirmatory Factor Analysis was carried out using AMOS. The proposed three factor structure was modelled and the analysis was run. The results were then compared to one factor and two factor structures and to a second order model.

Results

The proposed three factor structure showed the best fit to the data (χ^2= 62.8, df = 51, p = .124, CFI = .912, RMSEA = .050, AIC = 140.83, n = 92). The standardised results for the model can be seen in

Figure 4-5. The one factor structure and second order models did not fit the data as the iteration limit was reached for each model. The two factor structure with the value and struggle items in the same factor did not fit the data as well as the three factor structure (χ^2= 76.97, df = 55, p = .027, CFI = .837, RMSEA = .066, AIC = 146.97). Thus the confirmatory factor analysis supported the three factor structure.

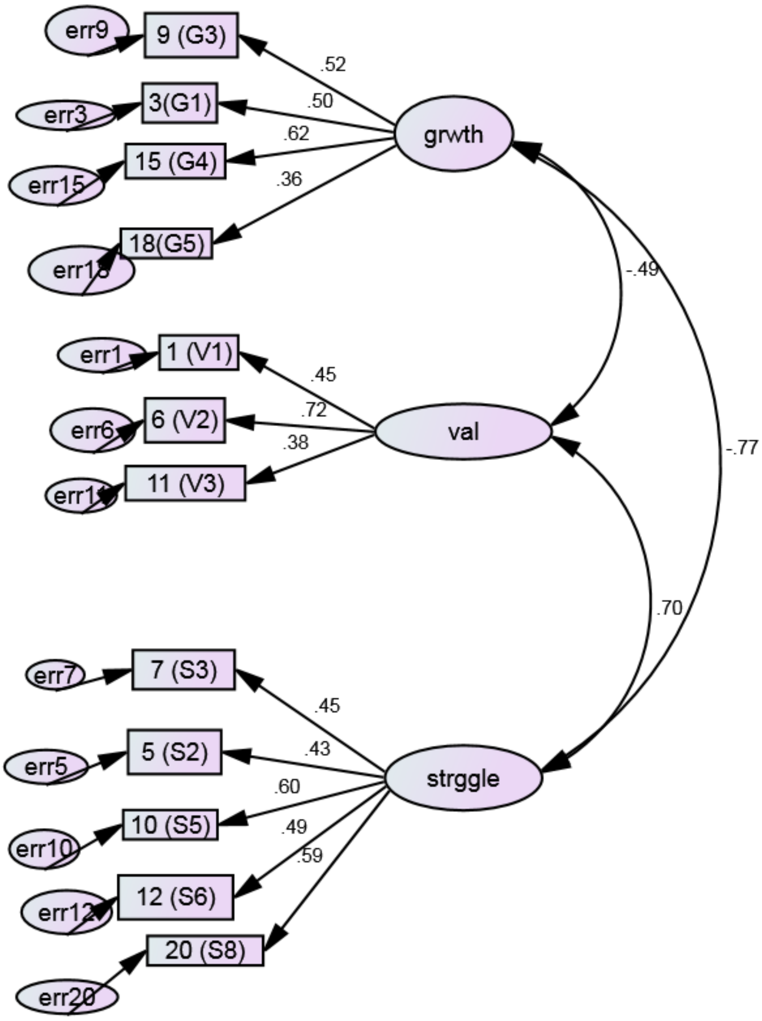

Figure 4-5 Standardised Results for the CFA of the Three Factor Structure

Test Retest Analysis

To assess the test retest reliability of the scale it was retested in five of the seven schools (n=255). Schools 1 and 2 did not take part in the retest as they had piloted earlier versions of the scale. The gap between tests varied due to the schools' requirements and ranged from 4 weeks to 8 weeks as shown in Table 4-11. This was not ideal as test retest statistics are dependent on the length of time between tests (Deyo, Diehr & Patrick 1991) so this was taken into account during the analysis.

Table 4-11 Number of Weeks Between Scale Administrations in Test Retest Analysis of BCMRS

School	Gap between administrations
3	4 weeks
4	4 weeks
5	7 or 5 weeks*
6	4.5 weeks
7	8 weeks

*The first administration had to be done in two groups two weeks apart due to researcher illness

Spearman's correlations were calculated for the scores on the three subscales and the scale total in the two administrations and can be seen in Table 4-12. The subscales and scale total were significantly correlated with themselves in the two administrations, although the correlation coefficients showed unacceptable reliability.

Table 4-12 Spearman's Correlation Statistics for the Test Retest Analysis of the BCMRS

	Spearman's Correlation Statistics (n = 255)
Growth	r = .451, p <.001
Struggle	r = .332, p <.001
Value	r = .340, p <.001
MR	r = .329, p <.001

4.4 Conclusions

In this chapter existing scales for measuring MR were considered and rejected as unsuitable for the current research. In order to understand the development of MR and its links to performance in Year 1 children, and to evaluate an intervention designed to help parents of Year 1 children it was necessary to create a new scale. Thus a scale for measuring MR in Year 1 children was developed from the MRS (Kooken et al. 2013). Items were adapted and cognitive interviewing was used to validate the items. The scale was then tested for reliability. The procedure validated a 12 item, three factor scale with the three factors corresponding to growth, struggle and value as expected. The scale can be seen in Appendix 6. The internal consistency of the scale was acceptable (Cronbach's alpha >.7) (Field 2014). Confirmatory factor analysis validated the factor structure on a different sample of Year 1 children. Test retest analysis showed that the reliability of the scale over time was disappointing. However, the intervals between testing varied in different schools (see Table 4-11) and in some cases were considerably longer than the 1-2 weeks that is frequently cited as the ideal interval to assess test retest reliability (e.g. Deyo et al. 1991). Thus the scale has been found to be reliable and valid for use in the research.

As well as the applications for which it will be used within this thesis, the Baker Children's Mathematical Resilience Scale (BCMRS) also gives the opportunity for MR research to be extended in the future, facilitating studies about young children's MR and its links with performance and early mathematical development. No equivalent scale is currently in existence and therefore the development of the BCMRS is a significant contribution to research into early mathematics education.

Chapter 5 A Study into Links between Mathematical Resilience and Performance

5.1 Chapter Summary

This chapter considers links between MR and performance in mathematics. It describes a study that investigates links between performance on a specific mathematics task, self-rated competence in mathematics and scores on the Baker Children's Mathematical Resilience Scale (BCMRS). The BCMRS is compared with the *Mathematics Attitudes and Anxiety Questionnaire* (MAAQ: Thomas and Dowker 2000) and the ability of each to predict performance is considered. The study concludes that self-rated competence in mathematics can be predicted by the BCMRS. The complexity of problem solving strategy chosen by an individual can be predicted by both the BCMRS and the MAAQ but when used together they provide a better model for variability in performance. Thus it is concluded that the BCMRS is linked to performance in mathematics and can be used alongside the MAAQ to provide a fuller picture of how a child's attitudes to mathematics affect performance. Suggestions for future research are made.

5.2 Introduction

In Chapter 2, the development of MR was proposed as a potential solution for the problems that individuals encounter in learning and retaining the ability to do mathematics. In particular, these included combatting the dislike of mathematics and disinclination to work at the subject, MA and the fact that many learners have certain subject areas missing in the development of their mathematical knowledge. It was claimed that learners who possessed MR would perform better in the subject but there is little evidence for this among young children. Chapter 4 detailed the development and validation of a scale for measuring MR in Year 1 children. This scale enables links between MR and performance in young children to be studied.

When considering performance in mathematics, differing levels of success can be identified. Performance on a micro level is performance on an individual task while success on a macro level is success over time. This chapter considers micro level success. Depending on the nature of the task a successful outcome can be achieved by prior knowledge, luck or by using a successful strategy combined with prior knowledge to solve the task. Children who are mathematically resilient are said to have better strategies for struggling in mathematics i.e. better strategies for solving mathematical problems using the mathematical knowledge that they possess (Lee and Johnston-Wilder 2017). Therefore children's performance on a task is hypothesised to be positively linked to their MR.

A further aspect of performance is the learner's own assessments about their ability in mathematics. These assessments are based on their previous experiences in mathematics. Dowker, Cheriton, Horton and Mark (2019) found that higher self-rating in mathematics in English children was linked with better performance. Individuals who possess MR would be expected to have higher self-rated competence because they see struggle as part of the process of learning mathematics rather than a sign that they are bad at mathematics (Lee and Johnston-Wilder 2017) so their self-rating would not be so strongly linked to their previous performance. Thus it was hypothesised that self-rated competence and MR would be positively correlated with each other and with performance on the task.

Since learners who possess MR understand that it is necessary to struggle to learn mathematics it was also hypothesised that higher levels of MR would be linked with lower levels of MA. Thus this chapter explores links between MR and MA with the hypothesis that MR will be negatively correlated with MA.

In order to investigate these hypotheses, a task was developed to see whether MR was linked to the ability to solve a problem more successfully. While the problem could be solved by simple mathematics; perseverance and strategic thinking would solve it more certainly and more quickly. This allowed children across the age range to complete the same problem, enabling conclusions to be drawn about strategy which were not age dependent. Links between performance on the task and scores on the BCMRS and MAAQ were considered.

To summarise, this second study had the following aims:

1. To assess the associations between MR (as measured by the BCMRS) and self-rated competence and MA (as measured by the MAAQ)
2. To assess the extent to which MR , self-rated competence and MA were associated with performance on the task

5.3 Methodology

5.3.1 Design

Details of recruitment can be found in Section 3.5. A correlational mixed methods design was adopted with data collected at a single time point. The data collected was MR (BCMRS), attitudes to mathematics (MAAQ) and the child's output from the mathematics task in the form of the sheet of paper they wrote on.

5.3.2 Participants

Full details of participants can be found in section 3.6.6. There were seventy-four children varying between the ages of five years eleven months and twelve years eight months.

5.3.3 Background Measures

The *BCMRS* (see Section 3.7.1) which was used to assess the children's MR was designed for use with Year 1 children. Since all of the children in the study were in Year 1 or older it was concluded that they would be able to access the scale successfully. The study took place before the final format of the scale had been decided and the scale used was an earlier 15 item version. This scale did not contain one of the value items which ended up on the final version of the scale (Item 1) and had an additional 4 items. For the purposes of this research the extra items were ignored and the 11 items which appeared on the final BCMRS and which had been administered to the children were used in the analysis. This was not ideal as it left the value subscale with only two items and thus any analysis on this scale should be regarded with caution.

Each item on the BCMRS was scored from -2 to 2 with an answer indicative of MR being scored positively. Therefore the three subscales had scores ranging as follows: growth (-8 to 8), struggle (-10 to 10) and value (-4 to 4). The MR total was calculated by scaling the subscales scores before adding them using the following formula:

$$MR\ Total = \frac{Growth\ Total}{4} + \frac{Struggle\ Total}{5} + \frac{Value\ Total}{2}$$

This was done in order to give equal weighting to the three elements of MR and gave a possible range for total MR from -6 to 6.

The *MAAQ* was used to measure MA, self-rated competence and attitude (See Section 3.7.2).

5.3.4 Procedure

Two researchers ran the experiment simultaneously. Both read from a script in order to provide the children with the same experience. The script can be found in Appendix 7. The children completed the background measures before beginning the task. They were then asked to think of a sum that had the answer of 8 but which no-one else had suggested during the week in which the event was taking place. They could have as long as they wanted to think of sums and write down as many possibilities as they would like but once they said they were finished they were not allowed to come up with any more sums. Children who came up with at least one sum no-one else had got were given a “Pointless” certificate. Whilst this was the apparent aim of the task, the research aim was to see how long the children persevered before they felt sure that they had got a unique or difficult-to-think-of answer and what strategies, if any, they adopted to ensure they had done so. The length of time they worked on the task was recorded along with the number of sums they listed. Their list of sums was retained.

5.3.5 Data Scoring and Analysis

The data collected was analysed using quantitative and qualitative methods. Correlation analysis and multiple regressions were used to assess whether the children’s MR and attitudes were linked to each other and to their performance on the task. The strategies that the children had adopted in their lists of sums were coded and links between MR, attitudes and strategy adopted were explored.

Success in the task for the child was getting a pointless answer. However, this could be achieved in lots of ways, for example by listing a lot of sums, by making up one very hard sum or using a simple sum but with big numbers that no-one else might have thought of. Perseverance was a possible strategy, because the more sums on the page, the more likely it was that one was a unique one, but there were better, shorter strategies to ensure a solution of this problem. In order to capture this information performance on the task was measured in three ways.

Perseverance was measured by how long the child worked on the task (*time in seconds*) and the *number of sums* they wrote down.

Strategy was measured qualitatively. The lists of sums that the children had produced were coded. Firstly, they were coded on the strategy the child had used. Codes were developed iteratively from the data. Each child's script was given a descriptive code relating to the most complex type of sum used. Once all data had been coded and final codes had been decided upon all scripts were checked and coding was unified. Descriptions of the final codes can be seen in Table 5-1.

Table 5-1 Codes for Strategies Used by the Children in Study F

Code	Description	Example
Number bonds	The child uses known addition and subtraction number bonds to come up with sums.	$7 + 1$ $6 + 2$
Numbers bonds and times tables facts	The child uses known multiplication facts and associated division facts. They may also use number bonds in other sums but do not combine the two.	2×4 $16 \div 2$
Number bonds with negatives	The child uses simple number bonds but introduces a negative at the start to attempt to find a unique solution.	$-2 + 10$ $-4 + 12$
Mixed Operations	The child uses a range of different operations in one sum. Note the child is not required to use brackets or correct mathematical sentence structure as long as the intention is clear.	$(4 + 12) \div 2$ $10 - 8 + 4 + 2$
Addition with non-integers	The child produces only addition sums but uses decimals or fractions.	$5 + ½ + ½ + ½ + ½ + ½ + ½$ $7 + ½ + ½$ $0.4 + 7.6$
Seed Sum	The child started with a sum they knew and then used a mathematical operation they knew such as doubling or multiplying by 10 to make the numbers bigger while retaining the answer.	$824 \div 104$* $1648 \div 208$ etc. Or $16 \div 2$ $160 \div 20$ $1600 \div 200$ etc.
Most complex sum	The child produced very few sums (usually 1 or 2) but made the sum/s they did produce as complex as they could so no-one else would have suggested it. Note the strategy is one the child thinks complex with regard to their knowledge but may be mathematically simple (e.g. repeated addition).	$2 + 2 + 2 + 2$ 2^3 $1 + 1 + -1 + -1 + 3 + 3 + 3 - 2 + 2 - 2 + 39 - 41 + 2 - 3 + 2$

*Note that although this sum is incorrect, under the coding scheme it was allowed as evidence of the strategy of using a seed sum

The codes are listed in increasing order of how likely it was felt that the strategy would succeed in finding a novel sum. Sums did not have to be correct to be classified into one of these strategies. The coding was designed so that children of different ages could fit into the same category, for example 10 - 2 was deemed a number bond but so was 568 - 8. It was not the complexity of the numbers, which would naturally be restricted by age in some cases, but the complexity of the strategy, given what the child knew of mathematics, that the researcher was interested in assessing.

Secondly, the children were given a code indicating whether the sums they had generated were standard sums which they would have encountered in school such as number bonds or times tables or more complicated sums which they would not generally see. These were coded as typical or atypical sums. Use of atypical sums illustrated children who had taken ownership of the mathematics and were trying to adapt it themselves rather than follow others. Examples can be seen in Table 5-2.

Table 5-2 Examples of Typical and Atypical Sums Found in Study F

Typical Sums	6 + 2
	2 x 4
Atypical Sums	2 + 4 – 4 + 6
	3 x 5 – 9 + 2

Once the coding of the strategies had been completed the codes were verified by an independent researcher. The children were ranked in order of MR and links between MR and the strategy adopted were investigated using correlation analysis.

5.4 Results

One participant was removed because their scores were outliers in several categories. This left seventy-three participants. Descriptive statistics for the time taken, number of answers and scores on the two scales are shown in Table 5-3.

Table 5-3 Descriptive Statistics for Data Collected in Study F (n =73)

	Mean	SD	Minimum	Maximum
Time Taken (seconds)	202.27	204.549	16	1102
Number of Answers	7.79	8.085	1	54
Growth	4.51	2.814	-4	8
Struggle	7.15	2.612	1	10
Value	3.36	.839	1	4
MR Total	4.23	1.043	1.6	6
Self-Rated Competence	27.97	4.589	11	35
Enjoyment	25.92	5.395	7	35
Response to Failure	18.16	4.622	7	31
MA	18.99	5.631	7	33

The study was designed so that children of all mathematical abilities could access and be successful on the task. In order to check that this was the case and that perceived ability was not introducing a confounding influence on children's mathematical attitudes; Pearson's correlations were run between self-rated competence and the time taken on the task and number of answers, no significant correlations were found (see Table 5-4), indicating that self-reported ability was not a significant influence on performance on the task.

Table 5-4 Correlations Between Self-Rated Competence and Performance in Study F (n = 73)

	Time Taken	Number of Answers
Self-Rated Competence	r = .148, p = .265	r = .081, p = .495

In order to check that performance on the task was not affected by the age of the children and all children could be considered together in the analysis; Pearson's correlations were calculated (see Table 5-5). There was no significant correlation between age and time taken on the task, r = .080, p = .501 or between age and number of answers found, r = .093, p = .435 indicating that it was acceptable to consider all children together in the analysis. There was, however, a significant correlation between age and the scores on the growth (r = .273, p = .019) and value subscales (r = .293, p = .012) and the MR scale total (r = .392, p = .001). From the MAAQ there was a significant correlation between age and score on the enjoyment subscale, (r = .237, p =

.044). These findings suggested that as children got older they enjoyed mathematics more and had greater levels of MR.

As might be expected there was a significant positive correlation between the time spent on the task and the number of answers found (r = .793, p <.001). Those children giving more answers took longer to complete the task. There were no significant correlations between scores on either scale and the time taken on the task or the number of answers found (see Table 5-5).

Table 5-5 Correlations Between BCMRS and MAAQ and Age, Time Taken on the Task and Number of Answers (significant correlations in bold) (n = 73)

	Age	Time Taken	Number of Answers
Growth	**r = .273, p = .019**	r = -.088, p = .461	r = -.053, p = .658
Struggle	r = .179, p = .129	r = -.044, p = .710	r = .079, p = .506
Value	**r = .293, p = .012**	r = .040, p = .738	r = .038, p = .753
MR Total	**r = .392, p = .001**	r = -.065, p = .583	r = .019, p = .872
Self-Rated Competence	r = .207, p =.079	r = .014, p =.905	r = .081, p = .495
Enjoyment	**r = .237, p = .044**	r = .063, p = .598	r = .033, p = .783
Response to Failure	r = .043, p = .715	r = -.116, p = .329	r = .016, p = .895
MA	r = .141, p = .234	r = .030, p = .800	r = .104, p = .383

Correlations were run between the BCMRS and the MAAQ (see Table 5-6). A higher score on the MA subscale of the questionnaire represents a lower level of maths anxiety. There were significant correlations between total MR and self-rated confidence, enjoyment and response to failure. This suggests that those who had higher MR rated their mathematics ability more highly, enjoyed mathematics more and responded more positively to failure in the subject. Contrary to the hypothesis there was no correlation between MR and MA. There was a significant correlation between growth and three of the attitude scale strands: self-rated competence, enjoyment and MA. These correlations suggested that children with higher belief in growth were less mathematically anxious, and had higher self-rated competence. They also had a greater enjoyment of mathematics. There was a significant correlation between struggle and self-rated competence. This suggested those who had a higher belief in struggle rated their own mathematics ability more highly. There were no other significant correlations.

Table 5-6 Correlations Between the BCMRS and MAAQ (Significant correlations in bold) (n = 73)

	Self-Rated Competence	Enjoyment	Response to Failure	MA
Growth	**r = .405, p<.001**	**r = .317, p = .006**	r = .223, p = .058	**r = .271, p = .020**
Struggle	**r = .390, p = .001**	r = .200, p = .090	r = .168, p = .155	r = .001, p = .993
Value	r = .223, p = .058	r = .095, p = .422	r = .099, p = .403	r = .063, p = .598
MR Total	**r = .558, p <.001**	**r = .353, p = .002**	**r = .275, p = .019**	r = .209, p = .076

The lists of sums produced by the participants were coded as described in Section 5.3.5. Once the lists of sums had been coded they were put in ascending order of MR and links between strategies used and MR were considered. Table 5-7 shows a summary of the resulting order which can be seen in full in Appendix 8.

Table 5-7 Percentage of Children in Study F Using Each Strategy by Level of MR (n = 73)

Total MR Score	N in group	Strategies used
1-3.0	10	Number bonds (70%) Number bonds and times table facts (20%) Number bonds with negatives (10%)
3.1-4.0	21	Number bonds (24%) Number bonds and times table facts (29%) Mixed operation (9%) Addition with non-integers (9%) Most complex sum (29%)
4.1-5.0	27	Number bonds (18%) Number bonds and times table facts (22%) Number bonds with negatives (4%) Mixed Operation (15%) Addition with non-integers (4%) Seed sum (4%) Most complex sum (33%)
5.1-6.0	15	Number bonds (13%) Number bonds and times table facts (7%) Mixed operation (7%) Addition with non-integers (13%) Seed sum (7%) Most complex sum (53%)

None of the children scoring between 1 and 3 on the MR scale used the optimal complex sum strategy. Of the children scoring between 3.1 and 4, 6 out of 21 or 29% used the optimal strategy. Of those scoring between 4.1 and 5, 9 out of 27 or 33% used the optimal strategy. Of those scoring between 5 and 6 inclusive, 8 out of 15 or 53% used the optimal strategy. Thus the use of the optimal strategy increased with MR. The strategies were numbered and Spearman's correlations were run between the MR score and the strategy used. There was a significant positive correlation, $r = .379$, $p = .001$, between MR and the strategy used. When the subscales were considered separately, the strategy used was positively correlated with the growth ($r = .295$, $p = .011$) and struggle subscales ($r = .236$, $p = .045$). There was no significant correlation between the strategy used and the value subscale ($r = .072$, $p = .544$). This shows that children with higher MR, particularly those with a higher belief in growth and struggle, were significantly more likely to use more optimal strategies to solve the problem.

Spearman's correlations were also run between the MAAQ and strategy. Significant correlations were found between the strategy chosen by the child and their self-rated competence ($r = .395$, $p =.001$), enjoyment of mathematics ($r = .325$, $p = .005$) and MA ($r = .389$, $p = .001$). This shows that higher levels of self-rated competence and enjoyment of mathematics and lower levels of MA were correlated with more optimal strategies on the task. There was no significant correlation between response to failure and the strategy chosen ($r = .172$, $p = .139$).

T-tests were run to compare scores on the BCMRS and MAAQ of children who used typical and atypical sums. Table 5-8 shows the means and standard deviations for each group.

Table 5-8 Further Means for Data Collected in Study F (Standard Deviations in brackets)

	Typical Sums (n = 35)	Atypical Sums (n = 38)
Growth	3.57 (3.27)	5.37 (2.01)
Struggle	6.74 (2.78)	7.53 (2.42)
Value	3.20 (.93)	3.50 (.73)
MR	3.84 (1.13)	4.60 (.81)
Self-Rated Confidence	26.43 (5.22)	29.39 (3.41)
Enjoyment	24.11 (5.95)	27.58 (4.27)
Response to Failure	17.14 (4.43)	19.11 (4.65)
MA	16.86 (5.01)	20.95 (5.51)

For the BCMRS, those who used atypical sums had significantly larger scores on growth (t (55.57) = -2.805, p = .007, r = .35) and MR (t (71) = -3.30, p = .002, r = .36). There were no significant differences on the struggle (t (71) = -1.286, p = .203) or value subscales (t (64.16) = -1.52, p = .132). For the MAAQ, those using atypical sums had significantly greater levels of enjoyment (t (71) = -2.88, p = .005, r = .32) and were less MA (t (71) = -3.31, p = .001, r = .37). They also had significantly higher self-rated confidence (t (57.85) = -2.85, p = .006). There was no significant difference in response to failure (t (71) = -1.842, p = .070) between groups.

Multiple regressions were run with strategy as the dependent variable and the BCMRS and MAAQ as the predictors. The BCMRS significantly predicted the strategy used, R^2 = .168, F (3, 72) = 4.66, p = .005, as can be seen in Table 5-9.

Table 5-9 Regression Model for Strategy Used in Study F with BCMRS Subscale Scores as Predictors

	B	SE b	B	p
Constant	.367	1.330		.783
Growth	.248	.098	279	.014
Struggle	.252	.107	.263	.021
Value	.160	.331	.054	.483

The MAAQ also predicted the strategy used (R^2 = .273, F(4, 72) = 6.368, p <.001) as shown in Table 5-10.

Table 5-10 Regression Model for Strategy Used in Study F with MAAQ Subscale Scores as Predictors

	B	SE b	B	p
Constant	-2.830	1.688		.098
Self-Rated Competence	.182	.078	.334	.022
Enjoyment	.022	.067	.046	.748
Response to Failure	-.134	.080	-.247	.100
MA	.181	.068	.407	.010

However, the model that best predicted the strategy was a combination of both scales, $R^2 = .338$, $F(7, 72) = 4.746$, $p<.001$. The regression model can be seen in Table 5-11.

Table 5-11 Regression Model for Strategy Used in Study F with the BCMRS and MAAQ as Predictors

	B	SE b	B	p
Constant	-2.750	1.800		
Growth	.121	.100	.137	.227
Struggle	.249	.109	.260	.026
Value	.046	.311	.015	.883
Self-Rated Competence	.088	.086	.162	.306
Enjoyment	.027	.065	.059	.677
Response to Failure	-.174	.080	-.321	.034
MA	.214	.069	.481	.003

5.5 Discussion

The study explored links between children's levels on the BCMRS and their self-rated competence and MA. The data supported the hypothesis that MR, in particular belief in growth and struggle, was positively correlated with self-rated competence. Although higher overall MR was not correlated with lower MA as hypothesised, higher scores on the growth subscale were. It also considered how scores on the BCMRS and MAAQ were correlated with performance on the task. There were no correlations between time taken on the task or number of answers and MR. Higher levels of MR and self-rated competence and lower levels of MA were linked to more optimal problem solving strategies as predicted. Higher self-rated confidence and belief in growth and lower levels of MA were linked to greater use of atypical sums.

As hypothesised, MR was positively correlated with self-rated competence. This provides support for the claim that children with higher MR are more confident in their mathematics abilities and thereby better prepared for on-going mathematics studies (Johnston-Wilder and Lee 2010a and b, Lee and Johnston-Wilder 2017 and this thesis). In particular, the growth and struggle subscales were positively correlated with self-rated competence. This suggests that children who believe that it is possible to get better in mathematics and know that it is necessary to struggle to do so rate themselves more highly than those who believe their ability level is fixed and that struggle is not a part of learning mathematics. This suggests that in order to develop self-rated competence, which Dowker et al. (2019) found was positively correlated with performance, children need to experience both growth and struggle while learning mathematics in school.

In this study, MR was not correlated with MA, although higher scores on the growth subscale were linked with lower levels of MA. This suggests that belief around the ability to get better in mathematics may be linked to MA. In particular, if an individual believes that their level of mathematics ability is fixed it is possible that this will contribute to anxiety about participating in mathematics activities. Therefore it is recommended that schools and wider society should be actively promoting the belief that everyone is capable of improvement in mathematics as a means of reducing levels of MA in the population.

In terms of performance on the task, there was no correlation between the time taken on the task or the number of answers given and MR. However, in this particular task, taking a longer time or producing more answers was a strategy that would usually meet with success but was not the strategy most likely to lead to success. It was observed that rather than taking a long time to produce lots of sums many children were using strategies to produce more obscure sums and thus got a sum that met the brief in a much shorter period of time. This would explain the lack of correlation between time taken and number of answers and MR, since it was found that children with higher levels of MR were more mathematically able and picked the shorter, more successful strategy. In this task, perseverance did not necessarily mean better performance. It is suggested that in future studies the strategies that children are using, as well as the amount of time they are spending on a problem are recorded as they were here.

Choosing the optimal strategy was positively correlated with MR. This provides the first evidence amongst young children for the claims of this thesis and Lee and Johnston-Wilder (2017) that children with higher levels of MR are better equipped to solve problems. With the emphasis of the National Curriculum (Department for Education 2014a) on problem solving, this provides further support for the claim that a focus on developing MR could lead to an improvement in performance.

Children with higher belief in growth in this study were more likely to use an atypical sum, that is, one they developed themselves rather than replicated from something they had seen before. This suggests that belief in the ability to get better in mathematics may be linked to the ability to experiment with mathematics. The link between growth and using mathematics to creatively solve problems rather than simply replicating what has been seen before may be the reason for Lee and Johnston-Wilder's claims that mathematically resilient learners are better equipped to solve problems in mathematics (2017).

Higher levels of self-rated competence were also positively correlated with choosing an optimal strategy and use of atypical sums. This suggests that those who were rating their competence highly in this study had a realistic view of their own abilities. It may also be the case that since they felt they were good at mathematics they were more able to try more complex strategies. Those who had lower levels of MA were also more likely to choose an optimal strategy, again possibly because they felt more able to try something difficult. This is supported by the fact that lower levels of MA were linked to a greater likelihood of choosing an atypical sum, meaning that those who were less MA were more likely to try out sums they had not met at school than those who were more highly MA and stuck to replicating what they had previously seen.

It was also notable that there was a positive correlation between age and levels of enjoyment and MR in this study. This could represent a difference from Dowker's findings (British Psychological Society 2018) that older children got more upset about struggling with mathematics or it could be because the older children in this study were a particular subsection of children.

This study has several limitations. Firstly the sample, which was opportunistic and taken from children brought by their parents to take part in a psychology event at a university in the summer holidays, is not representative of all school aged children. It is also relatively small (n = 73). All the MR levels amongst the children were positive, indicating that they had relatively high levels of MR. Findings may have been different amongst children who had negative levels of MR and it is suggested that this study be run with a wider range of children to see if it is replicated. It would also have been useful to have a measure of the children's current performance level which was not available in this case.

5.6 Conclusions

This study has provided evidence for the claims that children who possess higher levels of MR are better equipped to solve mathematical problems. In particular the belief that it is possible to get better in mathematics, that you do not have to be a 'maths person', is positively correlated with using more optimal problem solving strategies and being more creative in the mathematics used, which in turn would lead to better chances of solving problems. Given the findings in Chapter 2 that the belief that only 'maths people' can do mathematics is widespread in society, it is suggested that schools work on developing the belief amongst their pupils that it is possible for everyone to do well in mathematics. This belief was also correlated with lower levels of MA which was identified as another of the current problems in mathematics education in Chapter 2. The current study also found that higher levels of MR are linked with higher levels of self-rated competence, which in turn has been linked to higher levels of performance (Dowker et al. 2019). As this study is cross sectional and correlational, and as such does not imply causation, it is recommended that further studies into links between MR and performance are conducted to explore if there is a direct link between the two.

Chapter 6 A Longitudinal Study of Mathematical Resilience and Performance in Year 1 Children

6.1 Chapter Summary

The evidence discussed in Chapter 2 and results of the study in Chapter 5 suggested that there may be links between MR and performance in mathematics for Year 1 children. This chapter discusses a monitoring study to further assess these links and to assess how MR develops over the course of Year 1. It took place in five schools over the course of an academic year with performance and scores on the BCMRS being measured once a term. Associations between MR and performance were found. There were some changes in MR over the course of the year and these are discussed.

6.2 Introduction

As discussed in Chapter 2, the development of MR has been suggested by authors such as Lee and Johnston-Wilder (2017) as a way to overcome the issues of mathematics anxiety (MA), mathematics avoidance and incomplete development of early mathematical concepts in secondary and post-16 students with the intention of increasing performance levels in mathematics. This thesis has suggested that since attitudes to mathematics develop early in a child's school career, and continue to develop according to their experience of mathematics throughout their education, encouraging the development of MR at a young age and continuing to foster it thereafter may help reduce difficulties in mathematics. However, MR research has not generally been carried out with young children, its impact on the performance of primary children has not been convincingly investigated and little is known about how it develops.

MR research has traditionally been carried out at a single time point or pre and post intervention. Thus whether MR develops in children without direct intervention and if so how and when this development takes place has not yet been studied. Year 1 is the start of a child's formal mathematical education in England (Department for Education 2014a). Up until this point mathematics learning has been play-based but from Year 1 onwards, mathematics is taught more formally. It is therefore hypothesised that Year 1 may be the year in which initial attitudes to mathematics, formed mainly at home and from experiences in wider society, start to be more strongly influenced by experiences of mathematics at school. Interventions to develop MR in older students (e.g. Johnston-Wilder, Lee, Garton, Goodlad and Brindley 2013) have relied upon providing them with mastery experiences in mathematics, vicarious experiences of mathematics and talking to them about the mathematics that they are learning in order to help them understand the emotional states that are caused by learning mathematics (see Chapter 2). Children will be having these types of experiences, whether positive or negative, whilst formally learning mathematics in Year 1 and therefore what happens to the children during the year may be crucial in the formation of their MR. In order to investigate this, a longitudinal study was carried out with Year 1 children, monitoring them over the whole academic year to explore the hypothesis that their MR would develop over the year.

There are numerous factors that affect the type of experiences that children have when learning mathematics and which may affect their MR, but one of the main differences is the school they attend. Although the English education system is designed to be a comprehensive one, the fact that schools receive OFSTED ratings from Outstanding to Inadequate when inspected suggests that not all children receive the same experience of the National Curriculum. Thus the current study looks to investigate the hypothesis that MR will develop differently in different schools.

Another likely potential impact on the development of MR is early experience of success or failure. As discussed in Chapter 2, mastery experiences are linked to the development of positive attitudes towards learning (e.g. Bandura 1977, Johnston-Wilder et al. 2013). For this reason teacher assessed levels are used in this study, since they are the measure that young children have of success or failure in mathematics. As discussed in Section 3.7.3, there are disadvantages to teacher assessed levels as a measure of performance since they are interpreted differently by different teachers. Despite this, they are the most common feedback that a child receives about their performance in a mathematics classroom since many schools teach children in groups based upon their teacher's assessment of them and children are very aware of this fact (Marks 2012). Thus it is hypothesised that teacher assessed levels at the start of the year will be correlated with MR levels at the end.

In Chapter 5, positive correlations were found between MR, particularly growth and struggle, and the performance of primary children on a micro level problem solving mathematics task. The current chapter looks at macro level performance. Successful macro level performance is the ability to perform or continue to solve problems over the course of the mathematical lifespan. During the early years of learning mathematics it is possible to attain on-going success by knowledge alone. However, at some stage in all learners' mathematical careers they will encounter a problem that they cannot solve by knowledge alone and will have to learn to problem solve. Therefore being successful at mathematics in the long term relies upon being able to overcome difficulties that learners encounter when learning mathematics. It seems probable that as children progress through primary school, even those working in line with National Curriculum expectations for their age will encounter problems and this group may need to increase their belief in struggle in order to have continuing success in the subject. MR theory (Lee and Johnston-Wilder 2010) posits that those learners who possess MR are better placed to meet these struggles than those who do not and thus hypothesise that MR is positively correlated with macro level performance. The current study looks to investigate this by exploring the hypothesis that MR and performance as measured by teacher assessed levels is correlated. Since the link that is proposed by Lee and Johnston-Wilder is that MR affects performance because it changes the way children work in the mathematics classroom it is possible that MR at the beginning of the year will affect performance level at the end of the year, since if Lee and Johnston-Wilder are correct it will have been governing mathematical behaviour. For this reason a second performance hypothesis: MR level at the beginning of the year will be correlated with performance level at the end of the year, is tested.

In summary, the study looked at two distinct areas regarding MR in Year 1 children:

- Firstly the study investigated the development of MR. It considered the consistency of the children's MR scores over the course of the academic year and whether any development in MR was linked to original performance level or school attended.
- Secondly the study investigated links between performance and MR.

6.3 Method

6.3.1 Design

A longitudinal design was adopted with data collected at three time points during the school year, in the autumn (time 1), spring (time 2) and summer (time 3) terms. At each time point MR was measured and teacher assessed performance data were collected.

6.3.2 Participants

The data for this study came from Study G. Details of recruitment and participants can be found in Sections 3.5 and 3.6.7. Seventy-four Year 1 children provided data for at least two of the three time points.

6.3.3 Measures and Procedure

The *BCMRS* was administered as described in Section 3.7.1. The gap between administrations of the scale was 18 weeks.

Teacher assessed levels (see Section 3.7.3) were requested from the schools at the end of each term.

6.4 Results

Figure 6-1, Figure 6-2 , Figure 6-3 and Figure 6-4 show mean scores on the BCMRS by teacher assessed level and for all children at times 1, 2 and 3 respectively. The numerical data can be found in Appendix 9.

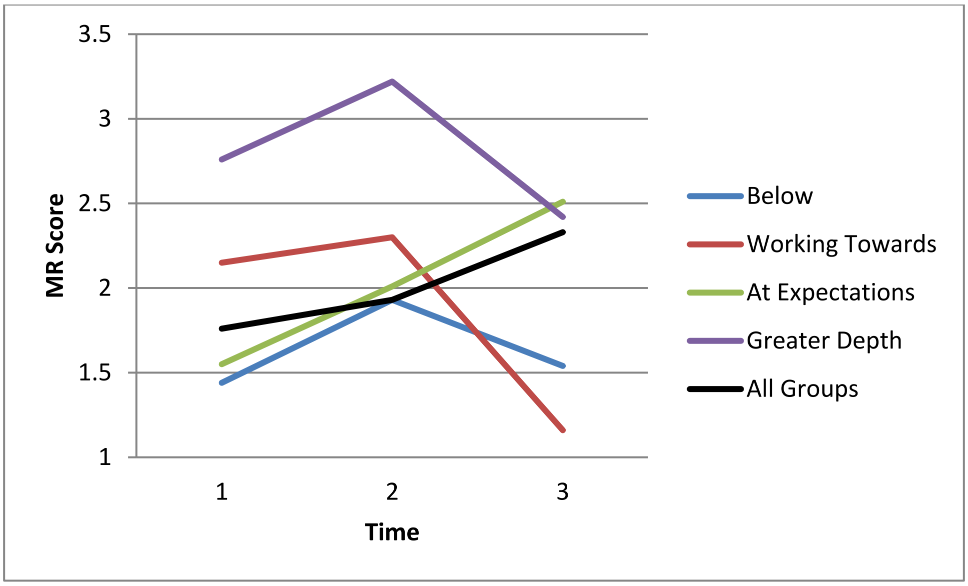

Figure 6-1 Graph to Show Study G MR Scores by Teacher Assessed Levels at Times 1, 2 and 3

Figure 6-1 demonstrates that while the trend for all groups is a rise in MR over the year, there are differences in MR and in changes in MR between groups. Those working below expectations have the lowest and those working at greater depth have the highest levels of MR throughout the year. While the MR of those working at expectations rises steadily throughout the year the other three groups rise to time 2 and then fall, in the case of the working towards and greater depth groups to a lower level than they were at the start of the year.

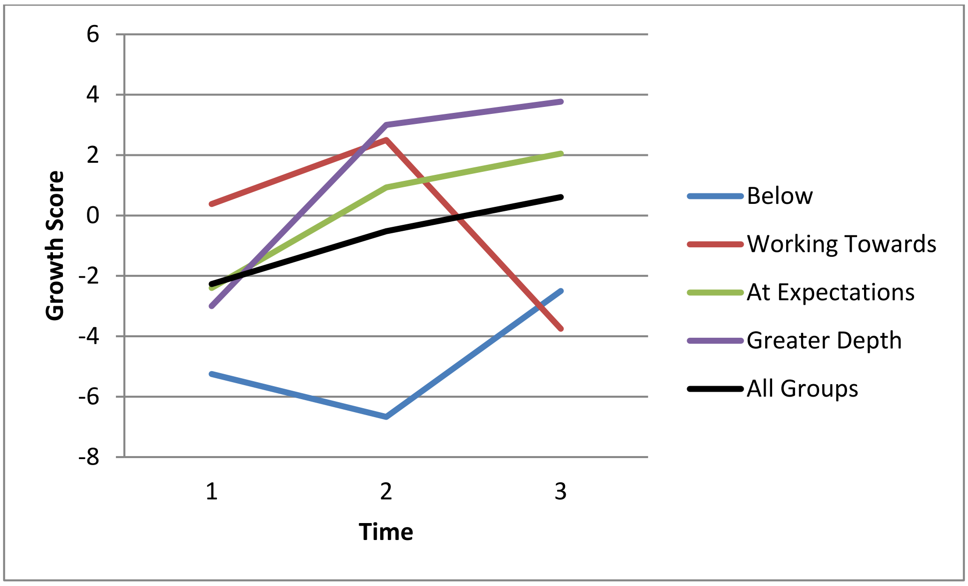

Figure 6-2 Graph to Show Study G Growth Scores by Teacher Assessed Levels at Times 1, 2 and 3

Figure 6-2 demonstrates that overall there was a rise in belief in growth throughout the year. This trend was made up of a rise in growth scores across the period in those performing at expectations and at greater depth; and an initial rise, then sharp fall in those working towards expectations. Those working below expectations had the lowest belief in growth for most of the year but their scores improved at time 3 to above those working towards expectations.

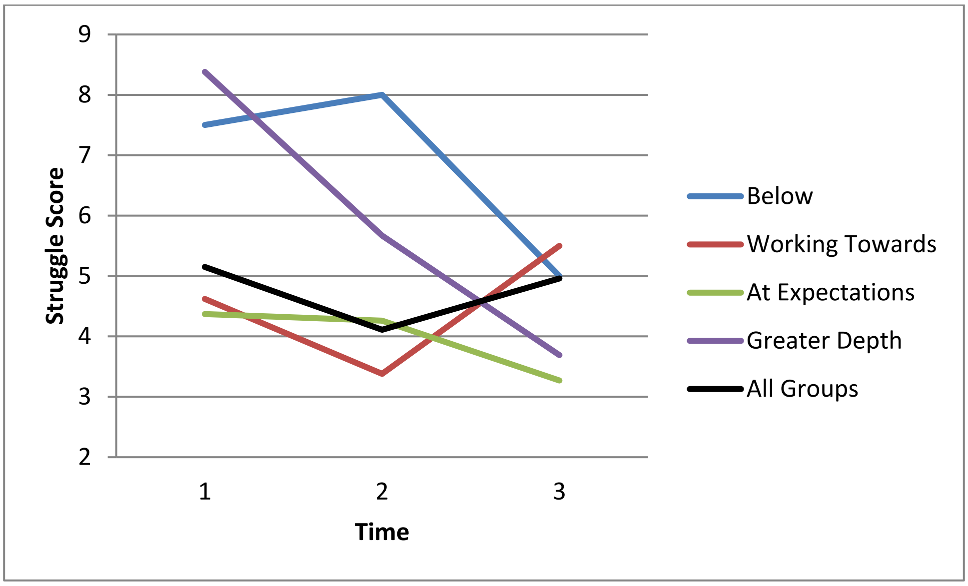

Figure 6-3 Graph to Show Study G Struggle Scores by Teacher Assessed Levels at Times 1, 2 and 3

Figure 6-3 shows that overall struggle scores remained fairly constant across the year but there were distinct differences between the groups. Those working towards expectations showed an overall rise across the year whilst the other three groups showed a fall with those working at greater depth showing the greatest fall in belief in struggle.

Figure 6-4 shows a slight overall fall in value scores over the course of the year. This fall was reflected in the working towards and greater depths groups with those working at greater depth showing the greatest fall. Those working below expectations showed an initial rise in their value for mathematics and then an equally large fall whilst those working at expectations showed an initial fall but then a rise in how much they valued mathematics.

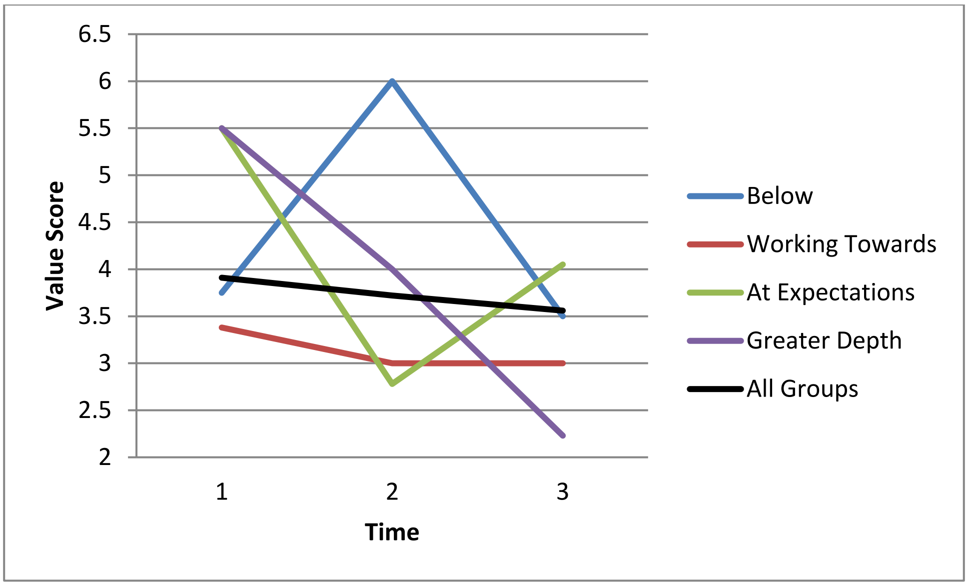

Figure 6-4 Graph of Study G Value Scores by Teacher Assessed Levels at Times 1, 2 and 3

Caution should be taken when interpreting these findings because, due to the way teacher assessed levels are calculated, the categories will likely not contain the same children at the end as at the start of the year (e.g. a child whose was working towards the expected level at time 1 might well be at the expected level by the end of the year). Thus the most useful statistics are the overall trends (the black lines) which show a rise in MR over the year made up of fairly consistent but slightly positive changes in growth and struggle scores and a slight fall in value scores. It is also notable that those children working below and towards expectations had the lowest MR and growth scores at all time points but by the end of the year these two groups were the ones with the highest belief in struggle.

In order to further investigate how children's MR was developing during the year, Spearman's correlations were calculated for each of the subscales and the scale total between time points. MR, struggle and value were significantly correlated at all three time points (see Table 6-1). The growth subscale scores were significantly correlated between times 1 and 3 and between times 2 and 3 but were not significantly correlated between times 1 and 2. For MR, struggle and value the correlations were also stronger between times 2 and 3 than between times 1 and 2 and 1 and 3.

Table 6-1 Spearman's Correlations for Study G BCMRS Scores Between Time Points (significant correlations in bold)

	Time 2 (n = 71)	Time 3 (n = 72)
Time 1 (n = 74)	Growth r = .145, p = .257	Growth **r = .203, p = .020, BCa CI [.066, .499]**
	Struggle **r = -.265, p = .044, BCa CI [-.003, .494]**	Struggle **r = .398, p = .002, BCa CI [.158, .615]**
	Value **r = .522, p <.001, BCa CI [.302, .709]**	Value **r = .446, p <.001, BCa CI [.185, .662]**
	Total MR **r = .390, p = .001, BCa CI [.123, .603]**	Total MR **r = .336, p = .006, BCa CI [.081, .540]**
Time 2 (n = 71)		Growth **r = .577, p <.001, BCa CI [.409, .712]** Struggle **r = .536, p<.001, BCa CI [.285, .738]** Value **r = .651, p<.001, BCa CI [.471, .787]** Total MR **r = .680, p <.001. BCa CI [.447, .868]**

Repeated measures ANOVAs were conducted with times 1, 2 and 3 as the grouping factors and the subscale and scale totals as the dependent variables. Where the assumption of sphericity was violated Huynh-Feldt or Greenhouse-Geisser corrections were used as appropriate. Mean growth scores were statistically significantly different between time points ($F(1.846, 114.42) = 9.63$, $p <.001$, $\omega^2 = .17$). Contrasts showed a statistically significant rise in growth scores from time 1 to 2 ($p = .032$, $r = .32$) and from time 1 to time 3 ($p <.001$, $r = .47$) but a fall between times 2 and 3 which was not significant ($p = .337$). For struggle, value and total MR, mean scores were not statistically significantly different between time points (Struggle $F(2, 124) = 1.23$, $p = .297$, $\omega^2 = .004$; Value $F(2, 124) = .52$, $p = .597$, $\omega^2 = -.007$; Total MR $F(1, 64.019) = 2.111$, $p = .151$, $\omega^2 = .02$).

In order to consider potential causes for the development of MR over the course of the year, BCMRS scores at time 3 were compared with teacher assessed levels at time 1. Table 6-2 shows mean scores on the BCMRS at time 3 according to the level the children were rated at by their teacher at time 1.

Table 6-2 Mean Study G BCMRS Scores at Time 3 according to Teacher Assessed Levels at Time 1

Teacher assessed level	Growth	Struggle	Value	MR
Below (n = 7)	.86 (3.89)	6.57 (3.55)	4.71 (1.60)	3.10 (.56)
Working towards (n = 13)	2.77 (4.68)	1.77 (5.99)	2.31 (3.84)	1.82 (1.95)
At Expectations (n = 44)	-.14 (5.08)	5.07 (4.71)	3.43 (3.60)	2.12 (2.04)
Greater Depth (n = 8)	1.00 (6.07)	8.13 (3.01)	5.25 (2.12)	3.63 (1.82)

In order to investigate the hypothesis that children's MR would be influenced by their initial performance level, partial correlations were carried out between time 1 teacher assessed levels and time 3 BCMRS scores, with time 1 BCMRS scores as the controlling factor. The results can be seen in Table 6-3. There was a significant correlation between struggle scores at time 3 and teacher assessed levels at time 1, controlling for struggle scores at time 1.

Table 6-3 Partial Correlations Between Study G BCMRS Scores at Time 3 and Teacher Assessed Levels at Time 1, Controlling for BCMRS Levels at Time 1

	Teacher Assessed Level
Growth	r = -.173, p = .168
Struggle	**r = .257, p = .039**
Value	r = .078, p = .539
MR	r = .052, p = .675

In order to further investigate whether children's experiences of success of failure were affecting the development of their MR, mixed effect ANOVAs were conducted to investigate links between changes in scores on the BCMRS and changes in teacher assessed level over time. The children were grouped into four groups, those whose teacher assessed level remained consistent at all time points, those whose level increased, those whose level decreased and those whose level fluctuated across the year. Children whose levels initially remained stable and then increased or decreased were put in the increased or decreased group respectively. Table 6-4 shows the number of children in each group.

Table 6-4 Number of Children in Each Group When Study G Data Were Grouped by Change in Teacher Assessed Level over the Year

Direction of Change in Level	Number of Children
Consistent	12
Increased	21
Decreased	2
Fluctuated	4

The results of the ANOVAs can be seen in Table 6-5. The only significant effect was that of time on the growth subscale, $F(2, 56) = 3.516$, $p = .036$, $\eta^2 = .112$, suggesting that there was no association between the variation in a child's performance and scores on the BCMRS.

Table 6-5 Results of Mixed Effects Anovas Comparing Links Between Variation in Performance and Score on the BCMRS in Study G

	Main Effect of Time	Main Effect of Variation in Performance	Interaction of Time and Variation
Growth	**F(2, 56) = 3.156, p = .036,**	F(3, 28) = .521, p = .671	F(6, 56) = .831, p = .551
Struggle	F(1.61, 45.21) = 1.009, p = .358	F(3, 28) = .749, p = .532	F(4.84, 45.21) = .514, p = .759
Value	F(2, 56) = .063, p = .939	F(3, 28) = .364, p = .780	F(6, 56) = 1.079, p = .386
MR	F(1.501, 42.025) = 1.861, p = .176	F(3, 28) = .676, p = .574	F(4.503, 42.025) = 1.216, p = .319

In order to investigate whether the changes in BCMRS scores were different in different schools, mixed effects ANOVAs were carried out for the three subscales and the scale total with time of testing as the within subjects factor and school as the between subjects factor. For MR, Levene's test based on the mean was significant for the time 2 scores, $F(4, 60) = 2.590$, $p = .046$ and the time 3 scores, $F(4, 60) = 3.217$, $p = .019$. There was no significant effect of school on MR, $F(4, 60) = .693$, $p = .599$, $\eta^2 =$

.044 indicating children in all schools had similar mean levels of MR. There was no significant effect of time, $F(1,120) = 3.75$, $p = .543$, $\eta^2 = .006$, indicating that the MR scores were similar in each term. There was also no significant interaction effect of school and time, $F(4.001, 60.018) = .719$, $p = .582$, $\eta^2 = .046$, indicating that changes in the children's MR scores were similar over the year in all five schools.

For the growth subscale there was a significant main effect of time, $F(2, 116) = 7.710$. $p = .001$, $\eta^2 = .117$, as expected given previous findings. Contrasts revealed that scores on the growth subscale were significantly higher at time 3 than at time 1, $F(1, 58) = 14.384$, $p <.001$, $\eta^2 = .199$. There was no significant difference in the growth subscale scores between times 2 and 3, $F(1, 58) = 1,997$, $p =.163$, $\eta^2 = .033$. There was a significant main effect of school , $F(4, 58) = 4.189$, $p = .005$, $\eta^2 = .224$, indicating that growth scores varied across the schools (see Figure 6-5) with schools 4 and 6 having higher scores on the growth subscale than the other schools. There was no significant interaction of time and school, $F(8, 116) = 1.487$, $p = .165$, $\eta^2 = .094$, indicating that the changes in growth subscale scores over time were similar in all of the schools.

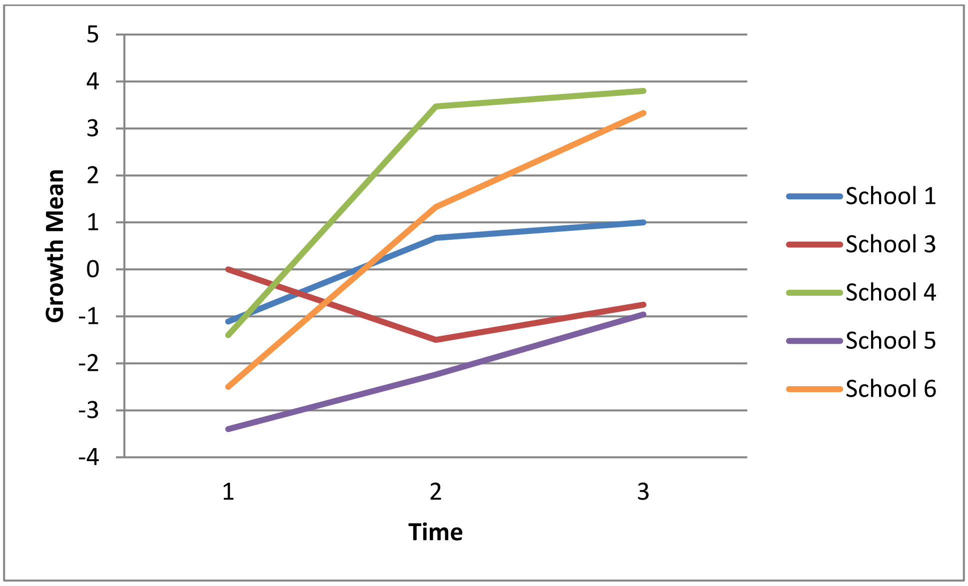

Figure 6-5 Mean Study G Growth Scores by School at Times 1, 2 and 3

For the struggle subscale, Levene's test was significant at time 2, $F(4, 58) = 4.447$, $p = .003$ and time 3, $F(4, 58) = 4.667$, $p =.002$. There was no significant main effect of time indicating that the struggle scores were similar across the year, $F(1.943, 112.699) =$

.500, p = .602, η^2 = .009. There was a significant main effect of school, F(4, 58) = 4.442, p = .003, η^2 = .235, indicating that the struggle subscale scores varied between schools (See Figure 6-6). There was also a significant interaction of school and time, F(7.772, 112.699) = 2.523, p = .015, η^2 = .148, indicating that the subscale scores varied in different schools over the course of the year. Contrasts showed that although the changes in scores between times 1 and 2 were not significantly different in different schools, F(4, 58) = 1.764, p = .148, η^2 =.108, the changes in different schools were significantly different between times 2 and 3, F(4, 58) = 4.937, p = .002, η^2 = .254. As can be seen in Figure 6-6, the struggle scores were higher in some schools at time 2 than at time 1, whilst in others they were lower. Similarly between time 2 and time 3 some schools showed a rise in struggle scores whilst others fell. Over the course of the year the scores in two schools rose, in two fell and in one school remained fairly constant.

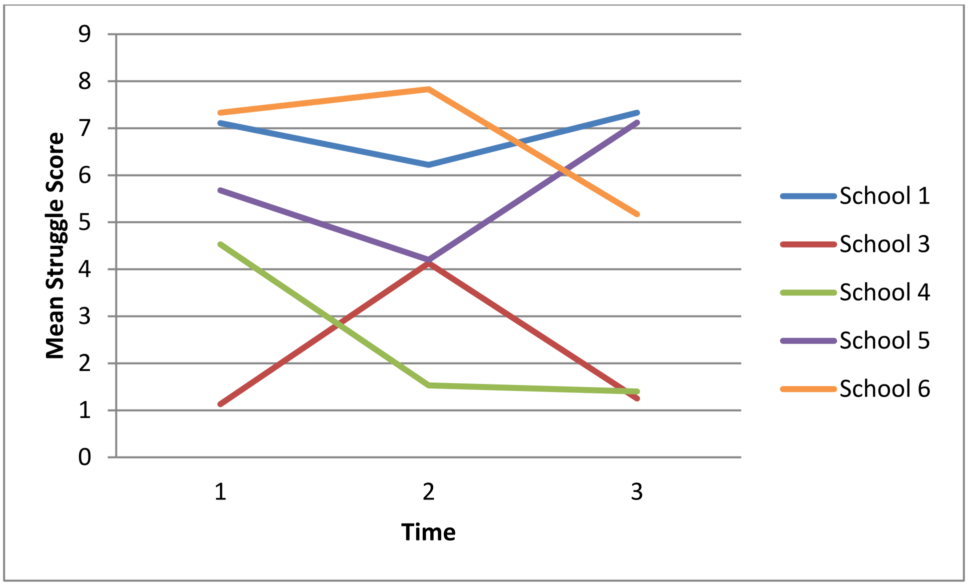

Figure 6-6 Mean Study G Struggle Scores by School at Times 1, 2 and 3

For the value subscale, Levene's test was significant at all three time points; time 1 F(4, 58) = 3.868, p = .007; time 2 F(4, 58) = 3.184, p <.001; time 3 F(4, 58) p <.001. There was a significant main effect of school indicating that the value subscale scores varied between schools, F(4, 58) = 3.536, p = .012, η^2 = .196. There was no significant effect of time indicating that the children's value scores were similar in each of the three terms, $F(2, 116) = .886$, $p = .415$, $\eta^2 = .015$. There was a significant interaction of school and time, $F(8, 116) = 2.890$, $p = .006$, $\eta^2 = .166$, indicating that there was a difference in the changes of value scores in different schools throughout the three terms (see Figure 6-7). As can be seen, the mean value score for two schools was lower in the summer term than in the autumn term whilst other schools had higher means for the value subscale.

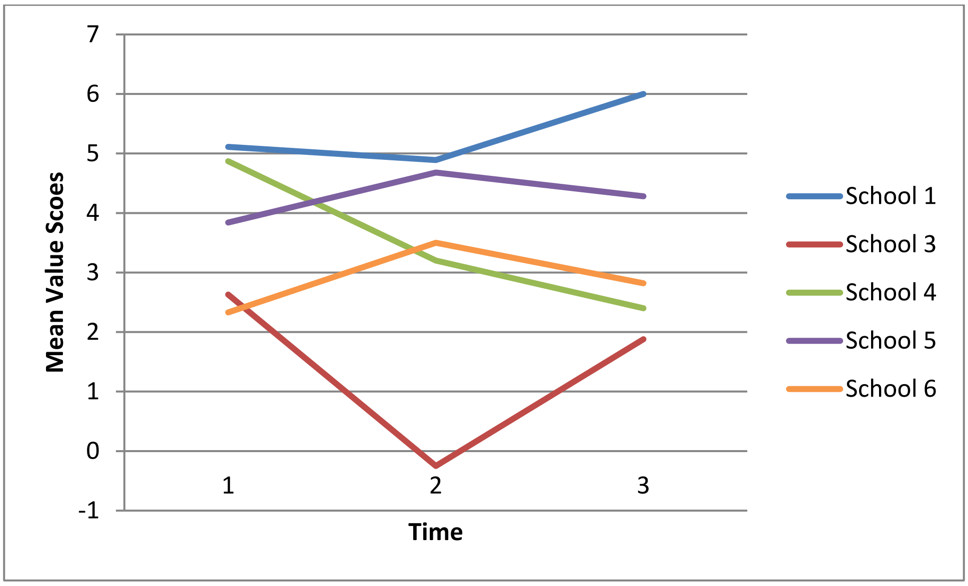

Figure 6-7 Mean Study G Value Scores by School at Times 1, 2 and 3

These findings showed that changes on all three subscales over the course of the year varied between schools although the MR total did not change. This supports the hypothesis that the different experiences the children are having in different schools may be affecting the way their beliefs in growth, value and struggle develop.

ANOVAs were carried out to investigate the relationship between teacher assessed levels and scores on the BCMRS for each of the three terms. Results can be seen in Table 6-6.

Table 6-6 ANOVAs Comparing Performance and Scores on the BCMRS in Study G (significant ANOVAs in bold)

	Time1	Time 2	Time 3
Growth	$F(3, 64) = 2.423$, $p = .074$	**$F(3, 40) = 3.485$, $p = .025$**	**$F(3, 40) = 2.870$, $p = .049$**
Struggle	$F(3, 67) = 1.997$, $p = .123$	$F(3, 40) = .847$, $p = .477$	$F(3, 40) = .131$, $p = .941$
Value	$F(3, 67) = 1.137$ $p = .341$	$F(3, 40) = .788$, $p = .508$	$F(3, 40) = .595$, $p = .662$
MR	$F(3, 67) = 2.345$, $p = .081$	$F(3, 40) = .266$, $p = .849$	$F(3, 40) = .632$, $p = .599$

At time 1, there was no significant effect of teacher assessed level on scores on the BCMRS. At time 2, there was a significant effect of teacher assessed level on scores on the growth subscale. Post hoc comparisons using the Hochberg test revealed that those who were assessed as working below at time 2 had significantly lower means on the growth subscale than all other groups (see Figure 6-2). There were no significant relationships between the teacher assessed levels and the other subscales or total MR. At time 3, there was also a significant effect of teacher assessed level on scores on the growth subscale but post hoc comparisons did not reveal significant differences between groups.

In order to investigate the hypothesis that initial MR levels would correlate with final performance levels, ANOVAs were run for the initial MR scores and the final teacher assessed levels. There were no significant effects of initial MR scores on final performance. The results can be seen in Table 6-7.

Table 6-7 ANOVAs Comparing Initial BCMRS Scores and Final Teacher Assessed Levels in Study G

Growth	$F(3,37) = 2.668$, $p = .063$
Struggle	$F(3,37) = 2.093$, $p = .119$
Value	$F(3,37) = 2.305$, $p = .094$
MR	$F(3,37) = .753$, $p = .528$

Multiple hierarchical regressions were run to see if scores on the BCMRS at the start of the year provided a better prediction for teacher assessed levels at the end of the year than initial teacher assessed levels alone. The models can be seen in Table 6-8. Only the growth subscale score when combined with the initial teacher assessed level predicted the final teacher assessed level.

Table 6-8 Multiple Regression Models for Study G Performance at Time 3 with Time 1 Performance and BCMRS Scores as Predictors

	b	SE b	β	P
Initial Teacher Assessed Level F(1.37) = 2.625, p = .114				
Constant	1.839	.240		<.001
Initial Level	.226	.140	.261	.114
Growth F(2,37) = 3.297, p = .049				
Constant	1.738	.237		<.001
Initial Level	.256	.136	.295	.067
Growth Score	-.046	.024	-.303	.060
Struggle F(2,37) = 2.897, p = .068				
Constant	1.613	.267		<.001
Initial Level	.244	.136	.281	.082
Struggle	.041	.023	.273	.091
Value F(2,37) = 2.608, p = .088				
Constant	1.601	.279		<.001
Initial Level	.182	.140	.209	.203
Value	.076	.048	.254	.124
MR F(2,37) = 1.392, p = .262				
Constant	1.774	.279		<.001
Initial Level	.216	.143	.248	.141
MR	.040	.086	.077	.645

6.5 Discussion

This study aimed to investigate two aspects of MR: its development in Year 1 and whether it was linked with performance in this age group. Findings about the development of MR throughout the year were mixed with different patterns of development on the scale total and subscales. There were differences in changes in scores on the scale and subscales between children at different levels of performance. There was evidence that initial teacher assessed levels were correlated with final struggle scores, when initial struggle scores were controlled for. School attended was also correlated with the development of MR. When links between performance and MR were considered, although no statistically significant correlation was found there was a trend towards those performing at the lowest attainment level having the lowest levels of MR and belief in growth.

When the development of MR was considered, there was a slight overall rise in MR over the course of the year. This rise was not statistically significant. There was a statistically significant increase in overall growth scores between time 1 and 2, and then continued to rise slightly between times 2 and 3. Overall struggle scores initially fell and then rose to levels similar to those at time 1 by the end of the year. Overall value scores fell throughout the year. Thus it was not possible to conclude a definitive overall direction for changes in MR in Year 1.

The significant rise in the growth subscale recorded between times 1 and 3 could be a result of increased belief in growth over the course of the year which could have occurred as children experienced being able to do mathematics questions that they would not have been able to do earlier in the year. However, the items on this subscale are all negatively worded and it is also possible that children struggled to understand them at the start of the year and this is the reason for the rise in scores later on.

In this sample there was a notable correlation between struggle scores at time 3 and teacher assessed levels at the start of the year when initial struggle scores were controlled for. This suggests that how a child's belief in struggle developed in this sample was associated with how their teacher had originally rated them in mathematics. One explanation for this finding could be that once they have made an initial assessment of a child, the teacher sets them work which is at the level of this assessment. Therefore the children are not experiencing work which they need to struggle with to achieve success. If this is the case, it suggests that the way children are being taught is not providing them with the conditions to develop a belief in struggle. This could be problematic given the proposed links between MR and performance. It is recommended that further research is undertaken to study this link between teachers' assessments of children and how their belief in struggle develops.

There was a significant effect of school on changes in MR levels over the year for this sample, suggesting that the changes in belief in the three strands of MR may have been dependent on the experiences the children were having in school. This may reflect differences in the quality of practices used in schools. It also suggests that there may be some experiences that improve MR and others that reduce it, and therefore if these could be identified interventions to improve MR would be possible. Observations of mathematics classes with a specific focus on their impact on the development of MR should be a focus for future MR research.

This study showed links between performance and total MR, growth and struggle in Year 1 children although this was not always statistically significant. Children who were performing below or working towards expectations had lower MR and growth scores by time 3 than the other two groups as would have been expected. However, they also had a higher belief in struggle. This finding does not necessarily dispute Lee and Johnston-Wilder's claims for MR. As discussed in the introduction, it is only when children start to struggle with mathematics that the possession of MR helps them to overcome problems and achieve success. It may be that these Year 1 children have not yet experienced serious problems with the mathematics they are studying and therefore the link between performance and MR has not yet fully developed. Further research is suggested to determine if this is the case.

There are several limitations to this study. Firstly, as mentioned in the introduction, teacher assessed levels are not an ideal measure of performance since they can vary significantly in interpretation between schools and individual teachers. They were used here both to cause least disruption to the schools and because they are the most common measure of performance communicated to children in Year 1, and as has been seen they were linked to children's development of belief in struggle. However, the fact that children moved from one group into another as they learnt more throughout the year made the interpretation of results, particularly performance level trends, very difficult. It is therefore recommended that future longitudinal studies into MR and performance use a standardised measure as well. The sample size in the study was also smaller than ideal. The fact that one school withdrew and a second did not provide teacher assessed levels for time 2 and 3 meant that for many analyses there were only 41 participants. A larger longitudinal study is suggested.

6.6 Conclusions

This study found that there was a trend towards links between MR and performance in this age group, the first time that such a link has been found in such young children. Those children performing at lower levels in mathematics had lower levels of MR and belief in growth, but higher belief in struggle. Further longitudinal studies are suggested, ideally spanning the whole of primary school, to establish the significance of links between MR and performance. A link between a teacher's initial assessment of a child's performance level and the child's belief in struggle at the end of the year was also found. Assuming the on-going nature of such links, as suggested by Lee and Johnston-Wilder (2017), it is important to understand which experiences are contributing to the differences in development of MR seen in different schools and at different performance levels in this study. Studies of links between classroom practice and MR are suggested to facilitate this and to suggest how schools could improve the MR of their children and thus better prepare them for their future mathematical careers.

Chapter 7 A Second Longitudinal Study of Mathematical Resilience and Performance in Year 1

7.1 Chapter Summary

Chapter 6 outlined the need for longitudinal studies into links between MR and performance in Year 1 children which used standardised measures of performance. This chapter describes such a longitudinal study conducted in two different schools using a standardised performance measure. The study considers the links between MR, MA and performance over the course of an academic year. Children participating in the study completed the BCMRS, the MAAQ and the mathematics elements of the standardised Wechsler Individual Achievement Test – Second UK Edition (WIAT-II) (Wechsler 2005) once a term for an academic year.

7.2 Introduction

Chapter 6 advised of the necessity for longitudinal studies into MR and performance, particularly using standardised performance measures. The current chapter discusses such a study. In Study J data were collected from a control group of twenty-three children over the course of an academic year, providing the opportunity to study this data with regard to the development of MR and links between performance and MR. The standardised performance measure used, the Wechsler Individual Achievement Test – Second UK Edition (WIAT-II: Wechsler, 2005) has two subscales measuring mathematical performance: the numerical operations subscale and the mathematical reasoning subscale. The numerical operations subscale measures the ability of children to perform mathematical calculations while the mathematical reasoning subscale measures their ability to use mathematical knowledge, together with logical thinking, to solve problems. Both of these aspects are regarded as essential by the National Curriculum (Department for Education 2014a). Lee and Johnston-Wilder (2017) and this thesis claim that higher levels of MR lead to better performance in mathematics hence it was hypothesised in Chapter 6 that BCMRS scores and performance scores would correlate. Although the study in that chapter did not find a statistically significant correlation between MR and performance, it did find trends towards those performing at the lowest levels having the lowest MR. These may be stronger with a standardised measure and thus it is hypothesised that there will be a positive correlation between MR and both subscales of the WIAT-II, both at any given time and between initial MR and later performance.

Lee and Johnston-Wilder (2017) claim that possessing MR better prepares children for the problems that they will encounter in mathematics, and thus, since the mathematical reasoning subscale measures problem solving ability, it could be supposed that correlations between MR and numerical operations and MR and mathematical reasoning scores would differ. It was therefore hypothesised that associations between the BCMRS and mathematical reasoning subscale would be stronger than between the BCMRS and the numerical reasoning subscale.

When considering the development of MR, the hypothesis that MR would develop over the course of Year 1 was again investigated. Associations between performance at the start of the year and MR at the end were also considered with the hypothesis that they would be correlated, particularly for struggle as they had been in the previous chapter. Since only two schools took part in the current study it was not possible to test for differences in MR development between schools. However, it was hypothesised that children who steadily improved in mathematics during the year may develop different levels of MR to those who had different patterns of development. This hypothesis was also investigated.

The study also gave the opportunity to further test the validity of the BCMRS. During the study, the children also completed the MAAQ (see Section 3.7.2), a measure of attitude to mathematics developed with young primary aged children. This gave the opportunity to assess the construct validity of the BCMRS by comparing results on the two measures. It was hypothesised that both scales were measuring attitudes to mathematics so may be correlated but since the BCMRS was measuring a different construct to the MAAQ these correlations would not be strong. It was also hypothesised that the BCMRS and MAAQ would predict scores on the WIAT-II.

In summary, the study looked at three distinct areas to do with MR and performance in Year 1 children:

- Firstly the data from the study was used to further investigate the validity of the BCMRS in the Year 1 population by comparing it with the MAAQ.
- Secondly the study investigated the consistency of the children's MR levels over the course of the academic year and whether this was linked to the consistency of their performance.
- Thirdly the study investigated whether MR and performance in mathematics were linked and if so how.

7.3 Method

7.3.1 Design

A longitudinal design was adopted with data collected at three time points during the school year, in the autumn (time 1), spring (time 2) and summer (time 3) terms. The variables measured at each time point were MR, attitudes to mathematics and performance in numerical operations and mathematical reasoning.

7.3.2 Participants

The data for this study were taken from the control group of Study J. Details of the recruitment and participants can be found in Section 3.6.10. Of the twenty three children who formed the control group there were 8 boys, 11 girls, and 4 children where no details of gender were provided. The average age of the children at the start of the school year was 5 years 6 months. One parent did not provide a date of birth for their child. Twelve of the children were British, of these five were described by their parents as black or mixed British. One child was classified as mixed-other, two were African, one Latvian, one Bulgarian, one Pakistani and one Sri Lankan. One child was described as white and no details of ethnicity were provided for the remaining three children. Four of the children had English as a second language. There was one child with a hearing difficulty and four with visual difficulties corrected with glasses. None of the parents reported that their children had special educational needs.

7.3.3 Measures and Procedure

MR was measured by the *BCMRS,* administered once a term in the 2017-2018 academic year, as described in Section 3.7.1. The gap between administrations varied but was approximately 4 months.

Attitudes to mathematics were measured by the *MAAQ* (See Section 3.7.2).

Performance was measured by the *Numerical Operations* and *Mathematical Reasoning* subscales of the *WIAT-II* administered according to the handbook.

7.4 Results

Table 7-1 shows mean scores on the BCMRS, MAAQ and WIAT-II scales. Mean standardised scores were close to 100 on both the numerical operations and mathematical reasoning subscales at all three time points, indicating that the sample were scoring close to average. Raw scores on the WIAT-II are used for analysis unless stated.

Table 7-1 Means Scores on the BCMRS, MAAQ and WIAT-II for the Study J Control Group (standard deviations in brackets)

	Time 1 (n = 23)	Time 2 (n = 22)	Time 3 (n = 23)
Growth	-1.52 (5.704)	1.55 (4.626)	1.22 (4.552)
Struggle	6.22 (4.492)	5.41 (4.469)	7.26 (2.848)
Value	5.39 (1.076)	5.18 (1.368)	5.09 (2.043)
MR	2.66 (1.619)	3.20 (1.813)	3.11 (1.731)
Self-Rated Competence	21.78 (4.908)	23.32 (3.969)	21.18 (5.216)
Enjoyment	22.96 (4.791)	23.82 (4.636)	21.32 (4.735)
Response to Failure	14.96 (7.991)	13.32 (8.731)	11.27 (7.929)
MA	16.61 (8.084)	14.50 (7.787)	13.27 (9.382)
Numerical Operations	8.48 (1.997)	9.59 (2.482)	10.35 (2.757)
Standardised Numerical Operations	101.95 (10.228)	102.43 (10.930)	102.27 (12.236)
Mathematical Reasoning	15.70 (3.795)	17.45 (5.440)	21.04 (6.109)
Standardised Mathematical Reasoning	100.68 (10.956)	97.62 (14.868)	98.05 (13.545)

Table 7-2 shows Spearman's correlations between the BCMRS, MAAQ and WIAT-II subscales across the year.

Table 7-2 Correlations Between the Scales at all Three Time Points

		Time 1									
		BCMRS				MAAQ				WIAT-II	
		Growth	Struggle	Value	MR	Self-Rated Competence	Enjoyment	Response to Failure	MA	Numerical Operations	Mathematical Reasoning
Time 1	Growth		r = -.189 p = .389	r = -.064, p = .773	**r = .719, p <.001**	r = .328, p = .127	r = .114, p = .604	r = -.007, p = .974	r = -.267, p = .219	r = .388, p = .068	**r = .517, p = .011**
	Struggle			r = .305, p = .157	**r = .418, p = .047**	r = - .037, p = .871	r = .273, p = .208	r = -.064, p = .773	r = -.089, p = .686	**r = .446, p =.033**	r = .014, p = .948
	Value				r = .282, p = .193	r = -.284, p = .190	r = .076, p = .732	r = -.132, p = .549	r = -.286, p = .185	**r = .543, p <.001**	r = .199, p = .362
	MR					r = .187, p = .393	r = .270, p = .213	r = -.003, p = .987	r = -.289, p = .181	**r = .675, p = <.001**	r = .371, p =.081
	Self-Rated Competence						**r = .671, p <.001**	**r = .504, p = .014**	**r = .429, p = .041**	r = -.137, p = .533	r = .316, p = .142
	Enjoyment							r = .354, p = .097	r = .373, p = .079	r = .053, p = .812	r = -.111, p = .614
	Response to Failure								**r = .670, p <.001**	r = -.208, p = .341	r = .010, p = .965
	MA									**r = -.531, p = .009**	r = .075, p = .741
	Numerical Operations										r = .331, p = .123

		Time 1									
		BCMRS				MAAQ				WIAT-II	
		Growth	Struggle	Value	MR	Self-Rated Competence	Enjoyment	Response to Failure	MA	Numerical Operations	Mathematical Reasoning
Time 2	Growth	**r = .684, p <.001**	r = -.011 p = .960	r = .311, p = .159	**r = .532, p = .011**	r =. 147, p = .513	r = .095, p = .674	r = -.039, p = .862	r = -.227, p = .309	r = .402, p = .064	r = .373, p = .087
	Struggle	r = .046, p = .839	**r = .705, p <.001**	**r = .467, p = .028**	**r = .567, p = .006**	r = .144, p = .522	**r = .433 p = .044**	r = -.014, p = .949	r = -.042, p = .851	**r = .495, p = .019**	r = .177, p = .432
	Value	r = .212, p = .343	r = .102, p = .651	r = .383, p = .079	r = .266, p = .231	r = .267, p = .229	r = .160, p = .478	r = .085, p = .707	r = -.118, p = .600	r = .263, p =.236	r = .363, p = .096
	MR	**r = .466, p = .029**	r = .374, p = .086	**r = .472, p = .026**	**r = .658, p = .001**	r = .250, p = .262	r = .310, p = .160	r = -.057, p = .800	r = -.217, p = .333	**r = .532, p = .011**	r = .372, p = .088
	Self-Rated Competence	r = -.018, p = .935	r = .037, p = .871	r = .152, p = .501	r = -.008, p = .972	r = .121, p = .591	r = .340, p = .122	r = -.148, p =.511	r = -.024, p = .916	r = .247, p = .268	r = -.238, p = .286
	Enjoyment	r = -.076, p = .737	r = .039, p = .862	r = .164, p = .466	r = -.063, p = .781	r = .155, p = .490	r = .310, p = .160	r = -.155, p = .490	r = -.014, p = .950	r = .257, p = .248	r = -.245 p = .271
	Response to Failure	r = .067, p = .766	r = .089, p = .695	r = .093, p = .680	r = .199, p = .375	r = .292, p = .187	r = .236, p = .289	**r = .735, p <.001**	**r = .472, p = .027**	r = 148, p = .510	r = -.096, p = .672
	MA	r = .070, p = .756	r = .134, p = .551	r = -.077, p = .732	r = .168, p = .456	r = .403, p = .063	**r = .442, p = .040**	**r = .635, p = .002**	**r = .663, p = .001**	r = -.056, p = .806	r = -.098, p = .666
	Numerical Operations	**r = -.459, p = .032**	r = .265, p = .233	**r = .501, p = .018**	**r = .544, p = .009**	r = -.177, p = .431	r = -.028, p = .900	r = -292, p = .187	**r =-.553 p = .008**	**r = .764, p <.001**	**r = .558, p = .007**
	Mathematical Reasoning	**r = .474, p = .026**	r = .204, p = .364	r = .236, p = .291	**r = .535, p = .010**	r = -.025, p = .912	r = -.255, p = .252	r = -.030, p = .893	r = -.272, p = .222	**r = .656, p = .001**	**r = .612, p = .002**

		Time 1									
		BCMRS				MAAQ				WIAT-II	
		Growth	Struggle	Value	MR	Self-Rated Competence	Enjoyment	Response to Failure	MA	Numerical Operations	Mathematical Reasoning
Time 3	Growth	**r = .444, p = .034**	r = -.109 p = .622	r = .236, p = .279	r = .382, p = .072	r =. 276, p = .202	r = -.007, p = .974	r = -.037, p = .868	r = -.164, p = .456	r = .152, p = .489	**r = .508, p = .013**
	Struggle	r = .123, p = .577	r = .114, p = .606	r = .220, p = .314	r = .165, p = .451	r = .263, p = .225	**r = .524 p = .010**	r = .015 p = .946	r = 196, p = .371	r = -.088, p = .690	r = -.144, p = .512
	Value	r = .387, p = .068	r = .149, p = .496	R = -.018, p = .935	r = .390, p = .066	r = .250, p = .250	r = .242, p = .266	r = -.123, p = .577	r = .118, p = .593	r = .171, p = .435	r = .106, p = .630
	MR	**r = .460, p = .027**	r = .117, p = .594	r = .317, p = .140	**r = .520, p = .011**	r = .367, p = .085	r = .281, p = .193	r = -.035, p = .873	r = -.061, p = .782	r = .210, p = .337	r = .338, p = .114
	Self-Rated Competence	r = .406, p = .061	r = .104, p = .645	**r = .516, p = .014**	**r = .560, p = .007**	r = .145, p = .519	r = .277, p = .212	r = -.063, p =.782	r = -.087, p = .701	**r = .503, p = .017**	r = .204, p = .363
	Enjoyment	r = -.198, p = .378	r = .193, p = .388	**r = .429, p = .046**	r = -.111, p = .624	r = .213, p = .342	r = .327, p = .138	r = .279, p = .209	r = .267, p = .229	r = .187, p = .406	r = -.059 p = .795
	Response to Failure	r = -.181, p = .420	r = .179, p = .424	r = .266, p = .231	r = .104, p = .646	r = .042, p = .852	r = .049, p = .829	r = .387, p = .075	r = .298, p =.178	r = .372, p = .088	r = -.079, p = .726
	MA	r = -.088, p = .696	r = .118, p = .600	r = .321, p = .145	r = .197, p = .381	r = .193, p = .389	r = .108, p = .632	**r = .541, p = .009**	r = .282, p = .203	r = .227, p = .310	r = .017, p = .940
	Numerical Operations	r = .338, p = .115	r = .370, p = .082	r = .306, p = .156	**r = .534, p = .009**	r = .012, p = .956	r = .156, p = .477	r = -.125, p = .570	r = -.402 p = .057	**r = .699, p <.001**	**r = .513, p = .012**
	Mathematical Reasoning	**r = .579, p = .004**	r = .177, p = .420	r = .210, p = .335	**r = .574, p = .004**	r = -.003, p = .989	r = -.257, p = .236	r = -.285, p = .188	**r = -.456, p = .029**	**r = .645, p = .001**	**r = .578, p = .004**

		Time 2									
		BCMRS				MAAQ				WIAT-II	
		Growth	Struggle	Value	MR	Self-Rated Competence	Enjoyment	Response to Failure	MA	Numerical Operations	Mathematical Reasoning
Time 2	Growth		r = .198 p = .376	**r = .469, p = .028**	**r = .754, p <.001**	r = .117, p = .605	r = .111, p = .624	r = .060, p = .789	r = .042 p = .854	**r = .526, p = .012**	**r = .469, p = .028**
	Struggle			r = .370, p = .090	**r = .703, p <.001**	r = .199, p = .374	r = .185 p = .411	r = .051 p = .822	r = 116, p = .608	r = .229, p = .306	r = .269, p = .227
	Value				**r = .755, p = <.001**	r = .303, p = .171	r = .288, p = .193	r = .099, p = .660	r = .068, p = .763	r = .280, p =.207	r = .382, p = .080
	MR					r = .313, p = .157	r = .291, p = .190	r = .065, p = .773	r = .092, p = .684	**r = .447, p = .037**	**r = .472, p = .027**
	Self-Rated Competence						**r = .946, p <.001**	r = .065, p =.773	r = .129, p = .567	r = -.039, p = .862	r = -.056, p = .806
	Enjoyment							r = .060, p = .790	r = .062, p = .785	r = -.047, p = .837	r = -.019 p = .932
	Response to Failure								**r = .855, p <.001**	r = -.044, p = .846	r = .214, p = .338
	MA									r = -.140, p = .535	r = .041, p = .857
	Numerical Operations										**r = .639, p = .001**

		Time 2									
		BCMRS				MAAQ				WIAT-II	
		Growth	Struggle	Value	MR	Self-Rated Competence	Enjoyment	Response to Failure	MA	Numerical Operations	Mathematical Reasoning
Time 3	Growth	**r = .503, p = .017**	r = .306 p = .166	**r = .466, p = .029**	**r = .609, p = .003**	r = . 068, p = .763	r = .086, p = .703	r = -.053, p = .815	r = -.029, p = .897	r = .217, p = .331	r = .286, p = .197
	Struggle	r = .336, p = .126	**r = .434, p = .044**	**r = .480, p = .024**	**r = .559, p = .007**	r = .352, p = .108	r = .310 p = .160	r = -.093 p = .681	r = 155, p = .490	r = -.161, p = .475	r = -.317, p = .150
	Value	**r = .464, p = .030**	r = .213, p = .342	r = .355, p = .105	**r = .452, p = .035**	r = .352, p = .108	r = .363, p = .097	r = .100, p = .659	r = .275, p = .216	r = .127, p =.574	r = .380, p = .081
	MR	**r = .631, p = .002**	**r = .510, p = .015**	**r = .652, p = .001**	**r = .821, p <.001**	r = .316, p = .152	r = .309, p = .162	r = -.028, p = .900	r = .074, p = .742	r = .163, p = .470	r = .230, p = .303
	Self-Rated Competence	r = .399, p = .073	r = .423, p = .056	**r = .469, p = .032**	**r = .557, p = .009**	r = .378, p = .091	r = .382, p = 088	r = .082, p =.724	r = .107, p = .645	r = .357, p = .112	r = .395, p = .076
	Enjoyment	r = -.068, p = .769	**r = .585, p = .005**	r = .294, p = .196	r = .330, p = .144	**r = .549, p = .010**	**r = .597, p = .004**	r = .348, p = .123	r = .327, p = .148	r = -.278, p = .222	r = .111 p = .964
	Response to Failure	r = -.170, p = .461	r = .104, p = .653	r = .094, p = .685	r = .-.060, p = .795	r = .101, p = .662	r = .167, p = .468	**r = .701, p <.001**	**r = .516 p = .017**	r = .082, p = .722	r = .275, p = .227
	MA	r = -.169, p = .464	r = .082, p = .723	r = .168, p = .467	r = -.038, p = .870	r = .-.024, p = .919	r = .001, p = .997	**r = .683, p = .00**	**r = .523, p = .015**	r = -.085, p = .714	r = .106, p = .647
	Numerical Operations	r = .397, p = .067	r = .353, p = .108	r = .270, p = .224	**r = .429, p = .046**	r = -.068, p = .764	r = -.055, p = .809	r = .018, p = .938	r = -.068 p = .764	**r = .910, p <.001**	**r = .584, p = .004**
	Mathematical Reasoning	**r = .424, p = .044**	r = .190, p = .398	**r = .493, p = .020**	**r =.560, p = .007**	r = .157, p = .485	r = .168, p = .455	r = .013, p = .955	r = -.096, p = .671	**r = .644, p = .001**	**r = .823, p <.001**

		Time 2									
		BCMRS				MAAQ				WIAT-II	
		Growth	Struggle	Value	MR	Self-Rated Competence	Enjoyment	Response to Failure	MA	Numerical Operations	Mathematical Reasoning
Time 2	Growth		r = .296 p = .170	r = .068, p = .757	**r = .823, p <.001**	r = .280, p = .208	r = .232, p = .300	r = -.289, p = .192	r = -.045 p = .841	r = .141, p = .522	**r = .424, p = .044**
	Struggle			r = .390, p = .066	**r = .653, p = .001**	r = .396, p = .068	r = .347 p = .113	r = -.235 p = .293	r = -.107 p = .634	r = -.213, p = .328	r = -.108, p = .624
	Value				**r = .455, p = .029**	**r = .501, p = .017**	r = .220, p = .326	r = .134, p = .551	r = .030, p = .894	r = .099, p = .653	r = .391, p = .065
	MR					**r = .510, p = .015**	r = .391, p = .072	r =- .205, p = .361	r = -.007, p = .977	r = .111, p = .616	**r = .432, p = .039**
	Self-Rated Competence						**r = .486, p =.022**	r = .169, p =.452	r = .314, p = .155	r = .250, p = .262	r = .371, p = .090
	Enjoyment							r = .315, p = .153	**r = .449, p = .036**	r = -.187, p = .404	r = -.108 p = .633
	Response to Failure								**r = .791, p <.001**	r = .180, p = .423	r = .128, p = .569
	MA									r =.019, p = .932	r = -.037, p = .871
	Numerical Operations										**r = .543, p = .007**

Correlations were run between the BCMRS and the MAAQ at all three time points in order to assess the construct validity of the BCMRS. At time 1 and time 2 there were no significant correlations between the two scales (see Table 7-2). At time 3 there were significant correlations between the MR total and self-rated competence and enjoyment of mathematics (see Table 7-2). This suggested that there was little association between the two scales early in the year but by the summer term those who had higher MR rated themselves as more competent in mathematics and enjoyed the subject more. This was likely related to children getting used to the school environment and expectations.

In order to study the development of MR, Spearman's correlations were calculated for the BCMRS between time points (see Table 7-2). The MR scores were significantly correlated between times 1 and 2, 2 and 3 and 1 and 3. The growth subscale scores were also significantly correlated between times 1 and 2, 2 and 3, and 1 and 3. The struggle subscale scores were significantly correlated between times 1 and 2, and 2 and 3 but not between times 1 and 3. The value subscale scores were not significantly correlated between any two time points, though the correlation approached significance between time 1 and time 2.

Repeated measures ANOVAs were conducted with times 1, 2 and 3 as the grouping factors and the subscale and scale totals as the dependent variables in order to investigate the hypothesis that MR levels would develop over the course of Year 1. Where sphericity was violated the appropriate corrections were used. There was a statistically significant difference in total MR scores between time points, $F(2, 42) = 3.754$, $p = .032$, $\omega^2 = .11$. Contrasts showed a statistically significant increase in MR total scores between times 1 and 3, $p = .030$, $r = .45$ but not between times 1 and 2, $p = .089$, or 2 and 3, $p = .250$. This indicates that the children's MR increased gradually over the course of the year. For the growth subscale, the results showed that the differences between the mean growth scores were statistically significant over the three time points, $F(2, 42) = 5.927$, $p = .005$, $\omega^2 = .16$. Contrasts showed a statistically significant rise in growth scores from time 1 to 2 ($p = .004$, $r = .57$) and 1 to 3, ($p = .015$, $r = .50$) but a decrease (which was not statistically significant) from time 2 to 3 (p =

1.00) (see Table 7-1). This indicates that although the children's belief in growth developed over the year, it became stable in the latter part of the year. For the struggle subscale and value subscales, there was no statistically significant difference in scores over the course of the year, struggle $F(1.670, 35.066) = 2.111$, $p = .143$, $\omega^2 = .06$ and value $F(2, 42) = .578$, $p = .565$, $\omega^2 = .12$, indicating either that the struggle and value subscale scores remained stable over the year or that children had not yet had a chance to develop their understanding of the need to struggle in and value of mathematics.

Mixed effects ANOVAs were conducted to investigate whether the way in which a child's performance level changed over time was associated with scores on the BCMRS. Children were put into one of 3 groups for each subscale of the WIAT-II based on their standardised scores: those children who had increased their score between each testing, those whose scores had decreased and those whose scores had increased then decreased or vice versa. Table 7-3 shows the number of children in each group and Table 7-4 reports the results of the ANOVAs.

Apart from the changes on the growth subscale over time that were identified previously, there were no significant differences. These findings showed that changes in the children's performance over the year were not significantly associated with changes in their scores on the BCMRS over the same period.

Table 7-3 Number of Children From Study J Control Group When Grouped by Variation in Performance

	Standardised Numerical Operations Score	Standardised Mathematical Reasoning Score
Increased	2	3
Decreased	6	6
Varied	13	12

Table 7-4 Results of Mixed Effect ANOVAs Comparing Changes in Performance to Scores on the BCMRS (significant ANOVAs in bold)

	Main Effect of Time	Main Effect of Variation in Performance	Interaction of Time and Variation
Grouped by Change in Numerical Operations			
Growth	**F(2, 36) = 8.290, p = .001**	F(2, 18) = .117, p = .890	F(4, 36) = 2.097, p = .101
Struggle	F(1.511, 27.199) = .611, p = .506	F(2, 18) = 1.220, p = .319	F(3.022, 27.199) = .493, p = .691
Value	F(1.380, 24.833) = .081, p = .854	F(2, 18) = .550, p = .587	F(2.759, 24.833) = 1.164, p = .341
MR	F(2, 36) = 4.180, p = .023	F(2, 18) = .917, p = .418	F(4, 36) = 1.379, p = .261
Grouped by Change in Mathematical Reasoning			
Growth	**F(2, 36) = 4.725, p = .015**	F(2, 18) = .992, p = .390	F(4, 36) = .581, p = .678
Struggle	F(2, 36) = .771, p = .470	F(2, 18) = .637, p = .540	F(4, 36) = .509, p = .729
Value	F(1.393, 25.065) = .315, p = .654	F(2, 180) = 2.446, p = .115	F(2.785, 25.065) = .372, p = .760
MR	F(2, 36) = 1.763, p = .186	F(2, 18) = 2.002, p = .164	F(4, 36) = .569, p = .687

In order to assess whether initial performance was affecting the development of MR, partial correlations were run between initial performance scores and final MR scores, controlling for initial MR scores. There were no significant correlations between initial scores on either WIAT-II subscale and final MR levels (see Table 7-5) suggesting that initial performance did not contribute to the development of MR.

Table 7-5 Partial Correlations for Initial WIAT-II Scores and Final BCMRS Scores Controlling for Initial BCMRS Scores

	Numerical Operations	Mathematical Reasoning
Growth	r = .026, p = .908	r = .372, p = .088
Struggle	r = -.073, p = .748	r = -.082, p = .717
Value	r = .190, p = .398	r = .097, p = .667
MR	r = -.270, p = .225	r = .105, p = .642

Spearman's correlations were carried out to assess correlations between scores on the BCMRS and scores on the numerical operations and mathematical reasoning subscales at each time point (see Table 7-2). At time 1 there was a significant positive correlation between MR and the numerical operation score (see Figure 7-1).

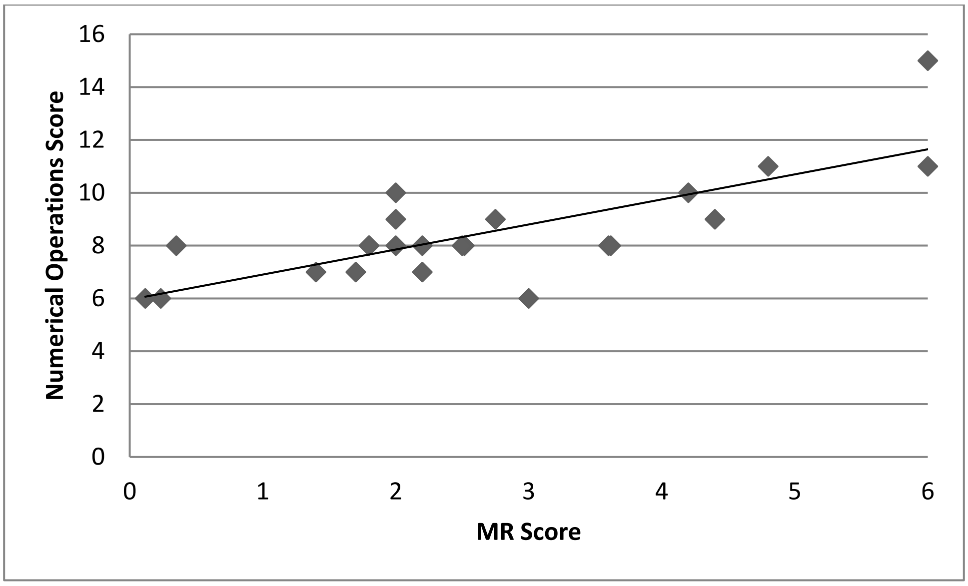

Figure 7-1 Graph of Scores on the Numerical Operations Subscale Against MR Score at Time 1

There was also a trend for a non-significant positive correlation between scores on the mathematical reasoning subscale and the MR total (see Figure 7-2).

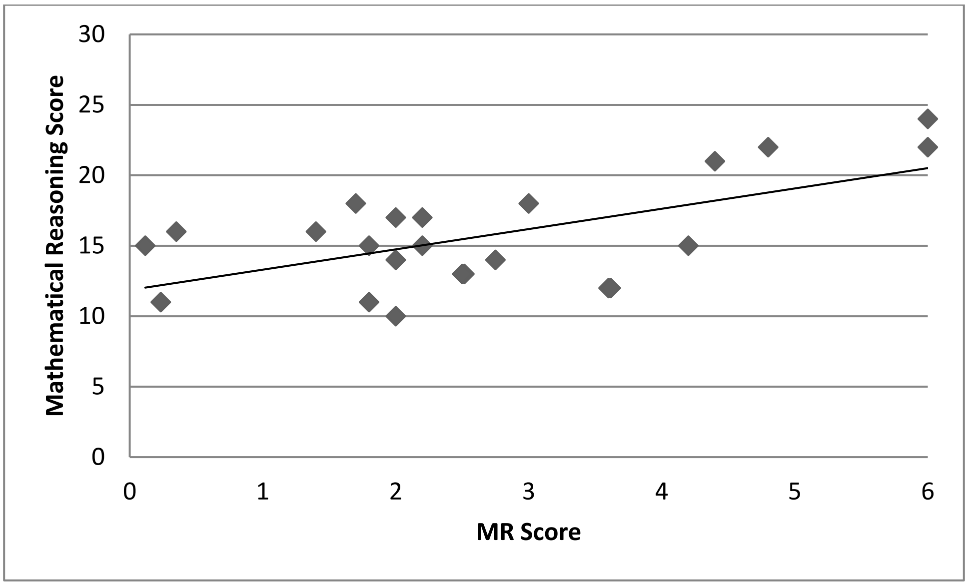

Figure 7-2 Graph of Scores on the Mathematical Reasoning Subscale Against MR Scores at Time 1

The fact that this was non-significant was likely to be due to the small sample size as the correlation approached significance.

Similar patterns were found at the other two time points. At time 2 there were significant positive linear correlations between scores on the numerical operations and mathematical reasoning tests and total MR. At time 3, there was a significant positive correlation between MR and scores on the mathematical reasoning test and non-significant positive correlations between MR and scores on the numerical operations test. Thus, although the correlations between MR and performance on the two tests were positive, they were not always significant. This may have been because of the small sample size.

At time 1 the correlation between scores on the growth subscale and the scores on the mathematical reasoning subscale was positive and significant (See Figure 7-3). At time 2 the correlations between both WIAT-II subscales and growth were positive and significant. At time 3 the only significant correlation was between the mathematical reasoning scores and the growth subscale scores – this correlation was again positive.

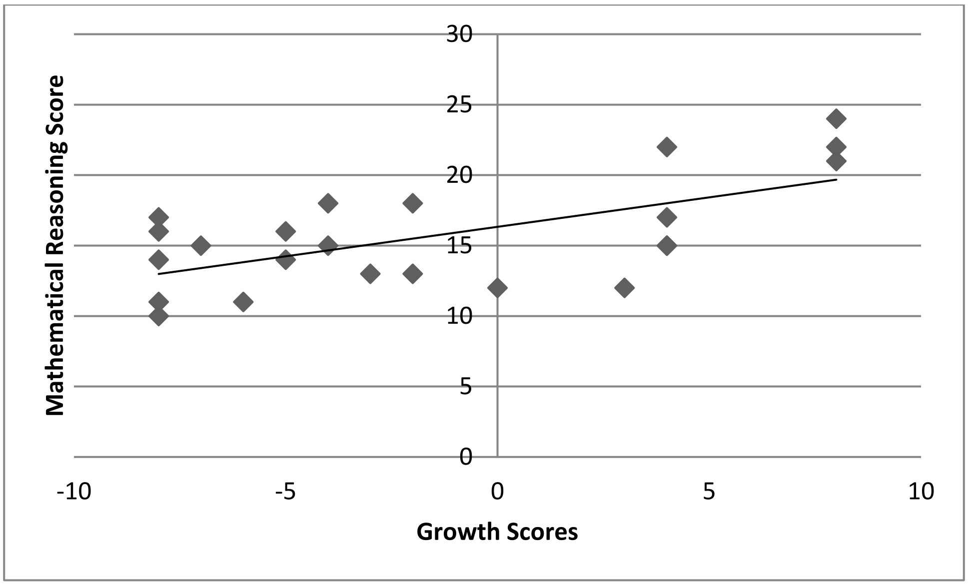

Figure 7-3 Graph of Scores on the Mathematical Reasoning Subscale Against Growth Scores at Time 1

The only correlation between struggle scores and the WIAT-II subscales was at time 1, when there was a significant positive correlation between struggle and numerical operations scores (see Figure 7-4).

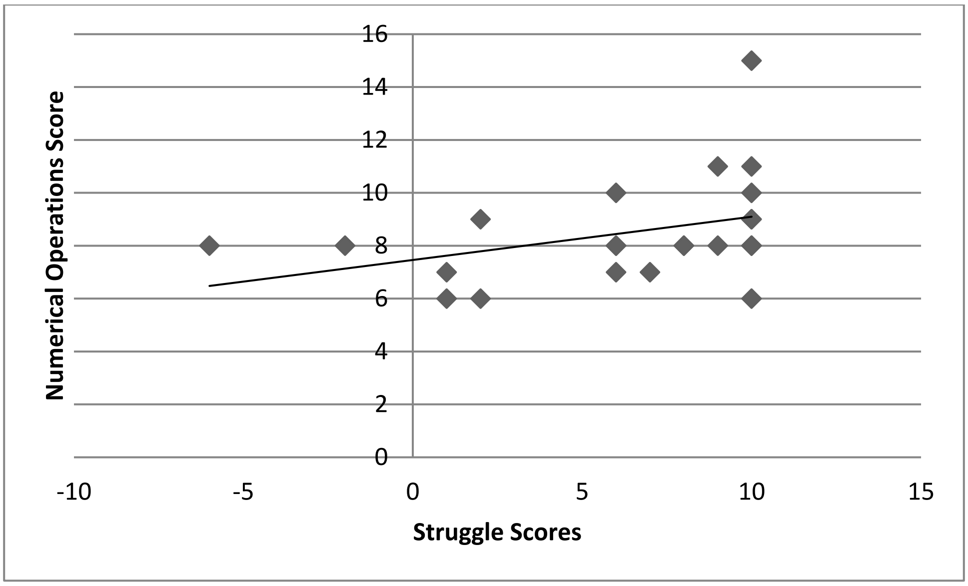

Figure 7-4 Graph of Scores on the Numerical Operations Subscale Against Struggle Scores at Time 1

The only correlation between scores on the value and WIAT-II subscales was at time 1, when there was a significant positive correlation between value and numerical operations. This correlation was not strong and was probably down to the small sample size, as can be seen in Figure 7-5 .

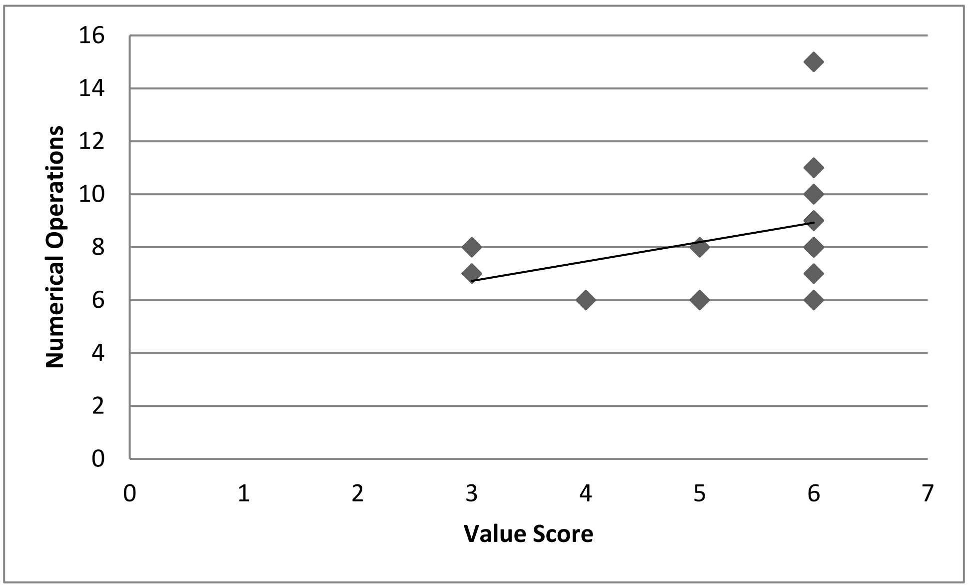

Figure 7-5 Graph of Scores on the Numerical Operations Subscale Against Value Scores at Time 1

In order to see whether initial MR levels were affecting final performance levels, partial correlations were run for final scores on the WIAT-II and initial score on the BCMRS, controlling for initial scores on the WIAT-II (see Table 7-6). No significant correlations were found although the partial correlation for initial MR and final mathematical reasoning was approaching significance (see Figure 7-6).

Table 7-6 Partial Correlations Between Initial BCMRS scores and Final WIAT-II scores Controlling for Initial WIAT-II Scores

	Numerical Operations	Mathematical Reasoning
Growth	r = .019, p = .933	r = .242, p = .277
Struggle	r = -.073, p = .746	r = .225, p = .313
Value	r = -.058, p = .797	r = .095, p = .675
MR	r = -.056, p = .806	r = .395, p = .069

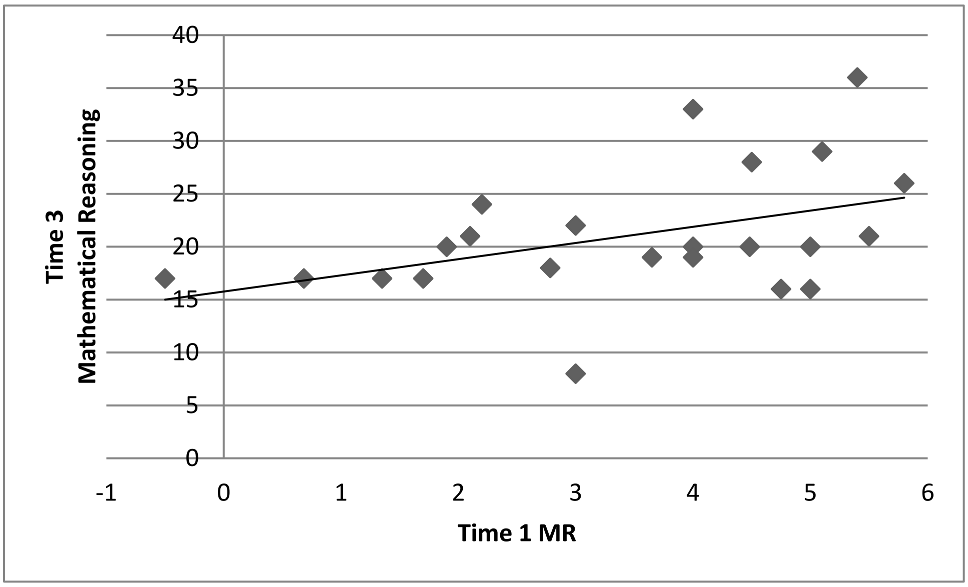

Figure 7-6 Graph of Time 3 Mathematical Reasoning Scores Against Time 1 MR Scores

Correlations were run between the MAAQ subscales and performance levels at all three time points (see Table 7-2). At time 1 there was a significant negative correlation between MA and performance on the numerical operations subscales indicating those children with lower MA were scoring more highly on the numerical operations subscale but there were no other significant correlations. At time 2 and time 3 there were no significant correlations between the MAAQ and performance measures.

7.5 Discussion

The study aimed to investigate the development of MR and links between MR and performance in Year 1 children. It also considered the construct validity of the BCMRS by comparing it with the MAAQ. In the current study, MR levels increased significantly over the course of the year. In particular, growth scores rose from the beginning to the end of the year although there was a slight drop in the mean score between time 2 and 3. Neither initial performance nor changes in performance over the year were significantly linked with MR. MR, particularly scores on the growth subscale, was found to be positively correlated with performance. The correlation between initial MR and final levels on the mathematical reasoning subscale was approaching significance. Comparisons with the MAAQ found that the BCMRS was measuring a different construct and that the MAAQ did not predict performance levels.

The study aimed to investigate the hypothesis that MR would develop over the school year. The MR total, whilst not showing significant differences term on term was statistically higher at the end of the year than the start. This suggests that MR scores rose gradually over the course of the year. The growth subscale showed a rise in scores between times 1 and 2 and 1 and 3 but not between times 2 and 3 (in fact they fell slightly), indicating that the scores had become more stable in the latter part of the school year. This may have been because of a genuine change in growth belief across Year 1 or difficulties in understanding the negatively worded growth items when the children were at an earlier stage in their education as discussed in Chapter 6. There was no evidence that initial performance levels or changes in performance levels over the year were linked to levels of MR. It is advised that future longitudinal studies into MR look at children over a longer period of time, preferably throughout their primary school career.

Positive correlations were found between MR and scores on both WIAT-II subscales, although these were not always significant. However, this could have been because of the small sample size as several correlations approached significance. Positive correlations were also found between the growth subscale and the WIAT-II subscales, most significantly with the mathematical reasoning subscale at all three time points. However, since mathematical reasoning might be expected to involve the same logical thinking that would enable a child to understand the negatively worded growth items on the BCMRS; this may explain the correlation rather than a genuine association between belief in growth and mathematical reasoning. Further investigation of this correlation is recommended.

Although there were no significant correlations between time 1 MR scores and time 3 performance measures, the correlation between initial MR and final mathematical reasoning scores was approaching significance. The lack of significance could have been due to the small sample size. This would support the claim that MR is positively correlated with performance.

The data showed that the BCMRS and the MAAQ were not significantly correlated and that the MAAQ did not significantly predict performance on the WIAT-II except at time 1. Notably, MR was not correlated with MA, reinforcing the claim that MR is not simply an absence of MA but a better attitude to approaching mathematics (Lee and Johnston-Wilder 2017). This adds to the evidence about the construct validity of the BCRMS since the lack of correlation with the MAAQ suggests that it is not simply measuring the same attitudes to mathematics but is measuring a separate construct.

This study had a small sample size, which was opportunistic and therefore not ideal. Larger scale studies are suggested in future to see if these findings are replicated.

7.6 Conclusions

The study discussed in this chapter further established the construct validity of the BCMRS. In this sample MR rose over the course of Year 1, suggesting the need for further studies to establish what factors were causing this development. Positive correlations between MR and scores on the WIAT-II subscale and initial levels of MR and final performance measures were also identified, providing further evidence that there is a positive association between MR and performance in Year 1 children. It is suggested that this association is investigated further with large scale studies.

Chapter 8 Effects of Parental Mathematical Resilience on Interactions with a Child in a Problem Solving Task

8.1 Chapter Summary

This chapter describes a study exploring how parents and children work together on a mathematics task. It investigates whether their attitudes to mathematics are linked and how these attitudes affect the way they work. It also investigates whether contingent support leads to more success on the task. The study concludes that a child's Mathematical Resilience (MR) is linked to their parent's belief in struggle and to the way their parent helps them with mathematics. It also concludes that parents with higher levels of MR and lower levels of Mathematical Anxiety (MA) support their child in more productive ways when working on mathematics together. In this particular task, contingent support as defined by the contingent shift ratio (see Chapter 2) does not lead to better performance but support contingent to the nature of the task does.

8.2 Introduction

In Chapter 2, the importance of parental influence on children's performance in mathematics was discussed. The evidence presented suggested that, in general, parents' views of mathematics and behaviour around mathematics contributes to the formation of their children's views but there is no research on whether this is true with regard to MR. Thus the current study aims to address this knowledge gap and explore links between a parent and child's MR.

In Chapter 2, it was also suggested that how parents work with their children on mathematics contributes to the child's success on individual tasks and in the longer term. It was highlighted that some parents knew how to support their child in appropriate ways, referred to as contingent support (Wood et al. 1978), whilst others were not aware of this. Goodall and Johnston-Wilder (2015) suggested that MR could be used to help parents understand their own experiences of mathematics and work more successfully with their children. However, there is no other evidence that parents who possess higher levels of MR are better able to help their children.

Therefore the current study explored whether parents with higher levels of MR had better helping strategies for mathematics than those with lower levels.

The current study therefore aimed to test four hypotheses regarding parental support in respect to MR:

1. A parent's and their child's attitudes to mathematics are correlated.
2. A parent and child's MR are associated with performance on a mathematics task.
3. Contingent support leads to a better outcome on a mathematics task.
4. A parent and child's MR are associated with how they work together on a mathematics task.

8.3 Methodology

8.3.1 Design

A cross-sectional study was conducted where parent and child dyads were studied. The parents and children completed questionnaire measures independently, and then were asked to work together on an open-ended task.

8.3.2 Participants

Details of recruitment and participants can be found in sections 3.5 and 3.6.5. Forty-two parent and child dyads took part in the study.

8.3.3 Procedures

Children were asked to work on a mathematics problem where they had to sort nine pictures of houses into groups in as many ways as possible (See Figure 8-1, University of Cambridge, 2016). The task was chosen because it was an open ended task with no 'correct' answer and was accessible to children of all ages and abilities. Thus it gave the opportunity for children to demonstrate belief in growth, struggle and value and for the researcher to look at the response of the parent when their child began to struggle with finding groups. The child was instructed to explain their groups to their parent who should record them. When the child began to get stuck, the parent was told that they could help them. If the parent and child consented, this activity was both video and audio recorded. Before starting the task, parents and children were also asked to independently complete MR questionnaires and the parents completed a MA questionnaire and background measures. The data collected were used to assess whether levels of parental MR and MA were correlated with their child's MR levels and whether the MR of parent or child or both was correlated with the outcome of the task. The video and audio data was transcribed and qualitative methods were used to assess whether the parents' or child's MR was linked to the way they worked together on the task and their success in the task.

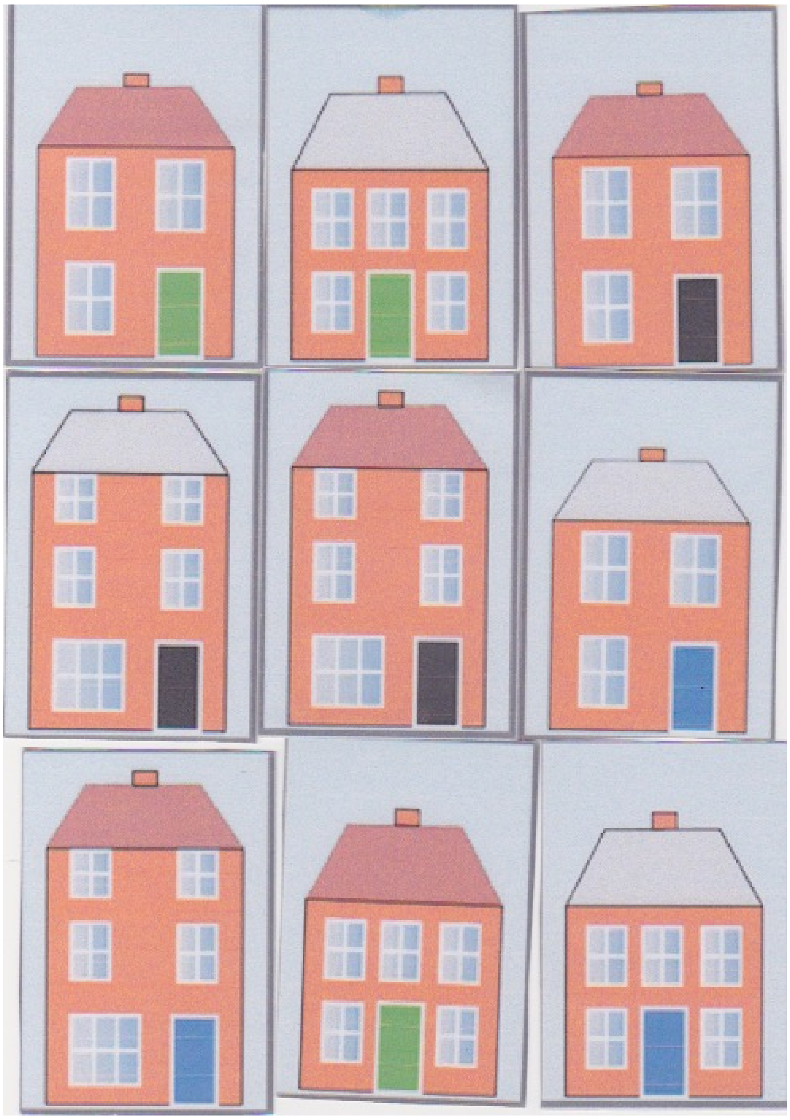

Figure 8-1 Photographs of Houses to be Sorted in the Sort the Street Task (University of Cambridge)

8.3.4 Background Measures

Quantitative Measures:

Parents:

The parents completed *the MRS* and the *MAS* (see Section 3.7).

Children:

The *BCMRS* was used to assess the children's MR (See Section 3.7.1). Although this scale was designed for use with Year 1 children those in the present study were older so it was concluded that they would be able to access the scale successfully. Since this study took place during the development of the scale the children completed an early 20 item version. The scores from the 8 items which were later discarded were not used in this analysis. Scoring was as described in 3.7.1.

Qualitative Procedures:

The audio data was transcribed and interactions were coded in two ways. Firstly coding was based on Wood's contingent levels of support (Wood et al. 1978). Every comment that the parent made to the child was coded from 1 to 5 with the levels as shown in Table 8-1 in non-italicised font. The author coded all 42 transcripts. A second researcher coded 3 of the transcripts, picked at random using the RANDBETWEEN command in Excel. The results of the coding were compared for inter-rater reliability. A further 4 transcripts, picked in the same way, were then coded by the second researcher and again compared for agreement. The coding protocol was amended and the author recoded the remaining 35 transcripts using the final agreed version of the coding (amendments shown in Table 8-1 in italics).

The data were used to assess whether there was a correlation between the type and frequency of intervention and a parent or child's MR and between the type and frequency of intervention and the outcome on the task.

Table 8-1 Coding Protocol for Study E Parent Interaction Data

Level 1: General verbal intervention. An intervention indicating they are listening, intended to keep the child on task but not suggesting any direction for the task. *Repetition of child's words or naming of child's groups. Interactions which are trying to establish what the child means.* Examples: "Go on then" "Well keep looking".
Level 2: Specific verbal intervention An intervention which draws the child's attention to a certain aspect of the pictures *(such as to look for a difference or similarity, what about the windows etc.)* but leaves them to figure out the link or pattern. *Asks a prompt question for thinking. Repeats the groups that have already been found to prompt thinking. It must attempt to lead the child's thinking in a direction they were not going on their own.* Example: "To do with the windows" "Look at the doors."
Level 3: Specific verbal intervention with nonverbal indicators. As level 2 but with a non-verbal interaction (such as moving the cards or pointing) which has been noted in the transcript or which is obvious from the comment. Example: "Those, what could you do with those?"
Level 4: Prepares for next action An intervention which directs the child to look at a specific aspect of a certain area of the pictures, where there is a definite answer the parent is looking for. Example: "What about the position of the windows?" "What about the colour of the doors?"
Level 5: Demonstrates next action An intervention where it is obvious the parent has sorted the pictures themselves or told the child how to sort them. *Telling the child they have got them all or it is time to stop. Parent tells the child their group is not valid, whether it is or not.* Examples: "You've got these ones, these ones and these ones; *I think that's all of them.*

This coding was also used to calculate the *contingent shift ratio* (Pratt et al. 1992). A contingent shift occurs when one individual who is helping another changes the level of support they offer in a way that is contingent with the amount of support needed. In line with the approach adopted by Pratt et al., a shift was seen as non-contingent if the level of support rose or fell by 4 levels on Table 8-1 or if the parent offered a higher level of support after the child succeeded or a lower level of support after the child failed at the task. Success on the task was seen as finding a new group or beginning to sort in a new way. The *contingent shift ratio* was calculated using the following formula:

$$\frac{Number\ of\ contingent\ shifts\ made\ by\ the\ parent}{Total\ number\ of\ shifts\ made}$$

Correlations between the contingent shift ratio and parent and child MR and outcome on the task were calculated.

A second coding was also carried out on the data. The dyads were ordered from high to low on child MR, parent MR, parent MA and performance. The top, middle and bottom three transcripts for each ordering were selected for comparison. The initial notes, made by the researcher during the task and at the transcription stage, were compared for any similarities or differences between groups. Where there appeared to be group differences the transcripts were further analysed by coding for the action that it appeared that the parent was trying to perform with their comment. Narrative accounts of the transcripts are also provided.

8.4 Results

8.4.1 Quantitative Analysis

Descriptive statistics for the MR and MA questionnaires, the amount of time the forty-two dyads worked on the task and the number of groups they found are shown in Table 8-2.

Table 8-2 Descriptive Statistics for Study E Data

	Mean	SD	Minimum	Maximum
Time Taken (seconds)	461.38	261.35	137	1153
Number of Groups	8.79	4.625	4	24
Parent Growth	39.48	5.17	27	49
Parent Struggle	41.62	6.44	29	56
Parent Value	45.31	6.31	27	56
Parent MR Total	126.40	14.15	92	149
Parent MA	30.83	13.50	10	62
Child Growth	5.24	2.70	-2	8
Child Struggle	6.98	2.73	1	10
Child Value	4.67	1.66	-2	6
Child MR Total	4.26	1.18	1.45	6

In order to assess the correlation between parent and child MR, Spearman's correlation coefficients were calculated for parent and child scores on the respective

MR scale and subscales. These correlations can be seen in Table 8-3. No significant correlation was found between the parents' and children's total MR scores, r = .301, p = .052, although this was approaching significance. No significant correlation was found between the parent and child scores on any of the subscales. However, the parents' growth subscale scores were positively correlated with the children's overall MR scores, r = .351, p = .023. This suggests that parent's beliefs about mathematics, particularly about the ability to get better in mathematics, may be linked to their children's MR.

Table 8-3 Correlations between Parent and Child MR Scores in Study E (significant correlations in bold)

	Child's Growth	Child's Struggle	Child's Value	Child's MR Total
Parent's Growth	r = .183, p = .247	r = .258, p =.099	r = .216, p = .170	**r = .351, p = .023**
Parent's Struggle	r = .174, p = .269	r = .184, p = .243	r = .167, p = .290	r = .265, p = .090
Parent's Value	r = -.092, p = .561	r = .042, p = .792	r = .153, p = .334	r = .068, p = .668
Parent's MR Total	r = .137, p = .388	r = .208, p = .187	r = .207, p = .188	r = .301, p = .052

In order to assess whether there was any correlation between parents' MA and their child's MR, Spearman's correlations were carried out between the parents' MA percentages and the children's scores on the BCMRS. There were no significant correlations (growth r = -.056, p = .725; struggle r = -.112, p = .480; value r = -.169, p = .284, total r = -.091, p = .565). This suggests that a parent's MA is not correlated with their children's beliefs about mathematics.

In order to assess whether a child's MR was influenced by a combination of their parent's MR and MA a multiple regression was run. Table 8-4 shows the regression model obtained. The combination of parent MR and MA did not significantly predict child MR, $R^2 = .089$, $F(2, 41) = 1.909$, $p = .162$.

Table 8-4 Regression Model Predicting Child MR From Parent MR and MA in Study E

	b	SE b	β	p
Constant	.786	2.135		.715
Parent MA	.004	.015	.046	.797
Parent MR	.027	.015	.319	.078

In order to assess the correlation between parent and child MR and outcome on the task, Spearman's correlation coefficients were calculated for parent and child scores on the MR scale and subscales and the time spent on the activity and number of groups found. These can be seen in Table 8-5.

Table 8-5 Correlations between Parent and Child MR, Time Taken and Number of Groups Found in Study E (Significant correlations in bold)

	Time Taken	Number of Groups
Child Growth	r = .125, p = .429	r = .112, p = .481
Child Struggle	r = .112, p = .479	r = .072, p = .652
Child Value	r = -.160, p = .313	r = -.058, p = .716
Child MR	r = .027, p = .867	r = .129, p = .415
Parent Growth	r = .069, p = .664	r = .084, p = .599
Parent Struggle	**r = .310, p = .046**	**r = .483, p = .001**
Parent Value	r = .039, p = .807	r = .175, p = .268
Parent MR	r = .208, p = .186	**r = .347, p = .024**
Parent MA	r = -.066 , p = .677	r = -.070, p = .660

There was a weak positive correlation between the parents' score on the struggle subscale and time spent on the task (see Figure 8-2).

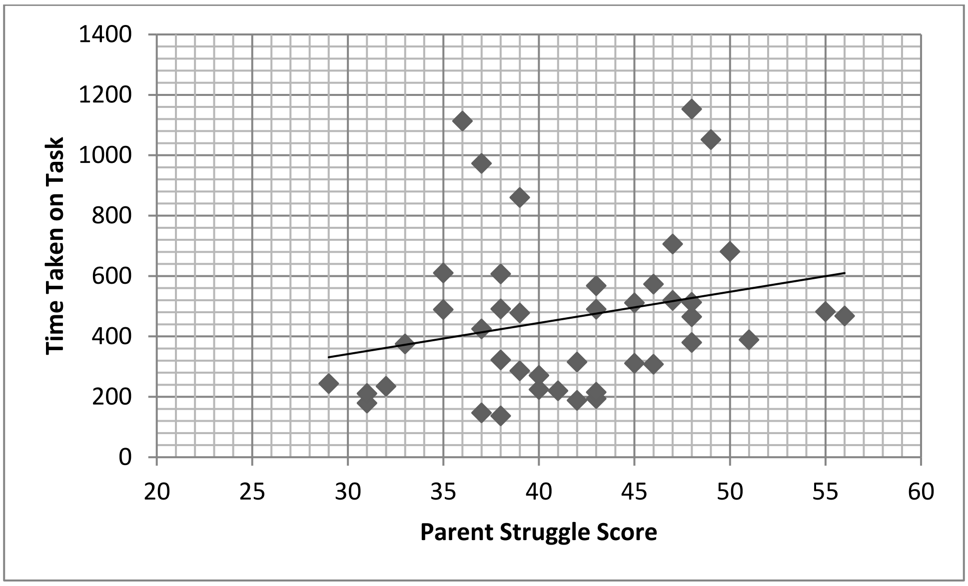

Figure 8-2 Graph to Show Parent Struggle Scores Against Time Taken on the Task in Study E

There was a strong positive correlation between the parents' struggle score and the number of groups found as shown in Figure 8-3. There was also a positive correlation between the parents' MR percentage and the number of groups found. There were no correlations between the children's scores on the scale or subscales and the time spent on the activity or the number of groups found.

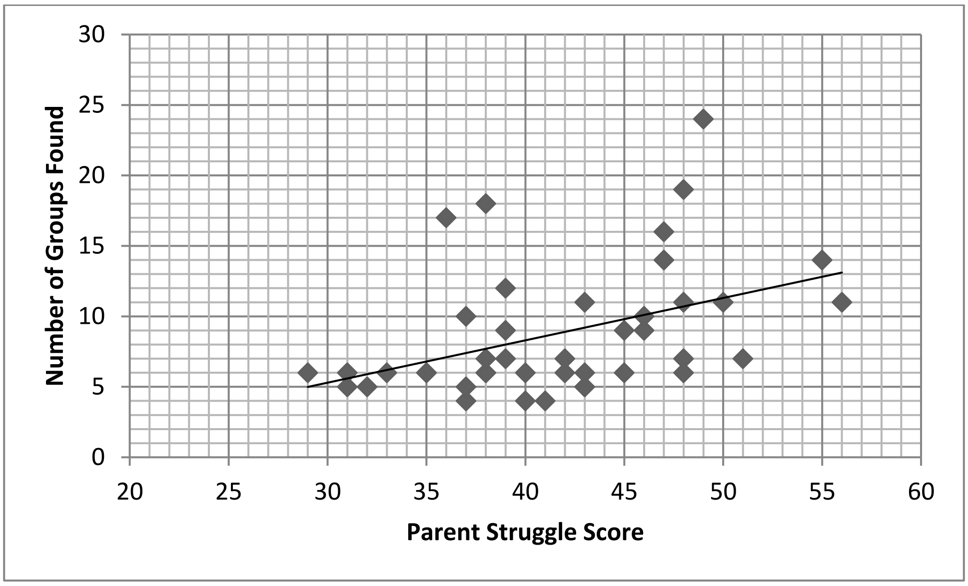

Figure 8-3 Graph to Show Parent Struggle Scores Against Number of Groups Found in Study E

Correlations were also run between the parent MA scores and time taken and number of groups found (see Table 8-5). No significant correlations were found. These findings suggest that it was the parent's MR and thus attitude to the task that was more strongly linked to how long the pair persevered and how successful they were than the child's. The results also suggest that a parent's own level of anxiety around mathematics was not necessarily a barrier to them spending time working on the problem with their children.

In order to assess whether contingent support from the parent led to better performance on the task, as suggested by Wood et al. (1978), correlations were run between the contingent shift ratio and the number of groups found and time spent on the task. No significant correlations were found (Number of groups: $r = -.221$, $p = .160$; Time Spent on Task: $r = -.137$, $p = .388$).

In this particular mathematics task, non-contingent support may have been a better strategy for finding more groups since giving the child suggestions as to how to sort the cards may lead to groups they would not have found on their own. In order to investigate whether the way a parent was helping, even if non-contingent, was linked to performance on the task the dyads were ranked in terms of the number of groups they found and the top, middle and bottom three transcripts were analysed. Table 8-6 shows the initial notes made during the activity and during transcription. These initial notes suggested that parents of children who found a low number of groups gave very little encouragement to continue. This was in contrast to those dyads who found a large number of groups and in which the parent was seen to either lead the dyad or provide encouragement, support and even equipment as necessary. In order to further investigate this finding, the transcripts of the interactions were analysed more closely.

Table 8-6 Notes on Dyads with Low, Medium and High Performance in Study E

Dyad	No of Groups	Group	Field notes from the day and during transcription
T	4	Low Performance	Advice to lay them out – practical, enabling. Then used this strategy independently. No further encouragement. Child entirely left in control of task. No encouragement to persevere.
E	4	Low Performance	No encouragement to look further except – look at the size. No ways to look suggested. Only made one more (grouping) after got stuck.
W	4	Low performance	Parent called time and so they stopped. Child was still looking.
O	6	Medium performance	Prompted to go on longer but didn't give prompts that encouraged thinking.
X	7	Medium performance	Went to subgroups alone. Told to find one more and did. Gave hint to look at the doors.
Y	7	Medium performance	Encouraged to find more but was (parent) finding – not encouraged to think more?
Z	18	High performance	Different technique to other??(sic) but worked well. Laughter. Found lots of ways of putting (all the houses) into one group. Humour.
AA	19	High performance	Corrected error in sorting. Provided equipment. Fantastic relationship between them. Respect of parent for child – equal status.
AB	24	High performance	Pattern of groups – exhausting options – first time seen this strategy. They were working as a team. (Parent) was definitely leading the team, prompting the thinking but (child's) contributions were equally valued. Was no hierarchy. Praise used. Also use of enthusiastic noises on discovery of a new group – (parent) sounded excited, engaged, interested. When other child arrived (parent) finished group they were doing and then said "Do you think we've got them all?" which prompted answer "Yes" and stop. Cue to stop??(sic) Before "What other ways could we do it? etc." - prompt to continue??*

*Note the arrival of the other child in this dyad may have caused the dyad to stop sooner than they would otherwise have done. However, since they were already the highest performing dyad their data was retained.

When the transcripts were analysed parents in the three lowest performing dyads were found to give very few or no suggestions for groups themselves. They were also found not to have prompted children towards groups or towards thinking when the children got stuck. Although this could have been because they did not understand that they were allowed to help, all parents in these dyads did give some advice so this was unlikely. In contrast parents in the middle and top three performing dyads gave more prompts towards thinking and groups and also gave their own ideas of groups. The difference between the medium and high performing groups was that in the high performing groups the parents gave more prompts to thinking than to specific groups or suggestions. Even when they made suggestions they were sometimes intended to get the children to think more creatively rather than to give them an extra group e.g. "What about the number of toilets in each house?" Parents in these dyads were working with their child to help them achieve success on the task but also respected their child's ability to complete the task. They were acting in a supportive rather than controlling role. Interestingly comments were made in two of the best performing dyads suggested that the way they were working on this task may not be the way they normally worked together on mathematics:

Parent 1	It's a lot calmer than when we do this kind of thing for homework isn't it?
Researcher 1	Is that not how it goes with homework?
Parent 1	I think normally there would be a few more I can do it Mum I don't need you to help me
Child 2	Why are you talking like a GCSE test passer (sic)?
Parent 2	I'm not I'm not really I'm just tryin' a help

Before assessing the impact of parental MR, MA and interactions on the task outcome, some other factors which might affect the outcome were considered. The task was considered to be accessible to children at all levels but to make sure this was the case, Spearman's correlation were run for the age of the child in months and the time taken and number of groups found. No significant correlations were found (time taken r = -

.181, p = .251; number of groups r = .173, p = .274) confirming that the child's age and level of mathematics education was not related to the task outcome.

The parent's level of mathematics education was another factor that may have been related to the outcomes of the pairs on the task. Spearman's correlations were run for the parents' highest level of mathematics education, the time taken on the task and number of groups found. No significant correlations were found (time taken r = .086, p = .588; number of groups r = .075, p = .638). This confirms that neither the parent's nor the child's level of mathematics education were related to the outcome of the task.

In order to check whether the parent's view of how good their child was at mathematics was related to the way in which the parent was helping, Spearman's correlations were calculated between the number of interventions the parent made and the child's age. No significant correlation was found (r = -.117, p = .462) which suggested that the extent that parents' were helping was not related to their child's age.

Table 8-7 shows descriptive statistics for the number and type of interventions made.

Table 8-7 Descriptive Statistics for Number and Type of Interventions Made in Study E

	Mean	SD	Minimum	Maximum
Number of Interventions	43.81	31.898	8	139
Number of Interventions per Second	.090	.031	.02	.15
Number of Level 1 Interventions	25.31	16.276	4	76
Number of Level 2 Interventions	4.29	4.198	0	18
Number of Level 3 Interventions	.052	.969	0	4
Number of Level 4 Interventions	6.45	7.174	0	27
Number of Level 5 Interventions	7.00	14.185	0	83
Proportion of Level 1 Interventions	62.64%	18.62%	26.61%	100%
Proportion of Level 2 Interventions	10.05%	7.81%	0%	34.62%

Proportion of Level 3 Interventions	1.05%	1.96%	0%	7.41%
Proportion of Level 4 Interventions	14.10%	10.47%	0%	42.50%
Proportion of Level 5 Interactions	4.71%	8.94%	0%	49.19%

In order to assess whether parent's MR and MA was related to the way they helped their children on the task, Spearman's correlations were calculated for the number of interventions the parent made during the task and the parents' scores on the MR scale, MR subscales and the MA scale. The results can be seen in Table 8-8. There was a positive correlation between the parents' struggle subscale score and the number of interventions they made, $r = .396$, $p = .009$, indicating that the more a parent believed in struggle the more interventions they made to help their child. None of the other subscales or the scale total were correlated with the number of interventions made. The parent's MA score was not linked to the amount of interventions they made.

Correlations were run between the parents' MA scores, MR scores and the number of interventions per second to take into account the fact that some pairs worked for longer than others on the task. No significant correlations were found, as can be seen in Table 8-8. Taken together with the previous finding this suggests that parents with a higher belief in struggle were encouraging their children to work for longer on the task and this was the reason for their greater number of interventions.

Table 8-8 Correlations between Parent MR and MA Scores and Number of Interventions Made in Study E

	Total Interventions	Interventions per second
Parent Growth	r = .005, p = .974	r = -.094, p = .552
Parent Struggle	**r = .396, p = .009**	r = .207, p= .188
Parent Value	r = .004, p = .980	r = -.081, p = .612
Parent MR	r = .196, p = .213	r = .041, p = .797
Parent MA	r = .077, p = .628	r = .151, p = .341
Child's Growth	r = .135, p = .394	r = .051, p = .747
Child's Struggle	r = -.080, p = .614	r = -.193, p = .222
Child's Value	r = -.208, p = .187	r = -.143, p = .366
Child's MR Total	r = .084, p = .597	r = -.138, p = .382

Correlations were also run between the child's MR scores and the number of interventions made by their parent in total and per second. No significant correlations were found as can be seen in Table 8-8. This suggests that the number of interventions a parent made was not linked to their child's attitude to mathematics.

In order to further assess whether parent MR and MA were influencing how a parent was helping their child on the task, correlations were run between parent MR and MA and the number and proportion of each type of interaction they made. The only significant correlation was between the parent's score on the struggle subscale and the number of Level 1 interactions they made, although several of the other level interactions were also approaching significant correlations with struggle (see Table 8-9). This suggests that those who believed more strongly in struggle were making more encouraging remarks and possibly more interactions of all levels.

Correlations were also run between the proportion of each type of interaction made and the MR and MA scores (see Table 8-9). There was a significant negative correlation between the parent growth score and the proportion of Level 1 interactions made suggesting that parents who believed more strongly that it was possible to improve in mathematics were making a lower proportion of encouraging statements. The correlation between parent MA and the proportion of Level 4 interventions made was approaching significance. This suggests that those who are more anxious about mathematics were making a higher proportion of interactions at a high level of support. There were no other significant correlations.

Correlations were run between the children's MR scores and the number and proportion of each level of interactions made (see Table 8-9). There was a significant negative correlation between score on the value subscale and number and proportion of Level 3 interactions made. This suggests that when children did not value mathematics as much, parents were making more interactions which drew their attention to an aspect of the cards by physically touching them. There was a significant negative correlation between the children's growth scores and the proportion of Level 1 statements the parents made and a significant positive correlation between the children's growth scores and the proportion of Level 4 interactions made. The correlations between the growth subscale score and the number of Level 4 interactions was also approaching significance. Children who believed more strongly in growth had parents who were more willing to make their own suggestions about how to complete the task and who made a higher proportion of these comments and a lower proportion of generally encouraging comments.

Table 8-9 Correlations between Types of Interactions and Attitudes of Parents and Children in Study E

	Number of Interactions at Given Level				
	Level 1	Level 2	Level 3	Level 4	Level 5
Parent Growth	r = - .025, p = .876	r = .080, p = .613	r = .187, p = .235	r = .056, p = .725	r = .130, p = .413
Parent Struggle	**r = .376, p = .014**	r = .265, p = .090	r = .037, p = .815	r = .269, p = .085	r = .249, p = .112
Parent Value	r = -.054, p = .732	r = .061, p = .703	r = .043 p = .786	r = .093 p = .557	r = .014 p = .930
Parent MR	r = .158, p = .318	r = .173, p = .274	r = .132, p = .406	r = .162, p = .305	r = .181, p = .251
Parent MA	r = -.033, p = .836	r = .143, p = .368	r = .101, p = .524	r = .230, p = .142	r = .140, p = .377
Child Growth	r = - .004, p = .978	r = .166, p = .294	r = -.149, p = .345	r = .298, p = .055	r = .261, p = .095
Child Struggle	r = -.026, p = .868	r = -.068, p = .670	r = -.209, p = .185	r = -.014, p = .928	r = -.026, p = .872
Child Value	r = -.085, p = .592	r = -.211, p = .181	**r = -.314, p = .043**	r = -.189, p = .232	r = -.107, p = .501
Child MR	r = -.076, p = .633	r = -.028, p = .860	r = -.266, p = .089	r = .145, p = .359	r = .061, p = .702
	Proportion of Interactions at Given Level				
	Level 1	Level 2	Level 3	Level 4	Level 5
Parent Growth	**r = - .320, p = .039**	r = .113, p = .476	r = .191, p = .226	r = .165, p = .298	r = .257, p = .100
Parent Struggle	r = -.114, p = .472	r = .049, p = .758	r = .027, p = .864	r = .090, p = .571	r = .187, p = .236
Parent Value	r = -.121, p = .446	r = .104, p = .512	r = .036, p = .822	r = .162, p = .307	r = .134, p = .399
Parent MR	r = -216, p = .170	r = .089, p = .576	r = .133, p = .402	r = .134, p = .397	r = .231, p = .141
Parent MA	r = -.231, p = .142	r = .210, p = .182	r = .090, p = .571	r = .298, p = .055	r = .105, p = .508
Child Growth	**r = - .493, p = .001**	r = .113, p = .475	r = -.141, p = .372	**r = .371, p = .016**	r = .134, p = .397
Child Struggle	r = .083, p = .599	r = -.080, p = .616	r = -.217, p = .167	r = .013, p = .935	r = -.105, p = .507
Child Value	r = .304, p = .050	r = -.169, p = .285	**r = -.318, p = .040**	r = -.111, p = .484	r = -.076, p = .634
Child MR	r = -.130, p = .413	r = .005, p = .974	r = -.257, p = .100	r = .278, p = .075	r = .023, p = .887

The contingent shift ratio was calculated for each dyad (mean = .871, SD = .093, min. = .645, max. = 1.000). To assess whether parents with higher MR and lower MA had better helping strategies, Spearman's correlations were run between the contingent shift ratio and parent scores on the MRS and MAS. As can be seen in Table 8-10 there were no significant correlations.

Table 8-10 Correlations between the Contingent Shift Ratio and Parent and Child Attitudes in Study E

Scale Score	Spearman's Correlations
Parent MA	r = .028, p = .861
Parent Growth	r = -.145, p = .359
Parent Struggle	r = .013, p = .937
Parent Value	r = -.176, p = .265
Parent MR	r = -.160, p = .311
Child Growth	r = -.226, p = .149
Child Struggle	r = .047, p = .769
Child Value	r = -.013, p = .934
Child MR	r = -.059, p = .712

To assess whether the strategy that the parent used to help on this task was connected to how the children's MR had developed, correlations were run between the contingent shift ratio and child MR. No significant correlations were found (see Table 8-10).

8.4.2 Qualitative Analysis

In order to investigate whether a child's MR was linked to the type of interactions they were having with their parent during this task, the children were ranked in terms of their MR scores and the top, middle and bottom three transcripts were selected. Table 8-11 shows the initial notes made by the researcher for those children who had the top, middle and bottom MR scores. These notes were either made as the children completed the task or as they were transcribed. At the point these notes were made the researcher was unaware of the MR scores of the children. It is notable that the children who had the highest MR appeared to be working more collaboratively with their parent. Parents in this category were also valuing the child's contribution equally, and sometimes more highly, than their own in contrast to parents in other categories.

Table 8-11 Notes Made on the Children with Low, Mid and High MR

Dyad	MR Score	Group	Field notes from the day and during transcription
A	1.45	Low MR	No encouragement to continue at all. Couldn't see any more so stopped. No strategy for looking, no encouragement to develop one.
B	1.73	Low MR	Brilliant mathematical talk but not many groups. He saw subgroups which (parent) didn't even see he saw. Constantly talking over each other. Both have fixed ideas, promoting their own point instead of working together for most of the time. Parent uses I a lot rather than we. Doesn't explain child misunderstanding.
C	2.13	Low MR	Child immediately stopped when parent said shall we stop.
D	4.27	Mid MR	Motivated for some but not too long.
E	4.28	Mid MR	No encouragement to look further except - look at the size. No ways to look suggested. Only made one more (group) after got stuck.
F	4.4	Mid MR	Encouraged to find more but was (the parent) finding – not encouraged to think more?
G	6	High MR	Subsets. Group > 1 (thing to group on) Parent = (importance to) child
H	6	High MR	Pattern of groups – exhausting options – first time seen this strategy. They were working as a team. Parent was definitely leading the team, prompting the thinking but daughter's contributions were equally valued. Was no hierarchy. Praise used. Also use of enthusiastic noises on discovery of a new group – parent sounded excited, engaged interested. When other child arrived parent finished group they were doing and then said "Do you think we've got them all?" which prompted answer yes and stop. Cue to stop??? Before "what other ways could we do it etc." prompt to continue???
I	6	High MR	Asked questions but closed questions. Pointed attention to certain aspects which enabled (child) to see things. Left to decide for herself a lot. Little interference.

In order to investigate these initial findings further the nine transcripts were analysed in more detail. The comments that the parents made were classified according to the purpose that they appeared to be trying to achieve; these will be known as actions. In the transcripts from the children with the three lowest MR scores there were six types of action. All six types were contained in all three transcripts. These actions, with examples, are shown in Table 8-12.

Table 8-12 Examples of Actions Carried out by Parents Ranked by order of Children's MR

Actions Carried Out by Parents of Children with the lowest MR	
General encouragement to perform the task	"What can we do now?" "So what else is there about the houses?" "So what types of groups can we put them in?"
Agreement	"OK" "Oh I see" "Yeah ok"
Echoing or verbalising the child's thinking	"Right then door colour" "So like the number of stories in the house right yeah" "So they are all one height"
Querying the child's thinking	"Alright what was that, size of roof or line?" "Have they got 12?" "So what are is (sic) that a different height to that one?"
Gives their own suggestion	"What about that?" "Are all the windows the same colour?" "What about chimneys, are they all the same size?"
Interactions around ending the task	"Are we done?" "I have no more" "Mum I think we've finished" – "No we haven't."
Additional Actions used by Parents of Children with middle MR	
Prompt to group	"Can you think of anything where there's two things in common now?" "What about what's the difference between that one and that one?" "So why are they different?"
Praise	"Good girl" "That's a good idea"
Recap of previous groups	"So you've done windows, you've done the same number of er same number of windows, the same colour of doors, same colour roofs"
Additional Action used by Parents of Children with high MR	

Prompt to reflect	"Have a look see if there's any more patterns like that." "What makes that grouping a bit difficult?" "Ah oh does that depend on the type of house so have those those (sic) two got the same roof and these two have got the roof same roof (sic)".

When the transcripts of the three children with middle MR scores were analysed they also contained all of the types of action used by parents of children with the lowest MR. However, in addition there were three other types of action, examples of which are given in Table 8-12. The most noticeable difference between the lower and middle MR transcripts was the presence of the "prompt to group" action which appeared in all three of the middle MR transcripts, but in none of the transcripts for the children with low MR. Rather than give the child a suggestion of a group, the parents of the middle MR children asked them questions which prompted them to think in a way that would lead them to find the specific group that the parent had in mind. This was only done a few times by each parent and they then reverted to suggesting groups. The other two types of interactions were only present in two of the three middle MR transcripts respectively.

When the transcripts of the high MR children were analysed two out of the three also contained all of the actions listed in children with low and middle MR whilst the other contained all except the parent making their own suggestions of groups. In addition to this however, they all contained a new action, a prompt to reflect on the groups that had been found and to use these ideas to create new groups. This was different to the "prompt to groups" (see Table 8-12) which directed the children towards a specific group or pattern that the parent had noticed and was endeavouring to get the child to notice. The new action aimed to promoting thinking about the task rather than finding a specific group. Examples are given in Table 8-12.

This analysis showed a trend in the actions of parents as children's MR increased away from simply supporting and making suggestions to them towards prompting them to do more of the thinking themselves. Initially this took the form of having a certain group in mind but prompting the child to find it themselves rather than simply telling them, and with those with the highest MR it became prompting them to think in ways that would lead them to find more groups which were not pre-determined.

Two transcripts stood out as illustrative of the difference between the interactions of parents with low and high MR children. In the first parent and low MR child transcript, the parent's querying of the child's thinking became argumentative and confrontational and the child became very frustrated. The following is an illustrative passage from the transcript:

Extract from Dyad B

Child	Let (sic) put the these two small ones the middle (sic) then
Parent	That one that one (sic) is a tall house I think even this one is a tall one
Child	Now we had no that's not
Parent	It is
Child	No it isn't
Parent	Isn't it the same size as this?
Child	No it isn't
Parent	Yes it is
Child	It isn't
Parent	It is
Parent	The short ones are these I think, yes. This is a short and that one
(Child Ok)	
Parent	and then this one's a tall
Child	No let Mum let mum let go (sic)
Parent	Concentrate

In this section of their interaction the child was working on sorting out a group he had come up with and the parent felt that he was sorting the houses incorrectly. Both were determined that their sort was the correct one. Neither was willing to listen to the other's point of view and by the end of this interaction the parent was moving the cards against the child's will. When he protested about this she attributed his refusal to listen to her to a lack of concentration on the task despite the fact that at this point he was very engaged with the task, although not in the way she felt was correct. When this had continued for a time, with the parent repeatedly making her own suggestions and the child not being listened to, the child no longer wanted to continue with the task, as can be seen in the following illustrative passage:

Extract from Dyad B

Parent	Look here that's a good way of doing it, have you seen now what I mean?
Child	See so let's put these black doors and see who's the smallest
Parent	Those are the same
Child	Oh Mum I know
Parent	Yeah
Child	I thought that um if you look at the so look look (sic) at the length of the roof
Parent	Um
(Child so)	
Parent	Not the length of the roof just the size of the house
Child	Mu-um we're looking at if I do put this on top of this that is um
Parent	Did you get my point first of all?
Child	Mum I don't know
Parent	You don't know what I mean? Let me let me show you yeah
Child Sighs	
Parent	I know you haven't gotten what I meant
Parent	If you look at this picture look
Child	Mum I think we've finished
Parent	No we haven't
Child	Yes we have

In contrast in the following extracts from a transcript of interactions between a high MR child and parent, the actions were mutually supportive and the parent was playing down their own role and stepping back to let their child control the activity rather than arguing with them:

Extracts from Dyad I

Child	Colour of the roof
Parent	Yep next one took me a while to click with wh (sic) what have you sorted them into
Parent	It's me being slow
Parent	You could do some oh go on
Child	Ch (sic) ones with five windows ones with three windows
Parent	Ah great
Parent	You don't have to wait til I've finished writing if you can think of another one
Child	I can't find anything
Parent	I think you've got more than I would get

These extracts from the two transcripts illustrate the trend that was seen amongst all the transcripts from children with low MR whose parents were controlling the activity to a higher extent than children with high MR whose parents were prompting them to think but were allowing the child to lead the activity.

In order to investigate whether the parents' MR was linked to how they worked with their children on the task the parents' MR scores were ranked and three transcripts were selected from the top, middle and bottom. Table 8-13 shows the initial notes made as the dyads completed the task or as the interactions were transcribed. These notes were made when the researcher was unaware of the parent's MR score. There were no obvious patterns in these initial notes and the transcripts were not analysed further.

Table 8-13 Notes Made on the Parents with Low, Mid and High MR

Dyad	MR Score	Group	Field notes from the day and during transcription
J	92	Low MR	Not remarkable.
A	96	Low MR	No encouragement to continue at all. Couldn't see any more so stopped. No strategy for looking, no encouragement to develop one.
D	99	Low MR	Motivated for some but not too long.
F	127	Mid MR	Encouraged to find more but was (parent) finding – not encouraged to think more.
G	128	Mid MR	Subsets. Group > 1 (thing to group on) Parent = (importance to) child
K	130	Mid MR	Some support, no suggestions as to how to try to find more – no strategies. Not particularly remarkable in any way.
L	145	High MR	Child very much in charge of the activity. Made suggestions but did not take over.
M	148	High MR	No encouragement to think further than was able to alone.
N	149	High MR	Moved (pictures) to position and left to see. When didn't see told (child) eventually. Encouragement led to (child) trying for longer than would have done alone. Parent first to talk. Parent kept repeating "anything else" – sing song tone. "Keep looking". Hints to one (parent) knows.

In order to assess whether parents' MA was influencing the way they worked with their children on the activity, parents were ranked by their MA score and three transcripts were considered from the top, middle and bottom. Table 8-14 shows the initial notes made by the researcher as the dyads completed the activity and as the interactions were transcribed. These initial notes suggested that those parents with low MA, i.e. those who were less anxious about mathematics, participated in the activity less than those parents who had higher MA. In order to investigate this finding further the nine transcripts were studied in more detail.

Table 8-14 Notes Made on Parents with High, Middle and Low MA

Dyad	MA Score	Group	Field notes from the day and during transcription
O	62	High MA	Prompted to go on longer but didn't give prompts that encouraged thinking.
P	61	High MA	
Q	57	High MA	Original groups split into subgroups to gain more. Prompted to keep going. Keep pulling back to the task. Considerable amount of mum's ideas input only when (child) got stuck – not at first. Not sure (child) understood what (parent) was showing – why they were doing what they were.
R	30	Mid MA	"You're doing a really good job" – lost interest?
S	29	Mid MA	-
T	28	Mid MA	Advice to lay them out – practical, enabling. Then (child) used the strategy independently. No further encouragement, child entirely left in control of task. No encouragement to persevere.
U	12	Low MA	Absolutely no interaction. I had to step in to stop experiment. Really long periods of silence. Child didn't reply to question from parent. Parent doesn't respond to groupings in any noticeable way except to matter of factly (sic) record them.
V	10	Low MA	Told an answer when (child) got stuck and then sat back again. Used as prompt to get him to continue? Later prompted to sort on two things, led to (child) continuing. Parent would have stopped before child – thought (child) was bored/tired?
L	10	Low MA	Child very much in charge of the activity. Made suggestions but did not take over.

When the transcripts were analysed they all contained actions from Table 8-12. There was a difference however, in the proportion of each type of action that they contained. Parents who were highly anxious about mathematics showed a tendency to make a larger proportion of their own suggestions for groups, whilst those who had low MA left many more periods of silence and were less likely to make their own suggestions for groups, with one making no suggestions at all. In fact, parents with low MA were less likely to prompt their children to further groups or thinking and were much more likely to act purely as the recorder of the groups up until their child got stuck as requested when the task was initially outlined. Parents with low MA scores were more likely to let their child decide for themselves when they should finish the task and not suggest they should continue as the parents with higher MA did. This suggests that the higher a parent's own MA, the more actions they took to ensure their child did well on the task.

8.5 Discussion

This study investigated how parents' and children's MR and MA were related, how parents and children worked together on a mathematics task and whether their interactions were affected by the pair's MR and parent's MA. The study initially considered whether a child's MR was affected by their parent's attitude to mathematics. No direct correlations were found between a parent and child's scores on the subscales although the positive correlation between their total scores was approaching significance ($r = .301$, $p = .052$). However, a parent's belief in growth was correlated positively with their child's MR. This is the first evidence on the relationship between parent and child MR and suggests that although MR does not directly pass from parent to child, if parents believe that being successful at mathematics is an inbuilt, natural ability, their children will have lower levels of MR. One way to help to improve the mathematical resilience and thereby performance of children in mathematics may therefore be to show parents how they themselves can improve in mathematics thus increasing their belief in growth. This was the approach which was successfully adopted in Goodall and Johnston-Wilder's (2015) case study and the current study provides further support for, and justification of, this approach.

The fact that parent MA and child MR were not significantly correlated supports studies by Goodall and Johnston-Wilder (2015) and Berkowitz et al. (2015) and provides support for the hypothesis that even mathematically anxious parents can have children who have strong MR and are equipped to do well in mathematics. This was reinforced by the regression model which showed that a parent's MR accounted for more of the variation in a child's MR than the parent's MA. Thus the study did not strongly support the hypothesis that parent and child attitudes to mathematics were linked. Rather it showed that parent's attitudes were not the only influence on a child's MR but their belief in growth in particular was an important factor.

The second consideration was whether task outcome was correlated with parent or child MR or MA. When the amount of time the pair spent on the task and the number of groups found was considered there was no correlation between these two outcomes and the child's MR. There was a positive correlation between the parent's belief in struggle and both the time spent on the task and the number of groups found. There was also a positive correlation between the number of groups found and the parent's MR. This suggests that as the parent and child worked together on the task it was the parent's belief in the need to struggle that influenced how long the pair continued to work and thus the amount of groups they found. If this finding was replicated when a parent was supporting a child with mathematics in the home environment it would imply that those parents who had lower belief in the need to struggle to do well in mathematics might not encourage their child to continue with a task they were finding difficult. Thus these children would receive less encouragement at home to master difficult mathematics tasks and over time this would impact on their performance in mathematics. A parent's MA was not influencing the outcome on the task however, indicating that parents who were maths anxious themselves could still support their children to success in mathematics.

The third aspect considered was whether contingent support was linked to task outcome. When the contingency of support was considered there was no correlation between child MR, parent MR or task outcome and the contingent shift ratio. However, in this particular task the idea was to come up with as many groups as possible and the qualitative analysis suggested that the parents in better performing groups were making more suggestions and providing more prompts to thinking than those who performed poorly. Strategies that would lead to the dyads finding more groups in this task and spending longer on it would therefore not necessarily be contingent and may have been different from those the parent adopts when working on other types of mathematics task. This difference from normal mathematics working was even alluded to in two of the transcripts. This highlights the fact that when researching parental support of mathematics learning, care should be taken to consider the impact of the particular task set on a parent's helping strategies. Ideally more than one type of activity should be presented and whether the parent adapts their helping style to the particular task should be considered. Since the parent may be helping in such a way as to promote the child's success on the task rather than their learning; this needs to be taken into account, and the contingent shift ratio alone may not be a sufficient measure of how a parent is helping.

The final aspect considered in this study was how a parent worked with their child on the mathematics task and whether this was influenced by the parent or child's MR. The quantitative data showed that parents who had a greater belief in struggle made more interventions than parents with a lower belief in struggle, although they made a similar number of interventions per second. This suggested that those who believed that you have to struggle to succeed in mathematics attempted to help their child with the task on more occasions and over a longer period of time, thus encouraging their child to work for longer on the task. This implies that parents with a higher belief in struggle would give more advice and encourage a greater degree of perseverance with homework. When the type of interactions made was considered, the higher a parent's belief in struggle, the more Level 1 (generally encouraging) interventions they made. This suggests that those who believed you need to struggle to get better in mathematics were giving their children more encouragement when they were doing so. The higher a parent's belief in growth, the lower the proportion of Level 1 interventions they made. This suggests that those who believed it was possible to get better in mathematics were encouraging their children less of the time, instead offering more suggestions as to how they could complete the task.

Interestingly, parental MA was not correlated with the number of interventions made, indicating that the parent's own worries about mathematics were not influencing how often they tried to help their children. However, the qualitative analysis noted that parents who had high MA made their own suggestions of groups more frequently than those with low MA and that parents with low MA were more likely to leave the child to work independently on the task and just encourage them. This was reinforced by the fact that those parents who had higher MA made a higher proportion of Level 4 interactions. These were interactions which instructed the child on what they should do on the task. This finding was approaching statistical significance and suggests that parents who are anxious about mathematics themselves are more likely to step in and tell their children what to do rather than leave them to figure it out for themselves. These findings may have been the result of a belief by the parents with high MA that a good performance on the task was necessary so they and their child would be seen to be good at mathematics. Thus their anxiety was causing them to try control the task and thereby come up with more groups for their child.

Maloney et al. (2015) found that when mathematically anxious parents worked with their children on mathematics the children's performance was negatively affected. The current study provides a possible explanation for this finding since highly maths anxious parents were more likely to control the task and not leave room for their children to investigate and discover things for themselves, in contrast to parents who had low levels of MA. If parents with high levels of MA could be encouraged to give their child more control when working together on mathematics this may be one way to stop the negative effects found by Maloney et al.

There were no significant correlations between the child's MR and the number of interactions made. However, when the interactions were analysed qualitatively, links were found between a child's MR and how their parent was helping them. Those children who had lower scores on the value subscale received a higher number and proportion of Level 3 interventions. These were interventions in which the parent directed the child's attention to the task with gestures and suggests that those children with lower value for mathematics may have been getting more distracted and needed to be redirected back to the task. Those children who had higher belief in growth received a lower proportion of Level 1 and a higher proportion of Level 4 comments from their parents. This meant that their parents were giving them help to solve the task more often. From further qualitative analysis, it was clear that those children with higher MR were being encouraged to think more by their parents while those who had lower MR were being offered support by means of being told what to do and which groups to make. Although causality cannot be inferred from this type of study, it is possible that if parents always supported their children in these differing ways, they could be contributory to the development of their child's MR. In particular it may be that by giving a child a hint to help them think their own way to a solution rather than telling them that solution, parents are encouraging mathematical resilience in their children.

This study had several limitations. The scope of the study meant that the complete qualitative analysis of the transcripts, which would have been ideal was not possible. Conversation analysis would have produced a more rigorous analysis and it is acknowledged that any conclusions drawn from this brief thematic analysis using conversational actions as the themes be regarded with caution. However, the fact that the conclusions made were supported by the conclusions made using Wood's Contingent levels of support as the basis of the coding suggests that if time or experience of conversation analysis is limited, a brief analysis of this type may give a more complete picture than the contingent support ratio alone.

The task used in this study was of a very specific type. It is very different from the tasks that children usually get given for homework and was completed in a 'fun' event with a time limit of 30 minutes before the next activity began. As such parents and children may have been interacting in a different way to usual when completing it. Some of the children's comments suggested that this may have been the case. In future studies it is recommended that more than one type of mathematical task be used in order to see how parents and children interact when the goals of the task are different and that how and where studies are conducted is taken into account.

A final limitation is that the sample for the study was drawn from parents and children attending a psychology event at a university. It may therefore be hypothesised that these parents may be more used to helping or better equipped to help their children in mathematics, or at the very least are the most involved kind of parents rather than being typical of all parents. Even were this true, a wide range of MR and MA were found among the parents and their approaches to helping also differed in effectiveness. Just because a parent is involved in their child's education does not mean they are ideally involved, as discussed in Chapter 2, and therefore studying these parents has value. Future studies should, however, try to attract a wider range of parents.

8.6 Conclusions

This study found no direct link between parent and child attitudes to mathematics. However, a greater belief by parents in the ability to get better in mathematics was positively correlated with higher mathematical resilience in their children, evidence of a link between parent's attitudes and their children's MR. For the first time this study also provides evidence that parents' level of MR is linked to the way they work with their children on mathematics. Parents who believed more strongly in struggle encouraged their children to work for longer on the task. Those who believed more strongly in the ability to get better in mathematics made a lower proportion of generally encouraging comments and a higher proportion of comments which would help their children think about how to find more groups. This suggests that if parents' beliefs about the ability to get better in mathematics could be improved they would be better equipped to support their children in mathematical activities. Furthermore if they could be taught the importance of struggle in learning mathematics they may be more inclined to spend longer helping their children. The following chapter therefore considers the development of an intervention to use MR to improve parental support of their children in mathematics.

Chapter 9 Development and Evaluation of a Parental Intervention to Improve the Mathematical Resilience of Children

9.1 Chapter Summary

In the previous chapters it was suggested that an intervention which aimed to teach parents about mathematical resilience (MR) and how they could promote it in their children might be a useful way to improve the MR and performance of their children in mathematics. This chapter details the development and trial of such an intervention. The efficacy of a pilot study is evaluated using quantitative methods and process evaluation. An online survey into the type of intervention parents would favour is discussed. Conclusions are drawn and suggestions for future research are made.

9.2 Introduction

In Chapters 5, 6 and 7 evidence has shown links between MR and performance in primary school children. The study in Chapter 8 provided evidence for a link between parental MR, particularly belief in growth, and a child's MR. In the same study parents who had higher levels of MR were found to be engaging more successfully with their children on a mathematics task. As a result of these findings it is hypothesised that if an intervention could be run to improve the MR of parents this may in turn have a positive effect on the MR and performance of their children.

As discussed in Chapter 2, evidence on how parental involvement impacts on the development of attitudes towards mathematics and performance in mathematics has been mixed (e.g. Borgovoni and Montt 2012, Patell et al. 2008, Maloney et al. 2015). Chapter 2 suggests that many parents do not know how to work with their children on mathematics. However, the ecological model, discussed in Section 2.3, suggests that working directly with parents does have the potential to affect their children's development. Therefore the current study aimed to develop, pilot and trial an intervention which taught parents about MR as well as how best to work with their children. The initial forms of the intervention were developed from a course written by the researcher for use in her own business between 2013 and 2016. It was designed to introduce parents to the methods their children were learning at school and help them to consider ways in which they could include mathematics learning in their children's everyday life. Initially the course incorporated aspects of MR implicitly, but after beginning to research the subject independently in 2014/15, the researcher began to talk explicitly about MR and the themes of growth, struggle, value and resources during the courses. The current study aimed to assess whether the intervention sessions, which anecdotally were helpful to parents, could be seen to be having a measurable impact on parents and children, either in terms of quantitative changes in attitudes or performance or in behaviours when talking about and working on mathematics together. If such changes were found the study aimed to understand what aspect of the intervention was bringing about this change, and in particular consider whether it was necessary to teach the parents mathematics techniques or whether it was enough to simply teach them about the concept of MR.

Shumow (1998) found that conversations with parents were more effective in promoting change in the way they worked with their children than literature alone. Both Goodall (2017) and Sheridan et al. (2007) emphasise the importance of engaging parents as partners in their children's learning along with schools. Thus the intervention used the principles of Conjoint Behavioural Consultation (CBC) (Sheridan et al. 2007) in which parents' knowledge of their children and their particular challenges is recognised as vital in helping them to work together. This meant that intervention sessions were to some extent directed by the parents who attended. Rather than being identically delivered top down lectures, some formal input was provided by the researcher and some of the session took the form of talking about and exchanging thoughts on the material being covered and on their individual children. This necessarily led to no two sessions being exactly alike. However, all sessions had session plans with fixed points to cover and materials to be distributed to parents and the process evaluation allowed conclusions about how true to this structure each session had been.

The study was originally designed to have two stages, an initial iterative piloting phase where different formats of intervention were tested and conclusions drawn, followed by a larger randomised trial over the course of an academic year during which the final form of the intervention was tested. A control group was to be monitored over the year for comparison. Analysis of both phases would be by means of process evaluation, qualitative and quantitative methods. However, recruitment of parents in the pilot phase proved problematic, an issue identified in interventions involving parents in the literature review in Chapter 2. In order to try and find a format that was more attractive to parents an online survey was conducted. Despite this, recruitment to the main trial was again problematic meaning that there were too few participants for a randomised control trial to be conducted.

9.3 Phase 1: Piloting of the Intervention

9.3.1 Methodology

Intervention Design

During this phase the intervention was piloted in three different forms, parents' views on its format and effectiveness were sought, and conclusions were drawn about which form of the intervention should be used for a larger scale pilot. Initially, a four session intervention was developed. In two of the sessions the parents were shown the mathematics techniques that their children would encounter during the course of primary school. In the other two sessions the aspects of MR were discussed along with how they might be relevant to the way in which the children were learning mathematics both at home and at school. The intervention was delivered to two groups, one with the mathematics sessions first and the other with the MR sessions first in order to assess whether order of delivery affected outcomes. All sessions were delivered using written materials with examples and practice questions which the course leader and parents worked through together. The parents saw the materials for the first time on the day of the intervention but could take them away afterwards for reference. Alongside the four sessions the parents were invited to join a private Facebook group where they could keep in touch with the course leader and others from the course and share any experiences or questions they had when working with their children on mathematics. A further two session pilot was then run consisting of one MR session and one mathematics session to assess whether the same impact could be achieved in a shorter number of sessions which may be more accessible for parents.

Recruitment and Analysis

Details of recruitment can be found in Section 3.5. Parents' data were used to assess the most effective format of the pilot by considering changes in the data pre and post intervention. Children's data were used to assess the most appropriate way to collect data during the main pilot rather than to assess changes in the children brought about by the intervention.

Participants

Details of the participants can be found in Section 3.6.8. Eight parents participated in an intervention. Table 9-1 gives details of the intervention that each group received.

Table 9-1 Type of Intervention Delivered to Each Group in Study H

Group	Number of sessions	Content	Order	Number of participants
1	4	MR and Maths Methods	MR first	3
2	4	MR and Maths Methods	Maths first	2
3	2	MR and Maths Methods	MR first	3

Background Measures and Procedures

The instruments were chosen in order to assess the research aim of producing a successful intervention. Since one of the aims of the pilot was to assess what was feasible in terms of assessment of parents and children, the means of assessment were adapted throughout the pilot and not all groups completed all assessment measures. Process evaluation allowed monitoring of this process.

Parent Measures

The MRS (Kooken et al. 2015, Section 3.7.1) and The Mathematics Anxiety Scale (MAS: Betz, 1978 3.7.2) were used to collect data on parents' MR and MA before, during and after the intervention. Parents were asked to fill in a voluntary reflective journal whilst taking part in the intervention. They were also asked to fill in a questionnaire at the end of the intervention (see Appendix 10). Intervention sessions were recorded and transcribed with the permission of the parents.

Child Measures

For this pilot study, data were only collected from the children to assess what would work in the main trial and the data were not analysed. The BCMRS was used to assess MR (See Section 3.7.1). Since this study took place during the development of the scale the children completed an early 20 item version. The MAAQ (Section 3.7.2) was used to measure MA and attitude to mathematics. The participants also completed WIAT-II (Section 3.7.3). Not all groups provided all data. Table 9-2 shows the data collected for each of the three groups.

Table 9-2 Data Collected by Group in Study H

Group	Data Collected
1	Parent MR and MA (Pre, mid and post), reflective diaries, post-intervention questionnaires
2	Parent MR and MA (Pre, mid and post), reflective diaries, post-intervention questionnaires Child MR, MA and Performance (Pre and post)
3	Parent MR and MA (Pre and post), reflective diaries, post-intervention questionnaires Child MR and MA (Pre)

Process Evaluation

Process evaluation was used to assess how effective the intervention was in the population as a whole and how well it was delivered. Process evaluation, often used for the evaluation of interventions in health research, considers the implementation of an intervention, the mechanisms of impact and contextual factors (Moore, Audrey, Barker, Bond, Bonell, Hardeman, Moore, O'Cathain, Tinati, Wight and Baird 2015). The following process evaluation methods were used to assess recruitment to the intervention (i.e. whether it followed ethical protocols and how successful recruitment was), the reach of the intervention (i.e. whether the intended participants were able to access it), the fidelity of delivery (i.e. to what extent the delivery of the intervention was as planned), intervention delivered and received (i.e. to what extent were all participants exposed to all aspects of the intervention and were they satisfied with the intervention they received) and the context of the intervention (i.e. were there any other factors that impacted on the delivery of the intervention):

Deliverer Reflective Journal

A reflective journal was used to assess all aspects of the interventions and reflect on the whole process. It was completed by the researcher as soon as possible after the intervention (always within the same week).

Deliverer Checklist

A checklist was used to self-assess delivery of the intervention by the researcher immediately after the intervention had taken place. This checklist (see Appendix 11) rated different aspects of the delivery on a numerical scale with descriptors (adapted from checklist used in Johnson, McNally, Rolfe, Ruiz-Valenzuela, Savage, Vousden and Wood 2019).

Observer Checklist

Some of the sessions were videoed and watched by an independent observer, a specialist in mathematics education, who rated the delivery of the intervention on the same checklist as the researcher. The two ratings were compared to ensure inter-rater reliability.

Records of Recruitment, Attendance and Participant Details

These were used to assess the reach of the intervention; that is how many of the envisaged participants were able to access the intervention. They were also used to assess recruitment, whether it followed the ethical guidelines set out in the design and whether there were any barriers to recruitment.

Participants' Reflective Diaries

These were used to assess whether participants had received the intervention as intended, whether they had understood what they had learnt and whether they had made any changes in their behaviour. Completion was voluntary and on some occasions the session over-ran which meant that diaries were not always handed out. Fifteen diaries were completed over the three pilots.

End of Course Questionnaires

These were completed by all participants at the end of the intervention and included questions about the delivery of the sessions, which aspects the participants found most successful, whether the participants had changed the way they approached mathematics with their child and whether they felt the intervention could be improved in any way.

9.3.2 Results

Process Evaluation of the Pilot

Recruitment

Recruitment to the intervention proved problematic. No difficulty was encountered in recruiting schools to the pilot. However, the percentage of parents recruited to take part in the intervention per school was low (See Table 9-3). It was hypothesised that the length of the 3 page letter initially sent home was off-putting to some parents so in the third pilot an A4 flyer was used and the intervention was advertised in the school newsletter. This approach did not attract any participants at all so the original format of the letter was then sent out resulting in 5 parents responding. The parents who took part did not recall seeing the notice about the intervention in the newsletter. Only one vaguely recalled seeing a flyer but said that they did not respond at that point due to time commitments and that "*The flyers are great and get to your audience but they compete with loads of others that come home on a daily basis and (I'm gonna be brutal) easy to discard when weighed against other commitments/tasks*."

Even when parents did express an interest a high percentage (39% of respondents) dropped out before beginning the intervention. The main reason given for this was that parents could not attend at any of the times offered by the researchers or agreed on by the majority of parents even though these were as flexible as possible. One parent had only filled in the form because they were told to by the teacher and when they realised what was involved they pulled out. A second participant was repeatedly contacted and despite saying they would get back to the researcher never did. A third agreed to take part at a certain time and then became unavailable after it had been arranged.

Of the 140 individual children who received letters with an option for their parents to reply and take part in the intervention, 9% were returned and 6% took part.

Table 9-3 Study H Response and Uptake Percentages by School

Pilot Number	Number of letters sent out	Percentage of parents who replied after first letter	Percentage of parents who replied after second letter	Percentage of parents who began course
Pilot 1	19	16%	NA	16%
Pilot 2	90	6%	NA	2%
Pilot 3	62 (2 per child)	0%	16%	10%

Reach

As intended all participants had a child in Year 1. In the initial pilot all participants also had older children and it was hypothesised that this may have influenced their decision to take part but this was not reflected in later pilots. All participants had English as a first language. Seven of the participants were female and the eighth was male. Five of the participants reported that they liked mathematics, three said they did not. Seven of the participants responded to questions about education level. Details can be found in Table 9-4.

Table 9-4 Study H Parents' Highest Mathematics and Overall Qualification

	GCSE	A-Level	Degree Modules	Undergraduate Degree	Master's Degree
Mathematics Qualification	6	1	0	0	0
Overall Qualification	1	1	2	2	1

Fidelity

The sessions were in the main delivered as planned. The deliverer's own checklist percentages ranged from 75% to 89% with a mean of 82% (see Table 9-5). The observer's scores were higher than the deliverer's by an average of 10%. This indicates the deliverer was underestimating how well she had delivered the course and that the intervention fidelity of delivery was around 80-90%. For such a flexible course this is strong fidelity.

Table 9-5 Checklist Scores for the Delivery of the Intervention in Study H

Session	Score	Percentage	Observer Percentage
BB1	31	86%	93%
BB2	28	78%	
BB3	30	83%	96%
BB4	29	81%	
TC1	32	89%	
TC2	31	86%	
TC3	29	81%	
BW1	27	75%	
BW2	29	81%	
Mean Score	29.5	82%	94.5%

Intervention Delivered

Of the eight participants who took part, five (63%) were present for all of the sessions allocated for their group. The other three participants missed one session each. One missed the second session and the other two missed the final session. The participants were all provided with written copies of the notes for the session that they missed. All three participants in the two session pilot attended both sessions.

When present in the sessions all participants appeared engaged and took an active role in the activities according to the researcher's reflective journal and their responses to the questionnaire.

Intervention Received

All parents who attended expressed a high level of satisfaction with the intervention and their ability to access and engage with the activities and materials provided. Even when participants reported finding the content hard they felt able to access it due to clear explanations. One participant suggested that having the mathematics methods materials the week before they were taught would have given them a chance to participate more fully in that session.

Although all parents were given the opportunity to access the Facebook support groups only one of the parents in the first pilot did so. Both participants in the second pilot and two of those in the third accessed the support group and continued to be active in the group after the intervention was complete.

Context

The three courses were taught in different settings and at different times to suit the participants. Two were taught in private homes, one the home of the researcher in the evening and the second the home of one of the participants on a Saturday afternoon. The third was taught in a public library on a Saturday morning. The atmosphere in the homes was more relaxed and private as there were no other people present. During one of the sessions in the public library the participants found it difficult to hear a video they were listening to due to noise created by members of the public attending the library. However, all the participants declared they were happy with the setting and did not report that it had negatively influenced their experience of the intervention.

Refreshments were provided at all sessions and these were mentioned positively by several of the participants. The researcher felt they helped break the ice at the start of a session and allowed participants to feel welcome and relax as the session began.

The emphasis of the three sessions was slightly different each time due to the different experiences of the participants. In the first pilot the participants all had older children and already knew each other and this influenced the directions of discussion in that they were using their prior experience with their older children to recognise scenarios that the researcher was presenting and anticipate problems they may have with their younger children. In the second pilot the school had been emphasising literacy and phonics and had not sent home any mathematics homework or details about mathematics and this group were more interested in finding out what their children were doing at school. One participant in this group had older children but the other did not. The emphasis in this course may also been influenced by the fact that this group did the mathematics methods sessions before the mathematical resilience session unlike the other two pilots. Participants in this group did not know each other prior to the intervention. In the final pilot two of the group were highly maths anxious and in this group the emphasis in discussion was on this and how to help their own children be more confident. Due to their mathematics anxiety it could have been hard for these parents to engage with the intervention but they said that the "safe" "intimate" setting (in one of the participants' homes) meant that this was not a problem. Two of the participants in this group were married to each other but they did not know the third participant prior to the sessions although their sons were good friends.

During one of the sessions of the first pilot the researcher was unwell and had problems making her voice heard. The two participants who were present did not mention this as a problem.

Quantitative Evaluation of the Pilot

Eight parents took part in three pilot trials and their scores were recorded pre and post intervention on the MAS and MRS. Since the number of participants was so low, all conclusions drawn in this section should be regarded with extreme caution. The Wilcoxon Signed Rank Test was carried out on the data since the sample size was small and normality could not be assumed. Pre and post intervention medians and ranges can be found in Table 9-6.

Table 9-6 Parental Pre and Post Intervention Statistics for Study H

	Pre Test Median	Pre Test Range	Post Test Median	Post Test Range
MA	39	53	35.5	52
Growth	36.5	23	39.5	23
Struggle	39	16	47.5	17
Value	43.5	18	48	18
Total MR	116	39	137	50

There was no significant change in the MA score of the participants; $T = 3$, $p = .12$. Participants overall MR scores were significantly higher post intervention than pre intervention; $T = 36$, $p = .012$, $r = .63$. This suggests that the parents were more mathematically resilient after taking part in the intervention. Changes in the subscales were considered in order to further understand this change in MR. Participants' struggle (T = 39, p = .021, r = .58) and value (T = 36, p = .012, r =.63) scores were significantly higher post intervention than pre intervention suggesting that the participants had a stronger belief in the need to struggle in mathematics and valued the subject more highly after the intervention.   There was no significant change in the belief in growth, (T = 36.5, p = .106). These findings suggested that the interventions were successful in improving parent's MR, particularly their value for and belief in the need to struggle in mathematics.

In order to inform decisions on whether a four or two session intervention was more effective the data was split into the number of sessions attended and analysed separately (see Table 9-7). A significant difference in MR was found in the four session pilots pre and post intervention, T = 15, p = .043, r = .64. No significant difference was observed in the two session pilot group although this may have been because of the small sample size (n=3) as there was a large positive change in the median for this group. It is therefore not possible to conclude whether there was a difference in the 2 session and 4 session conditions.

Table 9-7 Parental Pre and Post Intervention Statistics in Study H by Number of Intervention Sessions and Order Topics Were Delivered

	Pre Test Median	Pre Test Range	Post Test Median	Post Test Range
Four Session Intervention (n = 5)	113	33	133	32
Two Session Intervention (n=3)	116	28	157	6
MR First (n = 6)	114.5	39	142	50
Maths First (n = 2)	127.5	21	137	6

The data was also split by the order in which the interventions were run (See Table 9-7). There was a significant difference in the group where MR was taught first, T = 21, p = .028, r = .64 but no significant difference in the group where mathematics was taught first (Median pre = 127.5, post = 137, Range pre =21, post = 6, $n = 2$) but again this was the smaller group and there was a positive change in the median for this group.

The two groups who had four sessions also completed the scales after the second of the intervention sessions. Analysis showed that there was no significant difference in MR ($T = 11$, $p = .345$), MA ($T = 8$, $p = .257$) or any of the subscales at the midpoint of the intervention (Growth $T = 3$, $p = 1$; Struggle $T = 13$, $p = .138$; Value $T = 10.5$, $p = .416$). This suggests that it was necessary for parents to experience both the MR and the mathematics methods sections of the course to achieve the desired changes in MR and MA although with such small sample sizes this was not conclusive.

When the three groups were analysed individually there was no significant difference in MR in any group, indicating that the small sample size was the issue.

9.3.3 Discussion

The review of the piloting phase of the study used process evaluation and quantitative methods to evaluate the intervention. The process evaluation of the pilots showed that the intervention was in the main delivered and received as planned. Fidelity was high according to the researcher's own records and to an independent observer. Participants were very happy with the intervention they received and felt able to access it successfully. The emphasis of the intervention varied between different groups due to the prior experience of the participants but this enhanced rather than detracted from the sessions' effectiveness. All participants received the planned core content.

The main problem identified by the process evaluation was that of recruitment. Recruitment levels to the pilot were very low although this was expected due to low levels of participation in mathematics courses for parents generally. It was noticeable that retention and completion levels of those who indicated they wanted to take part were higher in those sessions run in homes rather than a community space (Pilots 1 and 3). The researcher was able to give parents more flexibility about times in these two pilots due to not having to book the location in advance. In some cases she was also able to rearrange sessions to accommodate last minute changes to parents' schedules resulting in more parents attending more sessions. Running sessions in private homes seemed to provide a flexibility that benefited recruitment, although there are obvious issues of safety and liability. However, this study suggests that choosing a location that gives the ability to move sessions to another time or location when parents encounter difficulties attending would be beneficial to recruitment and retention in future interventions. Parents who attended the intervention said they would be happy to recommend it to others and a second means of improving recruitment may be to run the intervention repeatedly and use peer recommendation to encourage later attendees.

The reach of the pilot was not as wide as could have been hoped. The participants were all white, English and in the main employed, with fairly high levels of education. Only one participant was male. This may have something to do with the areas that the schools were in and in future a more diverse range of schools needs to be approached. However, the school involved in Pilot 2 did have a more diverse catchment area and this was the school that had the lowest recruitment level. It is therefore important to consider why parents from such schools do not choose to participate and how a more diverse range of parents can be attracted.

One aspect of the intervention that was very successful was the online community. The five participants who took part were still active in the communities in the academic year after they took part in the intervention both responding to and posting their own comments about MR. This suggests that the intervention is still having an impact although they are no longer attending sessions and that this community is an important element for future interventions.

Quantitative methods showed that the intervention had achieved the aim of improving parents' MR although not their belief in growth. This could be because parents who chose to take part in an intervention to help their children in mathematics already believe that it is possible to improve in mathematics or attending the course would make no sense. This finding could also suggest a further reason for parents not attending mathematics courses, namely that they do not believe that it is possible to get better in mathematics. Consideration needs to be given to how to remove this potential barrier.

9.3.4 Conclusions

The analysis of the pilot of the intervention suggested that it was delivered as planned and was successful in making the desired changes to parents' MR although the small number of participants means all conclusions are tentative. This meant the study could proceed to a larger controlled trial. The format of intervention suggested by this analysis was a two session course with both MR and mathematics methods since this was seen to be long enough to bring about a change in behaviour but flexible enough to enable participants to attend all sessions.

9.4 Phase 2: Online Survey into Parents' Preferred Form of Intervention

After the low uptake from parents in the intervention pilot an online survey was conducted to investigate whether there was a form of intervention that would be more likely to encourage a wider range of parents to attend. This section describes the results of that survey.

9.4.1 Methodology

An online survey was conducted using the BOS online tool. Recruitment and participant details can be found in Sections 3.5 and 3.6.9. The questions were as follows:

1. What year/years are your children in?

2. Would you be prepared to attend any of these sessions to support you in helping your child with maths if there was no cost to you?

3. If you were going to attend a session where would you like it to be held?

For each question options were given and more than one option could be selected. Reasons for the answers to question 2 were required. Participants' consent was sort using a check box in the introduction to the survey. Three participants did not tick this check box and their responses were excluded from the research.

9.4.2 Results

The first part of the survey considered how parents would like to access support in helping their children with mathematics. Parents could choose as many of the options as they would be likely to use and were then asked to give a reason for their choices. The most popular way to gain information on how to help was an online course (41/55 parents) (see Figure 9-1). The main reason given was that “online you can do it in your own time”. This was seen as positive both to enable it to be fitted around other commitments such as “child care” and “busy lives” and also to allow parents to complete the course “without rushing”. Given that these parents filled out the survey online it might be assumed that an online course would be something they felt confident to access but this may not apply to all parents. The second most popular option was one 90 minute session on how to help your child with maths (23 people), closely followed by two 90 minutes sessions on the maths techniques your child learns in school (22 people) and the original four 90 minute sessions format (19 people). Several parents suggested in the comments that a “flexible online option would be good to support a couple of more structured sessions” or “online learning maybe followed up by a questions and answers session”.

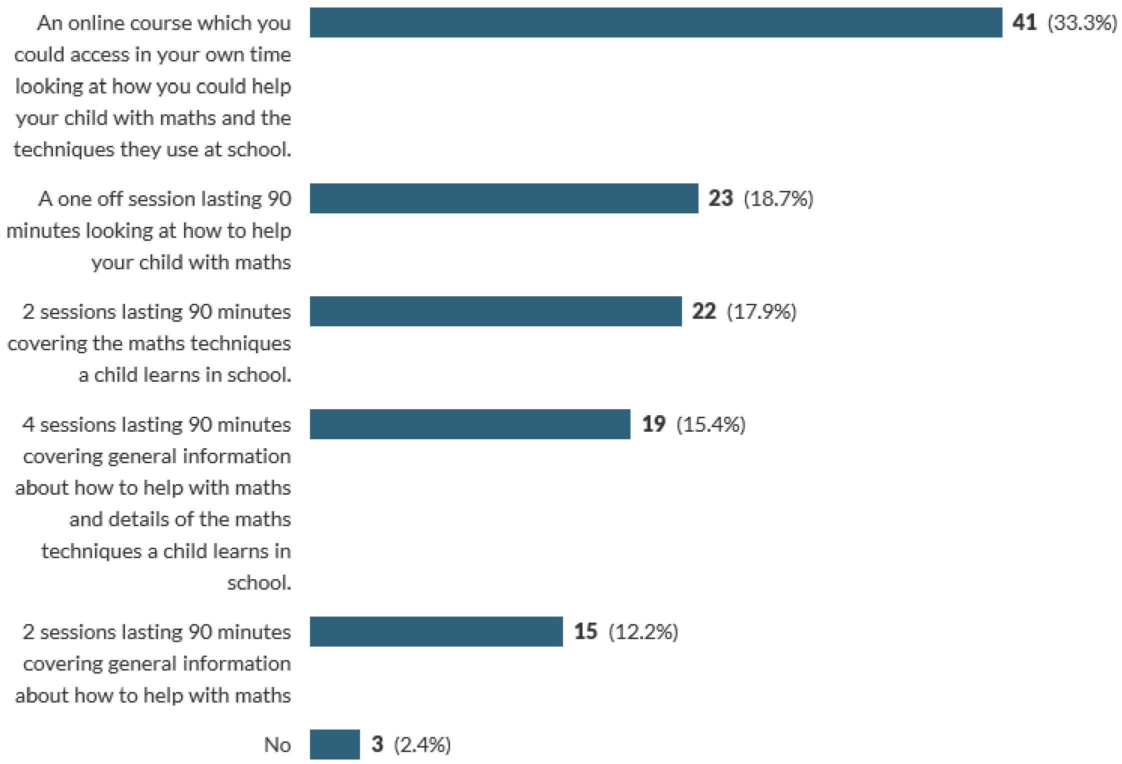

Figure 9-1 Parents Views on Intervention Format in Study I

During the initial pilots of the sessions it was noted that all of the parents who came to the sessions had older children as well as the Year 1 child that made them eligible to take part in the sessions. It was hypothesised that it may have been experiences with their older children that had encouraged them to sign up to the sessions and this may have been why there was a low uptake among the Year 1 parents generally. In order to investigate this hypothesis the participants' responses were considered by the age of their oldest child. From Figure 9-2 it can be seen that there is some difference in the willingness to attend courses of parents with older children and those with younger, namely that those with children in Year 1 or below were most willing to attend a two session course on maths methods rather than a longer or more general course. However, these differences do not appear big enough to suggest that it was only having older children that encouraged a parent to attend courses.

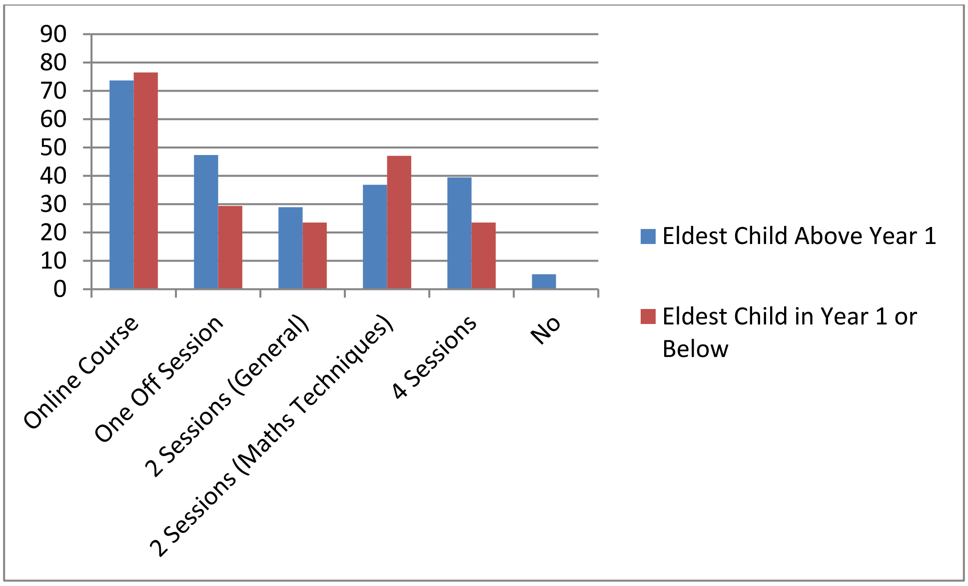

Figure 9-2 Percentage of Parents Willing to Attend Different Formats of Course by Age of Oldest Child

Figure 9-3 shows details of the parents' preferred locations for attending interventions.

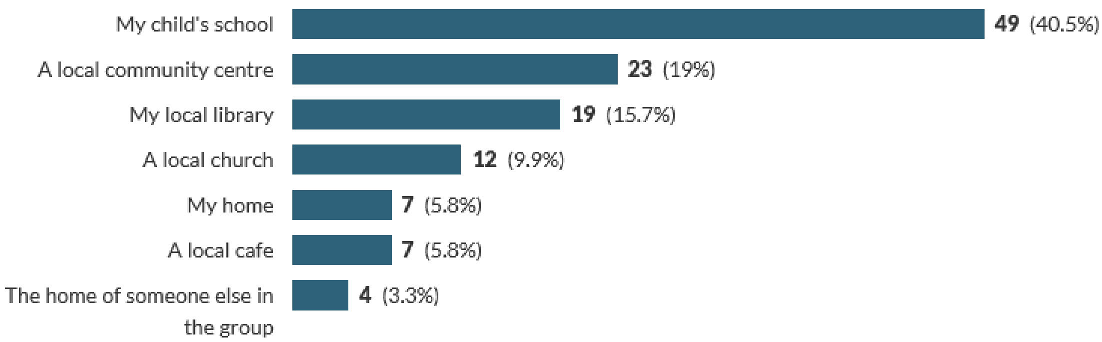

Figure 9-3 Graph to Show Preferred Locations for Interventions

As can be seen the child's school was by far the most popular location. A local community centre or library both also received a reasonable amount of support. Parents were not keen to participate in a course in a private home or café.

9.4.3 Conclusions

The results of the online survey suggest that fewer sessions, possibly with an online element would be more attractive to parents. These sessions should be located in a school or community setting.

9.5 Conclusions from Phase 1 and 2

The data gathered during the pilot suggests that an intervention involving teaching parenting for MR has a significant positive impact on the parents' own MR and thus merits further investigation. No clear conclusions could be drawn about the length of this intervention but it was decided to adopt a two session format in order to appeal to more parents and aid recruitment. Since no convincing evidence had been found over whether it was necessary to teach MR and mathematics methods it was decided to trial two different intervention groups in the follow up study, a MR only group and a mathematics methods and MR group.

9.6 Phase 3: Randomised Control Trial of the Intervention

An attempt was made to conduct a randomised control trial of the intervention (Study J) but recruitment was so problematic that no conclusions about the effectiveness of the intervention could be drawn. The data from the control group is discussed in Chapter 7.

9.7 Conclusions

This chapter has described the three phases of a study into the efficacy of interventions which use the concept of MR to improve parental engagement with mathematics. Whilst the pilot and online study suggested such an intervention had promise, the randomised control trial had to be abandoned.

The main outcome of the study described in this chapter was to provide further evidence for the difficulties of running interventions for parents, particularly around recruitment. This problem persisted despite efforts to make the process as flexible for parents as possible. It is therefore suggested that research is undertaken to further understand and improve recruitment of parents to interventions to help children with mathematics. The aim should be to understand how more and more diverse parents can be encouraged to attend. It is also suggested that the extent to which parents possess a growth mindset about mathematics is considered when assessing their likelihood to take part in an intervention.

The study has also highlighted the importance of process evaluation in intervention trials particularly in giving insights into why interventions have not worked as expected. It is suggested that all future intervention trials use process evaluation for this purpose.

The quantitative analysis of the data in the pilot suggested that, if recruitment issues could be overcome, the intervention showed promise as a means to improve parents' MR. Qualitative data also showed that the intervention had promise for changing the way parents worked with their children on mathematics. Some of this information, in the form of two case studies, is presented in the following chapter.

Chapter 10 Illustrative Case Studies Resulting from the Intervention Pilot

10.1 Chapter Summary

This chapter discusses two case studies, one of a mother and the other of a couple, who improved the way they worked with their children on mathematics after attending the intervention described in Chapter 9.

10.2 Introduction

During the intervention pilot discussed in Chapter 9, the cases of three participants and their children stood out as illustrating the benefits of teaching parents about MR and the potential for success of the intervention. These cases are included here as an illustration of the qualitative changes that the intervention brought about. All names have been changed and all identifying markers have been removed in relation to the parents, children and schools.

10.3 Case Study 1

This case study focusses on a mother and son dyad ("Jacky" and "Tom") who are taken together as a single case. The focus is on the interactions between the two, how those interactions affect the son's experience of mathematics and the effect of the intervention on the pair and how they work together on mathematics.

The case study relies on data collected from the mother, Jacky, in the form of questionnaires and reflective diaries before, during and after the intervention and from conversations that Jacky had with the researcher and the other members of the group during the intervention. These conversations were recorded on video and transcribed with the permission of the participants. Jacky was asked for and gave permission for data about her and her son to be used in this thesis.

10.3.1 Jacky and Tom's Story

Jacky took part in a pilot of the interventions. At the time Tom, Jacky's third child, was in Year 1 and her older children were at university and in Year 11. Jacky worked full-time in a professional career. She explained that she chose to attend the intervention because although she felt confident in her own ability in mathematics and generally enjoyed it:

> I don't think I've really been constructive in any of the help I've given any of my children because as soon as they don't get it I've lost the plot really. Because I think it's so simple.

She felt that having brought up two children already she would "like to think I'm gonna (sic) be much more constructive with Tom, I've got the third one to try on now." but that having loved mathematics herself at school she did not understand why her children struggled:

> Well I, I, (sic) no I can't get it at all, because I just can't understand why they don't one love maths, and two why they can't do it.

When she started the intervention, Jacky reported that Tom disliked mathematics and, according to his teacher, he was working towards, i.e. he was below the expected level set by the Testing and Standards Agency. Her attempts to work with him on mathematics, usually when she tried to help him to do his homework, often led to frustration on both sides:

> I think the thing that I get so frustrated because I don't think I can explain it well enough and then I think, it's so simple. I have no, I have absolutely no empathy with my children, any of them, that have not been able to do maths cos I'm like why can't you just do it?

She also related how she worried that other children and parents were finding it easier than them:

> I'm thinking can other children do these? Is this just that it's not pitched at the right level for Tom or does he just not get it? So I'm sometimes sort of sitting frustrated thinking everyone else's parent is flying

> through this with their children. It's either mine or I am just expecting too much really.

She frequently found it difficult to get Tom to do his homework:

> He just doesn't like his pen and a maths book and anything you know even, even (sic) some of the more boy things that you would expect, like the measuring, you know we were doing all that find objects and measuring, he was rolling his eyes. I think he found that just so simple.

but felt that she had to force him to do it in order to please the teachers:

> The problem is I am so like, I, I (sic) suppose cos we get told off for not doing homework cos he refuses, I'm so pushing him to do it that's, that's (sic) where the battle is, because it's a school where having had two children that have already been through it, it is is (sic), it is a great school and I love it there but I do think you've got to have a great relationship with the teachers because as soon as you've got anything that's not, you know. I would worry about not being in that zone, erm, and maybe seeing a parent as not supporting the school, which I am a parent who supports the school, so I do really push him.

This led to an unpleasant atmosphere at home when homework had to be completed, with both Jacky and Tom feeling anxious and stressed:

> I think that's where I'm getting wound up more than he is and then he's getting wound up cos I'm wound up. *Just do it.*

She described how this conflict meant that homework was frequently left until the last minute and how this made things more difficult as Tom was tired or they did not have the necessary equipment to hand. She was aware that this was a problem:

> I need to probably pick my moments a little bit better, rather than leaving it to the last minute, but I think it's cos I dread it.

During the intervention, Jacky was encouraged to think about working on mathematics with her son in a different way. She was introduced to the concept of mathematical resilience and the growth zone model (Lee and Johnston-Wilder, 2017). She was encouraged to see her role when working with her son on mathematics as about making it fun and relevant and that completing mathematics homework was her son's role rather than hers - her role was to facilitate the activity. In the language of MR she was encouraged to provide the *resources* to make sure that homework could be completed; promote her son's *value* of mathematics by showing that she was interested in it and then step back to allow him to *struggle* with his homework and thus recognise his own *growth.* In order to do this she was encouraged to give her son control over his own learning by allowing him to make choices about when and how he completed his homework, even if this was just a choice between which of two times he would complete it and to make sure that these times were not too near to the homework deadline. She was also encouraged to spend time doing fun mathematical activities with Tom rather than only talking with him about mathematics when she was forcing him to complete homework.

In her reflective journal at the end of the first week and in comments in the second session, Jacky reported that the intervention had already begun to change the way she was working with her son. She was "trying to plan when to do work, don't put ourselves under pressure to complete at last minute". She had also decided that mathematics should be more fun and "not a chore". She detailed how this had already had an effect as they completed the mathematics homework for that week together and then went on to play a mathematics game:

> I just sort of said "just being as like we've got quite a bit to do, erm, and it might be better to just do some rather than leave it all to later" so he did choose the maths and we did do the maths and the maths was really easy this week … but we did, so a game that I think I wouldn't have done before. Just, er, a numbers game that , em, that it wasn't a distinct game with numbers but it was just something that actually I

> thought do you know what, he's using numbers here, let's just go with this ... do you know what I would never have done that before.

In her reflective journal after the second week's session Jacky reported using practical measuring items with her son to further his knowledge of mathematics. She also reported that she was trying to take a step back from her son while he was doing his homework reporting in her reflective diary that she "used timing/resources & moving away to promote independent learning".

Another thing that Jacky experienced during the intervention that she had not encountered before was struggling in mathematics in the way that her son was. As she was introduced to doing sums in the way that her son was being taught at school, she experienced the feeling of learning mathematics for the first time in a way that she had not done since being at school herself. She expressed dislike for some of the methods but was encouraged to try them anyway and admitted feeling confused and lacking in confidence in her answer. When asked to reflect upon what she had felt she said:

> I was, even though we're doing the same sum and I was like recognising the numbers, I was thinkin (sic) was that right?"

Jacky also acknowledged that there were some of the methods that she did not like and that she was making mistakes:

> I started from the wrong end

This insight allowed Jacky to develop an understanding of what she had felt frustrated with her son about at the start of the intervention, namely how someone could struggle with relatively simple mathematics.

These new insights and approaches to working on mathematics together quickly proved successful. In the fourth and final session, Jacky reported how in the previous week she had been surprised to find that Tom had voluntarily completed his homework by himself:

> While I was away, cos I'm the only one that does his homework with him, and when I came back at the weekend he said I've done my homework, my maths. I said you're kidding. That doesn't happen.

She also reported how she dealt with an error he had made differently:

> He just wouldn't let me help at all. I said "well shall we have a look at that one?" No. So I went well that's fine then.

When asked to explain why she had done this she replied that:

> I thought I'm not goin (sic) there, I'm not gonna (sic) upset you. I can't. Happy place.

When the researcher asked if this was because he had done them all himself Jacky replied that:

> Yeah it was that I didn't want to discourage.

Her emphasis had changed from valuing accurate completion of homework to valuing Tom's agency in and enjoyment of mathematics.

10.3.2 Discussion

This case study describes a parent who on the surface was well placed to help their child with mathematics. However, prior to the intervention Jacky was not achieving the type of parental engagement necessary to benefit him, in fact she was contributing to her son disengaging from mathematics entirely. Participation in the intervention led to a change in the dyad's interactions around mathematics which in turn led to the son voluntarily taking charge of his own learning. This change occurred over the course of the four session intervention. Figure 10-1 shows how the intervention is theorised as having affected the pair's interactions around mathematics, moving the mother's actions from a negative version of parental involvement to parental engagement and the son from the Red or Danger Zone to the Growth Zone (Lee and Johnston-Wilder 2017).

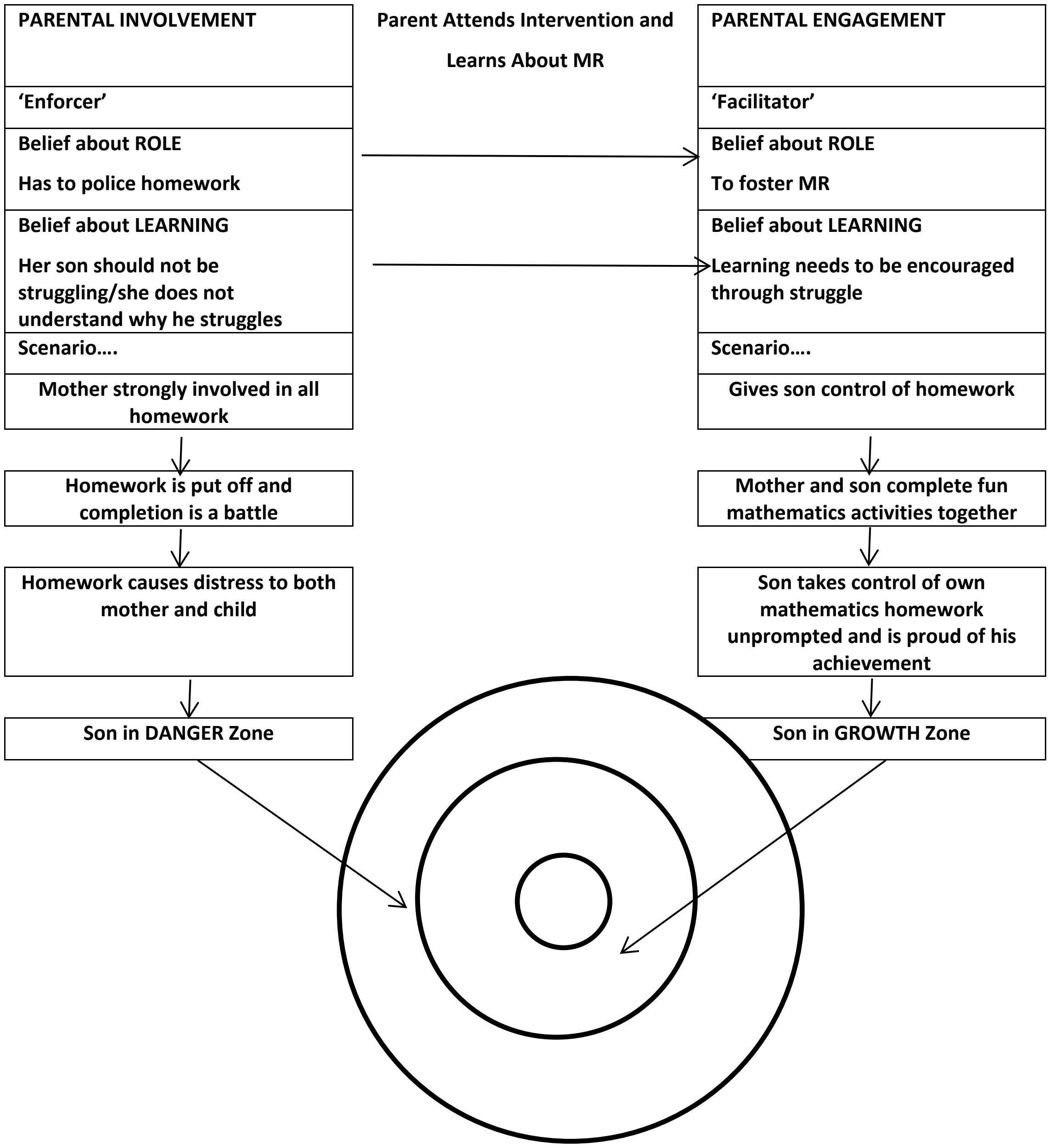

Figure 10-1 Diagram to Illustrate the Effects of the Intervention on the Dyad

When the researcher initially met Jacky she lacked agency to help her son with mathematics. As a person who had never struggled with mathematics herself, she lacked understanding about why he was struggling and how she could help. She was also restricted in her ability to help by her belief that the school was the authority on her son's learning. Initial conversations with Jacky showed that she felt strongly that it was her job to ensure her son met the school's expectations of him and she demonstrated a great deal of anxiety about this role. As long as Tom's homework was completed correctly, Jacky felt she had done her job - but this was proving very difficult to achieve. Although Jacky was clearly involved with her son's schooling she was not truly engaged with his learning, and this involvement, rather than engagement, was actually proving detrimental because she was restricting Tom's agency over his own work. In making sure that he did his homework she was not giving him the opportunity to take ownership of it and Tom showed strong resistance towards engaging with his mathematics homework. This situation led to feelings of tension around mathematics in both mother and son and led to them both procrastinating, rather than completing homework in a timely way, and a disinclination to do any mathematics that was not homework.

During the intervention, Jacky was encouraged to move from merely being involved in her son's schooling to actively engaging with his learning. She was encouraged to do this by helping him to develop his MR. Jacky was not a teacher and as she said herself she often did not understand why her son was stuck or how she could help him. By removing the focus from teaching and enforcing behaviour and instead emphasising the need to foster MR, Jacky was able to move along Goodall and Montgomery's continuum (Goodall & Montgomery 2014) and become actively engaged in his learning.

When encouraged by the researcher to concentrate on building MR in her son rather than policing his homework, the mother reported a significant change in her son's attitude to mathematics homework and to their relationship around mathematics. For the first time, Tom voluntarily took control of his own homework. He decided when to complete it and worked independently of his mother. Jacky, in turn, recognised and reinforced the agency Tom demonstrated by allowing him to make mistakes and wait for feedback from his teacher rather than insisting he correct errors before handing his homework in.

By thinking about how she could foster his MR, Jacky was also able to encourage Tom to engage with mathematics in new ways. For example, Jacky recalled that when Tom was given a weighing and measuring activity for homework, he was completely disinterested. When she presented him with a similar activity that could be completed in a practical way and which, presumably, took account of Tom's likes and dislikes, he really enjoyed it. Jacky combined her knowledge of Tom's interests with her new understanding of MR to help Tom explore mathematics in ways he enjoyed.

10.3.3 Conclusions

This case study illustrates the effectiveness of the intervention in bringing about a positive change in the interactions of mother and son around mathematics. After taking part in the intervention Jacky and her son were able to engage in mathematics more productively and with less stress on both parties. The study demonstrates how parents who are confident with mathematics can still encounter problems helping their children with the subject and how the intervention can help them to overcome these. Although these problems are different from the ones faced by parents who are mathematically helpless or challenged by mathematics, the study supports Goodall and Johnston-Wilder's (2015) suggestion that the problems of both groups of parents could be addressed through MR, rather than purely through mathematics methods education. Although an individual case study cannot be generalised, this case adds support to the other data collected in the pilot study and suggests this intervention has a positive effect on parental engagement around mathematics.

10.4 Case Study 2

This case study focusses on a couple where the mother ("Linda") and father ("Michael") both took part in an intervention. The focus of the study is their experience of the intervention and the impact it had on them afterwards.

The data for the case study were the interactions the researcher had with Linda and Michael during the intervention, the reflective diaries that they filled in and the posts that they made on the Facebook group after the session. Both Linda and Michael were asked for and gave their consent for their data to be used in this thesis.

10.4.1 Linda and Michael's story

Linda and Michael both asked to come along to one of the pilot intervention sessions and volunteered to hold the session in their own home when it became hard to arrange another venue. At the time of the intervention they had two children, one of whom was in Year 1. Whilst Linda was reasonably confident with mathematics, Michael was less confident. Both said they disliked mathematics but Michael stated that he hated the subject and was nervous about attending the sessions. Both were unsure about the mathematics their children would be doing at school and how best to help them. The school did not send home mathematics homework. This meant they had little idea how to help their children with their mathematics education.

During the intervention they were introduced to the concept of mathematical resilience and to some of the methods that their children would be using in school. Michael spoke of his own experiences with mathematics and related them to the concepts of MR, particularly the concept of flight, fight or freeze, that the group was discussing. He began to see that a lot of his experiences around mathematics had been based on fear and this may have been connected to his dislike of the subject. He was keen that his children did not have the same experience of mathematics. Over the two sessions he began to grow in confidence that he could do mathematics in the right circumstances and to realise that he did now use mathematics in his job although he did not think of it as such. At the end of the two sessions he said that he would be very keen to attend more sessions if they were offered, in marked contrast to his earlier nervousness.

In the weeks following the intervention both Michael and Linda began to incorporate tips that had been discussed in the sessions into their children's lives. They recorded these on the Facebook group. Their posts included a find of the mathematics game Smath at the local charity shop and a photo of their children playing a mathematics game called Shut the Box, both of which had been recommended in the intervention. They also showed a mathematics 'puzzle' that they had got their children to figure out at dinner – they only had 5 blueberries left and the two children had to work out how many they got each. There were pictures of both their children doing mathematics on a blackboard, one of which was entitled "maths is cool" and of the family playing other mathematics games together.

Michael later wrote about the impact of the intervention on him and their family:

> … this project is brilliant and you are doing amazing things. We have got so much out of it and you have helped someone (me) who hated maths to really engage and start to enjoy it and that is being passed on to our children. We are using your techniques daily.

Linda was also positively influenced by the intervention sessions. She purchased and read a book called "Great Minds and How to Grow Them". She sent this message to the researcher via the Facebook page about how she was spreading the advice she had received:

> I was on a graduate induction day today and one of the graduates told me he "wasn't good at maths" and this had influenced his choice of degree. I told him about your course and (Michael's) experiences with maths etc. He said I had given him a lot to think about and I think he went away feeling a bit more positive about himself.

The intervention led Linda and Michael to begin to incorporate mathematics into their children's lives in a fun and continual way. They felt empowered and knowledgeable in playing a role in their children's mathematics education that they had not been able to take before.

10.4.2 Discussion

This case study describes a couple, one of whom disliked mathematics and felt unable to help his children in the subject and the other who, though capable of doing mathematics herself, was not sure how to help her children. Participation in the intervention led to a marked change of attitude in the father in particular. He lost his own fear of mathematics and was able to become engaged in and enjoy the subject. Importantly he began to pass this new attitude towards mathematics on to his children. The mother also discovered ways in which she could engage with her children in mathematics that did not rely on the school sending home homework. Both parents became keen advocates of parents supporting their children with mathematics and volunteered to endorse the course to others and were very keen to attend future sessions on how they could help.

The case study describes a couple who lacked agency in helping their children in mathematics due to a lack of information and to bad experiences of mathematics respectively. The intervention gave both the agency to help and provided support and encouragement in doing so.

10.4.3 Conclusions

This case study shows that the intervention was successful in overcoming the effects of bad experiences in mathematics of one parent whilst at the same time providing the information needed by the other. After taking part in the intervention both parents were taking a much more active role in their children's mathematics education and became advocates for the importance of mathematics. Although an individual case study cannot be generalised, it adds support to the other data from the pilot for the efficacy of the intervention at improving parental interactions around mathematics.

10.5 Conclusions

These case studies both illustrate the effectiveness of the intervention in encouraging three parents to support their children in mathematics. In a wider context, they, along with the study presented by Goodall and Johnston-Wilder (2015) illustrate that without support parents can often find it difficult to engage with their child's learning effectively, either spending time involved in their child's learning without actively engaging or refraining from becoming involved altogether. The parent in Goodall and Johnston-Wilder's case study was struggling through her own lack of agency in learning mathematics, as was the father in Case Study 2, whilst the two mothers presented here possessed agency but were unsure how to help their children effectively. Despite the different problems they were facing, learning about MR provided a means for all four to work through them and begin to engage positively with their child's mathematics learning. Recommendations for successful parental engagement activities suggest that they need to be flexible and adapt to the needs of different parents (Campbell 2011, Goodall & Barnard 2015, Goodall et al. 2011) and thus teaching about MR, a concept that has been shown to work with parents with vastly different problems, seems one which is worthy of further research. In particular the intervention discussed here seems to provide the opportunity to support parents who are confident in mathematics alongside those who are less confident.

The case studies highlight that it is both mathematical techniques and approaches to working together with their children on mathematics that parents need to learn. Jacky, Linda and Michael reported large attitudinal and behavioural changes when they learnt about MR and had the experience of learning mathematics again themselves, even though the interventions were brief. If schools incorporated MR training into their mathematics information sessions for parents, this could be a cost-effective way to support parents to engage with their children's mathematics learning more readily and positively. The conclusions therefore echo Goodall and Johnston-Wilder's (2015) recommendation that schools should embrace the development of and knowledge about mathematical resilience in their communities as a core value and an essential tool to support parents, whatever their level of mathematical ability, and hence, improve mathematics outcomes for children.

The case studies also suggest that schools should carefully consider the roles of parents in helping with mathematics and whether parents are clear about what is expected of them. In the first case study, Jacky very clearly saw her role as acting as an enforcer of homework, so "they" did not get into trouble with school, and this prevented her and her son from engaging positively around mathematics and developing his MR. In the second, Linda and Michael did not know how to help their children because they had not been told what they were doing by the school and as they did not receive mathematics homework they never saw what they were working on. Key advantages of the present intervention and that reported by Goodall and Johnston-Wilder (2015) were the opportunities for researchers to listen in detail to difficulties and successes and allow parents to discuss and think through their problems and experiences in the light of information about MR. This suggests that schools need to determine their home learning policies alongside the evidence for developing MR and to promote open, honest dialogues with parents about learning.

Schools should ensure that parents are clear that the goal is not perfectly completed homework at any cost; rather developing MR should be the aim of any interactions parents have with their children around mathematics at home. It is recommended that facilitating this dialogue about how parents can best help at home and how schools can assist them in helping, as well as providing clear communication regarding homework expectations, should be key elements of focus for schools when considering the role of parental engagement.

Chapter 11 Discussion and Conclusions

This research project has evaluated the development and impact of mathematical resilience on the performance of children in mathematics using both qualitative and quantitative research on a cross-sectional and longitudinal basis. It is the first comprehensive review of mathematical resilience and performance in children as young as Year 1, facilitated by the development of the first scale to measure MR in this age group. An intervention has been developed that has shown success in changing the behaviour of parents when helping their children with mathematics.

Mathematical Resilience (MR), first written about by Lee and Johnston-Wilder in 2010, is a relatively new way of considering affective elements of learning mathematics. To date it has been used mainly with older students and little research has focussed on how MR develops. Much of the research on MR has been qualitative and anecdotal in nature, opening it up to claims of lack of rigour and replicability and making it hard to generalise findings. Whilst this type of research is undeniably relevant - qualitative and anecdotal evidence is vital for understanding lived experiences of learning mathematics - it is also important that such evidence is viewed in tandem with quantitative data, since the success of mathematics education is itself in the main measured quantitatively. This thesis has contributed to the development of such evidence.

MR has three separate aspects: growth, struggle and value. Growth is the belief that it is possible for everyone to get better at mathematics. Struggle is the belief that everyone finds mathematics difficult at times – this is a normal part of learning mathematics – and the possession of strategies and internal resources to deal with such difficulties. Value is the belief that mathematics is important, not just as an abstract concept but directly in the learner’s own life. During this study findings about the three different aspects of MR have differed and thus throughout this conclusion they will be discussed separately as well as combined together into the overall construct MR.

The first major contribution this thesis has made is the development of the Baker Children's Mathematical Resilience Scale (BCMRS). This scale enables the MR of Year 1 children to be measured for the first time. Chapter 4 details the process undertaken to ensure that this scale is valid, reliable and usable with young children. Through its use in the studies detailed here, the BCMRS has been found to be valid and reliable over time, although caution should be used when interpreting the growth subscale results with children at the very start of Year 1. However, the subscale has been found to be reliable with older Year 1 children, and with older primary children in the studies described in Chapters 5 and 8. The BCMRS is unique in MR scales in allowing an overall level of MR to be calculated. This overall level has proved reliable over time. The development of this scale gives the potential for future research into the development of MR and its effects on children throughout their school career.

The second contribution made by the thesis is to provide the first evidence of links between MR and performance in Year 1 children as discussed in Chapters 6 and 7. Whilst the Chapter 6 study looked at performance as measured by class teachers, the study discussed in Chapter 7 used a standardised performance measure. Both studies showed positive links between MR and performance by the end of the year. In Chapter 6, children who were working below or towards expectations had the lowest levels of MR and belief in growth, although they did have the highest belief in struggle. In Chapter 7 MR and growth were both positively linked with scores on the standardised tests and initial MR was correlated with final scores on the mathematical reasoning subscale with those who had higher levels of MR at the start of the year scoring more highly. It is unclear how much teacher assessed levels vary from children's actual performance level in mathematics, some research suggests that teachers' assessments are not always accurate (e.g. Watson 2000). In practice, however, it is an individual's ability to perform well in a test situation that determines their mathematical outcomes rather than the teacher's view of them. Therefore the fact that overall MR and growth are correlated with a standardised performance measure is strong evidence for the claims made in this thesis and by Lee and Johnston-

Wilder (2017) that the development of MR, particularly growth, in children could help to improve their performance.

The thesis also contributes evidence about the development of MR in Year 1 children. When considering how MR develops, the study in Chapter 6 found that patterns of change in MR differed in different schools and that initial teacher assessed levels were linked to final struggle scores, when initial struggle levels were controlled for. This suggests that the experience that a child gets in the classroom may impact on how their MR develops. During the course of carrying out this research and more widely in her teaching career, the researcher has observed differences which may have some impact on the development of MR. For example, when talking to a particular teacher about the current research, the teacher remarked that there were 'maths children' and children who could not do mathematics. This attitude would potentially affect how she treated the two (in her view) differing categories of children as opposed to how they would be treated by a teacher who believed both groups were equally able to do mathematics, and this may impact the development of the children's own belief in growth. Some schools are also actively trying to promote a growth mindset to education in general and this will possibly affect the development of their children's growth beliefs about mathematics. Similarly, in some schools teachers are seen to step in very quickly to help children when they begin to struggle whilst in others they are left to struggle for longer. This may impact upon their belief that struggle is necessary in mathematics, and, depending on the type of support they are given, restrict their ability to develop their own resources to help themselves when they are struggling. The correlation between initial teacher assessed levels and final struggle scores found in Chapter 6 suggests that the teacher's assessment of how a child is performing may also directly influence their belief in struggle. It was hypothesised in Chapter 6 that this may be through their choice of work for children at each level. Further investigation of which differences in a classroom are leading to these differences in the development of MR is required in the form of mixed method studies of classroom practice that look at which actions on the behalf of teacher's are linked to the development to MR. This is particularly important since the positive correlation between MR and standardised performance found in the Chapter 7 study indicates that schools in which MR is not being developed to as high an extent are at risk of their children performing at lower levels in mathematics.

The Chapter 7 study compared correlations between MR and other attitudes to mathematics and performance and found that MR was more strongly correlated with performance than the MAAQ in Year 1 children. It found no correlation between MA and MR suggesting it is possible to be mathematically resilient even whilst being anxious about mathematics. This is an important finding because it suggests that the protective factor MR can potentially be present at the same time as the risk factor MA and future research should look at the interaction of these two factors. It is possible that MR could act as an insulating factor for the negative effects of MA as proposed in Chapter 2. MR was also found to correlate with self-rated confidence and enjoyment in Chapter 5, which have both previously been associated with higher performance levels (e.g. Dowker et al. 2019). This reinforces the claims of this thesis that MR is a useful concept when considering the effects of attitudes to mathematics on performance.

On a task specific basis, the study described in Chapter 5 provides evidence for links between higher levels of MR and more complex problem solving strategies. Those children who had higher levels of MR were more likely to create their own mathematics rather than replicate familiar sums and to use a more optimal strategy for solving the problem. This provides evidence to support the claim that children with higher MR are better equipped to 'struggle' at mathematics – that is to know how to approach difficult problems in mathematics. The Chapter 5 study also failed to find a correlation between MA and MR, again suggesting that MA individuals could use MR to achieve success despite their anxiety.

All of these studies support Johnston-Wilder and Lee's claims (Johnston-Wilder and Lee 2010a and b, Lee and Johnston-Wilder 2017) that improvements in MR could lead to improvements in performance. In order to investigate how such improvements could be brought about the microsystem in the ecological model (Bronfenbrenner), in the form of interactions with parents, was considered in Chapter 8. The Chapter 8 study provides evidence of a link between a parent's belief in growth and their child's MR, namely that children of parents with a lower belief in the ability to get better in mathematics had lower overall MR themselves. Given the links between MR and performance found in the previous studies, this suggests that children of parents with a lower belief in growth may perform less well in mathematics. Interestingly parental MA was not correlated with a child's MR in this study, indicating that parents who are anxious about mathematics can still have mathematically resilient children.

The second important finding from the Chapter 8 study was that a parent's MR was correlated with how they interacted with their children. Those parents who had a greater belief in struggle were more likely to encourage their children to struggle for longer. Those who had a higher belief in growth were more likely to offer strategies to their children for working on the problem rather than being generally encouraging. Although this study took place with parents who were obviously interested and involved in their children's education, having brought them to a psychology event at the university in the summer holiday, it is notable that there were still a wide range of strategies used to help children and that those who were using better scaffolding techniques were those with the highest MR. Willingness to help children does not necessarily give parents the corresponding skills to do so but the presence of MR seemed to be linked to the possession of them in this study. Interestingly there was an association between low levels of parental MA and low levels of parental engagement on the task. This suggests that in order for parents to provide encouragement to their children it may be necessary for them to possess a moderate amount of MA.

Given the links between child performance and MR and between parental MR, effective supporting behaviours and child MR it was concluded that an effective intervention to improve parental MR could have a positive impact on performance. An intervention based on these principles was developed. Although links with performance could not be evaluated due to the small number of participants recruited and the short time scales involved, qualitative evidence of the changes in behaviour of parents who participated and their enthusiasm for the project suggest that the intervention has promise. The aspect of the intervention that proved most useful was giving the parents the opportunity to discuss the problems that they were having with their children around mathematics and empowering them to become partners in their child's mathematical education rather than feeling they were working alone to implement the school's, often unknown, expectations. The opportunity to review their personal relationship with mathematics and re-evaluate it through the lens of MR was also crucial.

Having said this, it is undeniable that the intervention was not successful in attracting participants. The researcher did not manage to overcome the barriers to parental engagement that were discussed in Chapter 2. Given the findings about parents and the development of MR in Chapter 8 it seems even more important that means are found to engage with and form partnerships with parents. This is of particular importance with so called hard to reach parents – the uptake of intervention sessions in schools with lower socio-economic backgrounds and a higher proportion of families with English as a second language was far lower than in the more affluent, white British areas in this study. Serious considerations needs to be given as to how to engage these parents and research into what such parents want in the way of support and how it could be provided is long overdue.

The current research also suggests a further barrier to parents participating in a mathematics intervention - a low belief in growth. Belief in growth was the only factor not changed in parents by the intervention and the parents that took part already had fairly high growth scores. This opens the possibility that parents are not participating in mathematics interventions because they do not believe that it is possible to get better in the subject. Therefore it would make no sense for them to attend an intervention to help their children improve in mathematics. It is suggested that further research is done into this possibility.

Finally it is necessary to return to the point raised in the introduction about the tension between qualitative and quantitative evidence, between the individual's lived experience and the schools' needs for results. When a teacher plans their teaching for the year, they are motivated by two, sometimes contradictory, aims. The first is to get the children to attain the level that the school requires them to during that year. This level is not always related to the child's previous attainment. The second is to prepare them for their future mathematical career. Unfortunately in the current climate, where teachers generally only stay with children for a year at the most, and their pay is linked to performance against numerical targets over that year, it is all too easy to focus on the former at the expense of the later. The researcher herself has felt this temptation as she returned to the classroom during the course of this PhD. It is possible to teach a child to answer certain types of question and succeed in mathematics without them developing MR. This is particularly true with children who have already attained the level expected and can thus be largely ignored by the teacher while they focus on those who can be moved from one level into the next. It is also hard to develop the MR of children who are never going to reach the expected level during the current year; the temptation here is to give up on them as they are not going to improve your statistics. The only way to overcome these problems is to begin to value children's preparedness for the mathematics they are going to encounter in the years ahead as well as their current performance level. The monitoring of MR may be one way in which this can be done. It is essential that further research is undertaken across the school lifespan to see to what extent early performance and early MR both contribute to later performance and to confirm the links between MR and performance. This research should include quantitative measures of performance and MR but should also qualitatively analyse the experiences children are having in the classroom and the messages they are receiving from their teachers and the impact they are having.

This thesis has supported claims that the improvement of MR amongst children could improve performance in mathematics. However, as with much affective research there are many factors affecting performance and the use of the concept of MR in isolation is not a golden bullet to fix the problems in mathematics education. Other attitudes, such as those measured by the MAAQ also have an impact. Where MR does have an advantage is in the ease in which it can be explained to parents and children alike, and in the direct practical applications of the concept. In the intervention study parents were quickly able to understand the concept and view their own experiences with their children in the light of this new knowledge, which in turn gave them the ability to change the way they themselves viewed mathematics and the way they worked with their children. The case studies provided here support a previous case study (Goodall & Johnston-Wilder 2015) in showing what dramatic effect learning about MR can have.

11.1 Recommendations

At the start of this thesis the researcher stated that she had long felt the "rightness" of MR as a theory. The studies carried out provide evidence that MR is measurable across the school age range and that the presence of MR is positively linked with performance. A means to measure MR from the time children start formal mathematics education has been developed and this gives the possibility of a large scale longitudinal study following children throughout their school lifetime and looking at the impact of MR on their outcomes. This is strongly recommended given these findings and the work of others on MR which has been discussed in this thesis.

The author also recommends that efforts to find means of reaching out to parents who are reluctant to engage with schools around mathematics education are developed and feels that a large scale study into more effective means of engaging parents is overdue. Once better methods of engagement are identified, an intervention involving both learning about MR and parents participating in mathematics activities themselves is strongly indicated as an effective way of helping parents to work more effectively with their children around mathematics.

Schools should take several recommendations away from this research. Firstly it is important that they think about whether and how they are conveying to their pupils that they are good or bad at mathematics. Belief in the ability to get better in mathematics is linked to performance and if some children are given the message that it is not possible for them to get better their performance level may be restricted. Secondly schools should consider whether they are providing children of all levels with work that requires them to struggle with mathematics, as again this is linked with performance. Finally schools should consider developing much stronger partnerships with parents around mathematics education. The case studies presented in this thesis suggest that parents struggle to understand and negotiate the expectations they believe the school is placing on them. Parents are keen to be involved in their children's mathematics education but without the correct guidance from teachers, in tandem with an understanding by those teachers of the problems parents encounter when working with their children on mathematics, this interaction can have negative rather than positive consequences. It is highly recommended that schools open a dialogue with their parents about mathematics as both sides will benefit from what they learn.

This thesis provides hope for those parents who do not feel they can help their children with mathematics effectively. The recommendation for them is that it is not always the correct answers and techniques that children need help with but that supporting them in learning to approach mathematics with the correct attitudes may be much more beneficial in the long term leaving the school to teach the tricky techniques.

Finally the thesis provides hope for those who find learning mathematics a difficult and unpleasant experience. It has shown that by fostering mathematical resilience individuals can be helped to have a much more positive and successful experience with mathematics in future.

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Appendices

Appendix 1 List of Potential Scales

Scale Name	Source Paper	α	Participants	Brief Description	Decision
Mathematics Anxiety Ratings Scale (MARS)	Richardson & Suinn (1972) The mathematics anxiety rating scale: Psychometric data, 19, 551-554 *Journal of Counseling Psychology*	.78 to .96	College students	98 item scale with situations that college students may feel anxiety in maths.	Measuring anxiety – not suitable.
Mathematics Attitude Scale	Aiken, L. (1974) Two scales of attitude toward mathematics *Journal for Research in Mathematics Education,* 5, 67-71	Enjoyment subscale = .95, Value subscale = .85	College students	Factors: enjoyment, value of maths	Consider for adaptation.
Fennema-Sherman Mathematics Attitude Scale	Fennema & Sherman (1976) Fennema-Sherman Mathematics Attitudes Scales: Instruments Designed to Measure Attitudes Towards Learning of Mathematics by Males and Females *Journal for Research in Mathematics Education* 7(5) 324-326	Various in many students. Most used affect instrument?	6^{th} – 12^{th} grade students	108 items, 9 subscales: student attitude, self-efficacy, anxiety, value of mathematics, gender, student perception of mother interest in maths, student perception of father interest in maths, student perception of teacher attitude toward maths, the usefulness	Consider for adaptation.

				of maths. Probably most used affect instrument (Chamberlin 2010)	
Revised Fennema-Sherman Mathematics Attitude Scale					
Mathematics Self-Efficacy Scale (MSES)	Hackett, G., & Betz, N. E. (1989). An exploration of the mathematics self-efficacy/mathematics performance correspondence. *Journal for Research in Mathematics Education*, 20, 261-273.		Undergraduate students		
Inventory of Attitudes Towards Mathematics (IAM)	Cueli, Garcia & Gonzalez-Castro (2013)Self-regulation and academic achievement in mathematics, *Aula Abierta,* 41(1) 39-48			Based on Fennema-Sherman, 86 items assessing 15 primary dimensions	
Attitude Toward Mathematics Inventory (AtMI)	Tapia, M. & Marsh II, G. E. (2004). An instrument to measure mathematics attitudes. *Academic Exchange Quarterly*, 8, 16-21.	49 item = .96 40 item = .97	High school students	49 or 40 items Elements measured: Confidence (or self-efficacy), anxiety, value, enjoyment, motivation, parent/teacher expectations.	

Mathematical Resilience Scale					
Student Attitude Survey	Morton, Yow and Cook				
Mathematics Value Inventory	Luttrell, V.; Callen, B.; Allen, C.; Wood, M.; Deeds, D. & Richard, D. (2010) The Mathematics Value Inventory for General Education Students: Development and Initial Validation *Educational and Psychological Measurement,* 70(1), 142-160				
Math and Me Survey	Adelson, J.L. & McCoach, D.B. (2009) Development and Psychometric Properties of the Math and Me Survey: Measuring third through sixth graders' attitudes towards mathematics			Two factors – enjoyment of maths and mathematical self-perceptions	
Mathematics Attitude Scale	Walkington 2013			12 item scale	
Attitude Inventory Side	Coppersmith 1967		Older students	Poorly worded English	
Mathematics Attitude Scale		.954		Adaptation of Biology Attitude Scale. 22 item survey, 14 Likert style	

				and 8 semantic differential	
The Mathematics Attitudes and Perceptions Survey			Undergraduates		
Achievement Goal Questionnaire	Eliot & McGregor (2001) A 2 x 2 achievement goal framework *Journal of Personality and Social Psychology* 80(3) 501-519			16 items Factors: Mastery approach, mastery avoidance, performance approach, performance avoidance, work avoidance	
Pupils' attitude towards mathematics scale	Tella, A. (2013) The Effect of Peer Tutoring and Explicit Instructional Strategies on Primary School Pupils Learning Outcomes in Mathematics	.87	Primary Students	20 items – yes/no response	
Tascione Attitude Survey	Tascione, C.A. (1995) The effects of student self-assessment on students' attitudes and academic performance in a college maths course [dissertation] Washington (DC) The American University	.7704	College students	31 items, Likert style Factors: attitudes about maths as discipline, communication in the maths classroom, assessment, mathematical ability	

Mathematics Attitude Scale (MAS)	Askar (1986)	.96		20 item, 5 point Likert	
Mathematics Self Efficacy Scale (MSES)	Umay, A. (2001) The effect of the primary school teaching program on the mathematics self-efficacy of students *Journal of Qafqaz University* 8, 37-44	.88	Primary students.	14 item, 5 point Likert Factors: perception of maths self-esteem, awareness of behaviours in maths, adapting maths skills to daily life	
Attitude Towards Mathematics Scale	Duatepe & Cilesiz 1999	.80		5 point Likert, 4 factors: interest/liking, pleasure, trust and fear, importance in daily/work life Not in English	
Mathematics Attitudes Scale	Erol 1989			Factors: benefits, parents' attitude, views that maths is for males, anxiety, perceived competence, interest in maths classes	
Students' Attitude towards Mathematics Questionnaire (SATMQ)	Unclear but used in Etuk, Afagideh & Uya (2013)	.94 (only 50 participants)	Senior School Pupils	18 items	

Kids' Ideas about Maths	Grootenboer & Hemmings (2007) Mathematics performance and the role played by affective and background factors *Mathematics Education Research Journal* 19(3) 3-20				
Maths Attitude Measure	Hemmings & Kay #83	.89	8-13 years	6 items that are part of a larger measure	
Your Opinions about Mathematics Scale	No source given but used and listed in Sengul & Katranci (2014)	.88 and .907	Seventh grade students	20 item Likert type scale, 12 positively worded and 8 negatively	
Positive and Negative Affect Scale (PANAS)		Positive scale = .81, negative = .86		Two 10 item scales, positive and negative	
Simpson-Troost Attitude Questionnaire (STAQ)	Simpson & Troost (1982)			Attitudes to STEM	
Student Interest in Mathematics Scale					
Self-description questionnaire	Marsh (1992)			Measure pre-adolescent self-concept	
Self-efficacy scale	Mathur & Bhatnagar (2012) Manual of self-efficacy scale,				

	Agra, National Psychological Corporation				
Attitude Scale Towards Mathematics Courses	Bayleul (1990)	.96	Older students	30 items	Not suitable as attitude towards particular skills
Attitude towards the Subject of Maths Inventory	Xu, X. & Lewis, J.E. (2011) Refinement of a chemistry attitude measure for college students *Journal of Chemical Education* 88(5) 561-568	Not verified	College students	Adapted from chemistry attitude scale by replacing word chemistry with word maths 8 items, two factors in original scale – intellectual accessibility and emotional satisfaction – but concluded more than this for maths	Not suitable as not properly tested
Questionnaire based on literature on self-regulated learning in mathematics	Zsoldos-Marchis, I. (2014) 10-11 year old pupils' self-regulated learning and problem solving skills *Review of Science, Mathematics and ICT Education* 8(1)	.81	10-11 year olds, Hungarian Public Schools from Romania	26 items Factors – forethought, performance control, self-reflection	Consider for adaptation.
Self-directed Mathematics Learning Attitude Scale	Lee, C. H., & Kim, S. H. (2005). Development of the self-directed mathematics learning test based on	αs only given for individual subscales.	Middle school students in Korea.	3 main dimensions, 57 items, 10 factors	Not suitable. Could not find copy of source paper, only paper

	Vygotsky. Journal of Korea Society of Educational Studies in Mathematics: School Mathematics, 7(3), 253-268.	Varied from .628 to .896			that adapted it for use with Turkish students. From this description had too many items.
School Subjects Attitude Scale	Nyberg, V.R. & Clarke, S.C. (1979) Technical Report of the School Subjects Attitude Scale, Alberta Journal of Educational Research	Not available to researcher.	Canadian Grade 5 – 8 students.	Scale distinguishing between positive and negative attitudes to social sciences, 24 items, students rated how useful and difficult they found them.	Not suitable – not affective attitudes looking at or maths.
Mathematics Confidence Scale	Dowling (1978)The Development of a Mathematics Confidence Scale and its application in the study of confidence in women college students, PhD Dissertation	Unclear.	College students	Students were presented with problems and asked to answer yes if they thought they could complete them and no if they could not.	Not suitable – does not measure any features of MR and problems aimed at college students.
Mathematics Attitudes and Anxiety Questionnaire	Thomas, G. & Dowker, A. (2000) Mathematics anxiety and related factors in young children, *Proceedings of the British Psychological Society Developmental Section Conference,* Bristol, UK	Not available	Primary aged children	28 items looking at 7 separate areas of maths. Items in four subscales: Self-rating in maths, liking, anxiety and happiness.	Use as anxiety measure alongside MR measure.

How I Feel About Maths Scale	Chapman, E. (2003) Development and validation of a brief mathematics attitude scale for primary-aged students *Journal of Educational Enquiry* 4(2) 63-73	Individual component alphas: α = .83, α= .69, α = .55	Primary students	10 items, 3 factors – overall enjoyment, perceptions of value, perceptions of ability to cope	Consider for adaptation.
Grit Scale	Duckworth, A.; Peterson, C.; Matthews, M.D.; & Kelly, D.R. (2007) Grit: Perseverance and Passion for Long-Term Goals *Journal of Personality and Social Psychology,* 92(6) 1087-1101	α = .85	Aged 25+	12 items, 2 factors – consistency of interests, perseverance of effort.	Consider for adaptation.

Appendix 2 Discussion of Scales

Fennema-Sherman Mathematics Attitude Scale

According to Chamberlin (2010) the Fennema-Sherman Mathematics Attitude Scale (Fennema & Sherman, 1976) may be the most widely used measure of affect in any field. The scale contains 108 items on 9 subscales with responses recorded on a five item Likert scale. Four of the subscales measure affective traits: Confidence, Effectance, Motivation, Mathematics Anxiety and Attitude Towards Success while the other five measure opinions on Usefulness of Mathematics, Mathematics as a Male Domain, and the influence of the Father, Mother and Teacher. Studies have been run using the full scale (e.g.) and individual or groups of subscales (e.g.). Although the full scale is unsuitable for use with Year One children due to the large number of items consideration was given to using one or more of the subscales. No one subscale had face validity for all the elements of MR and since the scale is over forty years old the language and terminology of some items was deemed unsuitable for young children. This scale would therefore only be suitable for use after extensive adaptation.

Mathematics Attitude Scale (MAS)

The Mathematics Attitude Scale (Aiken & Dreger, 1961) was developed by converting some paragraphs describing attitude to mathematics written by college students to scaled items. A revised version of the scale was published by Aiken two years later (Aiken, 1963) although he did not publish the research that led him to make these amendments. This second version of the scale has been used since 1963. The scale was designed for use with college freshmen and has 40 items on two subscales. In the years that followed it was used with other age groups although Aiken himself questioned the reliability and validity of the scale across the age range (e.g. Aiken 1970a, 1970b, 1972). The reported validity of the two subscales was strong (Enjoyment $\alpha = .95$, Value $\alpha = .85$) and a later study (Taylor 1997) reinforced the two factor structure. The value strand does have face validity for the value element of MR and some items appear to fit under the struggle element. However, the terminology would need adaptation and additional items would need to be added to cover the other elements of MR. As a 40 + item scale would be too long this scale would need extensive adaptation to work with 5 and 6 year olds.

Attitudes Towards Mathematics Inventory (ATMI)

The ATMI (Tapia & Marsh, 2004) is made up of forty items measured on a 5 item Likert response scale. It contains items measuring confidence (or self-efficacy); anxiety; value; enjoyment; motivation; and parent/teacher expectations. The value subscale directly maps to the value element of MR and some items have face validity with the struggle subscale but none have obvious face validity with the growth subscale. Again the language would also require substantial adaptation for use with 5 and 6 year olds.

Grit Scale

The Grit Scale (Duckworth et al, 2007) is a 12 item scale with two subscales; consistency of interests and perseverance of effort. The scale was developed with adults (25+) and thus uses words such as “diligent” which would not be suitable for use with 5 and 6 year olds. It is not specific to mathematics and has no obvious direct face validity with the MR subscales. As such it would require extensive adaptation to be suitable for the proposed study.

How I Feel About Maths Scale

The How I Feel About Maths Scale (Chapman, 2003) has the advantage of having been specifically developed for primary school pupils. It has only 10 items with language specifically designed to be accessible to children of this age. It has three factors: overall enjoyment, perceptions of value and perceptions of ability to cope. However, the items on the scale do not have good face validity with the elements of MR and thus additional items would need to be added for the scale to be suitable for the proposed study.

Zsoldos-Marchis Questionnaire

The Zsoldos-Marchis Questionnaire (2014) was developed from the mathematics self-regulated learning literature and used with Romanian. Although a Cronbach alpha of

.81 is quoted the sample size of 160 was small for the development of a 26 item scale (Streiner & Norman, 2008) and no details of development are recorded. The students were aged 10 to 11 so slightly older than those in the proposed research. The scale items would need to be translated into English. Some items had face validity with MR but extra items would need to be added. Thus the amount of adaptation was deemed too significant for use in the proposed study.

These scales were ruled out due to the extent of adaptation that would be necessary. The MRS and the Academic Resilience in Mathematics Scale initially appeared more suitable as they both measure MR and so were considered in more detail.

Kooken Mathematics Resilience Scale

In 2013 the Mathematical Resilience Scale (MRS) was developed as part of Johnston-Wilder and Lee's work into MR (Kooken et al 2013). The MRS developed from Johnston-Wilder and Lee's (2010a and b) research, with both co-authors working on the development, and from literature on resilience. The MRS was explicitly designed to measure the presence of value, struggle and growth in an individual with items reflecting each of these aspects so a score for each can be obtained. The scale was designed to be used in an evaluative way and is directly relatable to the proposed research sharing the same theoretical basis. During its development items were reviewed by nine subject matter experts for content validation. The final scale comprised 23 items relating directly to the definition of MR. Thus this scale has face validity as an MR scale. For participants unaware of MR the scale has face validity as an attitude to mathematics scale.

The factor structure of the MRS was identified using 2 iterations of Exploratory Factor Analysis to refine the items originally developed and one of Confirmatory Factor Analysis. Although each occasion of Factor Analysis had sample sizes over the suggested 200 minimum (253, 280 and 290 respectively) the analysis was not completed separately for the two sexes as suggested by Kline (2013). During the Exploratory Factor Analysis stages items were removed from the scale in line with recommendations if loadings were below .4 on all factors. During the first stage of analysis Resilience was removed as a factor due to the fact that "*Resilience items did not load solely on one factor and many were multidimensional*" (p4). This left three factors and items within these were again eliminated using the .4 criteria. The final list underwent Confirmatory Factor Analysis with the model adequately fitting the data, Chi square = 512.0, p<.001, root mean squared error of approximation = .066 (<.08 threshold) and comparative fit index = .91 (>.90 threshold). This indicates that the scale adequately measures the construct as defined.

Kooken et al (2013) reported on internal reliability of the final scale with coefficient alphas. Although these all met the minimum standard of .7 which generally suggests good internal reliability in a scale, Boardley (2015) suggested that a better target for new measures would be >.8, a standard not met by the Struggle Cronbach's alpha, α=.706.

MRS was tested on actuaries and college mathematics students in the first iteration of testing (the sample was declared to be "not well balanced" with fewer college mathematics students responding than required although figures were not given) and undergraduate students at research university in the second and third. These are the populations it has generally been used with to date and thus there is no data on its use with young children. In addition some items use scenarios that would not be relevant to young children so the scale would require adaptation before it could be used as planned.

<u>Academic Resilience in Mathematics (ARM) Scale</u>

The construct of academic resilience used in the ARM scale is based on the traditional one of "*success in school and in educational pursuits despite adversities*" (Ricketts et al., 2015 p1). Instead of viewing adversities as purely external the ARM paper proposes that the level of ARM that a person perceives themselves to have is a contributory factor in how well they will perform in the subject. The less resilience they perceive themselves as possessing, the more adversely performance will be affected. The authors claim that while much work has been done on the external risks which contribute to performance in mathematics, little research has been conducted on students' self-perceptions of resilience (p1). The ARM scale was developed to measure this and provide a discriminative tool which would establish if specific individuals or groups perceived themselves as less resilient. This would enable interventions to be designed for ‘at risk’ groups in mathematics to promote positive outcomes. The claim made by the authors that the scale measures academic resilience of individuals is debatable if it is measuring self-perception of resilience. No evidence is presented that self-perception of resilience is equivalent to actual resilience. The ARM does not consider the different factors of MR either so it’s relevance for assessing MR as defined may be limited.

The ARM scale was developed using Item Response Theory (IRT), in particular the Many-Faceted Rasch Model. The main reason for the use of IRT is that the resulting scales have interval-level properties - all items are measured over the same interval and are equally important to the construct so the score for each item can be legitimately added to obtain a total score representing the level of the construct in an individual.

The ARM scale is comprised of nine items, a figure which Kline (2013) suggests is lower than the minimum number of ten items necessary for a reliable test. Although there is a strong theory behind the research the construction of these items lacks a strong theoretical basis, five being adapted from other tests and four being researcher constructed. It is common to construct scales using items from others but it is usual to have a large number of items which are refined after testing (Streiner & Norman 2008). As this was not done further justification for the use of these particular items would be indicated particularly as no content validation was reported.

The ARM scale was administered to 538 participants meeting minimum sample requirements of 500 for IRT (Streiner and Norman 2008). Results were analysed using the Many-Facet model. It had high reliability of person separation (Rel. = .79) showing the scale could distinguish well between people with different levels of academic resilience. The fit of items to the model was tested using infit and outfit statistics with a figure between .8 and 1.2 a requirement for data to fit the model. Most items met this requirement although Item 9 (1.25) was outside the required range. Guidelines (p4) which recommend that each category of the six-category response format should have been chosen by at least 25 participants on each item in order for the analysis to be valid were not met for Item 9 which may have been a contributory factor. The authors recommend further testing of the scale due to this issue (p4).

ARM was tested on 7th and 8th grade middle school students. This difference in populations is less of a problem than in other forms of scale development due to IRT developing tests that are reliable across populations. However, some studies have suggested this is not the case (Streiner and Norman 2008) and ARM also fell down on some of the requirements of the Rasch model (namely infit and outfit statistics outside the accepted level) so the need for further testing is indicated before concluding generalizability.

The ARM paper reported on the ability of the scale to discriminate between different groups, namely those based on gender (Chi squared = 7.6, df = 1, $p<.05$), socioeconomic status (Chi squared = 1.3, df=1, $p=.25$) and student-reported teacher assigned grades (Chi squared = 54.1, df = 4, $p<.01$). This showed the scale was able to distinguish between groups in terms of gender and grade but found no statistically significant differences between groups with different socioeconomic status. The paper suggests this may be due to the definition of socio-economic status which relied on data about free school meals.

Appendix 3 Factor Analysis of the Kooken Mathematical Resilience Scale for Use with Parents

Since the original form of MRS had been used with students, data was collected from parents and a factor analysis was run to ensure that the same factors were found in this population.

Participants

91 participants in total completed the scale. 43 of these were parents who had brought their children to Coventry Young Researchers 2016 (CYR16). This event lasted for a week and was run by the Psychology, Behaviour and Achievement Research Centre at Coventry University in August 2016. Local children came in to the university library for half day sessions to complete psychology experiments, do crafts and learn about psychology. The parents of 43 of these children, who together with their child took part in an experiment run by the researcher, completed a paper version of the MRS before the experiment. The other 48 participants completed the scale in online form using the BOS online survey tool. Recruitment for the online survey was on the researcher's Facebook page Promoting Parenting for Mathematical Resilience. Of the sample that completed the scale at CYR16 approximately 84% were female while of those who completed online 75% were female. Thus the total sample was approximately 79% female. 5 parents failed to complete at least one item on the scale. No response was recorded and the analysis was run including these participants. Table 0-1 shows basic statistical data for the responses.

Table 0-1 Mean, Maximum and Minimum Values and Range for the MR scale as a whole and the subscales

	Growth Score (out of 49)	Value Score (out of 56)	Struggle Score (out of 56)	Total MR Score (out of 161)
Mean (to 2 d.p.)	39.48	44.40	42.35	126.23
Maximum	49	56	56	157
Minimum	27	10	29	88
Range	22	46	27	69

The number of participants was not ideal for a factor analysis being less than the recommended 10 per item (source) but it was felt that there were enough participants to assess if there was a problem with the scale so the factor analysis was run.

Factor Analysis

Factor Analysis was carried out using the method recommended in Pett et al (2003). Then means and standard deviations for the 23 items are presented in Table 0-2. The inter-item correlation matrix is presented in Table 0-3. The seven point scale was scored from 1 to 7 for positively worded items and 7 to 1 for negatively worded items. The means ranged from 4.71 (Item 2 *Struggle is a normal part of working on maths)* to 6.27 (Item 1 *Maths is very helpful no matter what I decide to do in the future*). Inspection of the correlation matrix showed that all items had correlations >.3 with at least one other item. No inter-item correlations were high enough to indicate a problem with multicollinearity.

Table 0-2 Means and Standard Deviations for the 23 Item MRS

	N	Mean	Std. Deviation
V1(1)	91	6.27	1.116
S1(2)	90	4.71	1.552
G1(3)	91	6.10	.932
G2(4)	91	5.70	1.159
S2(5)	90	5.03	1.402
V2(6)	91	5.88	1.210
G3(7)	91	5.69	.927
S3(8)	90	5.54	1.172
S4(9)	91	5.67	.989
G4(10)	91	4.77	1.274
S5(11)	91	5.70	1.059
V3(12)	91	6.05	1.099
S6(13)	91	5.31	1.061
G5(14)	91	5.90	1.265
S7(15)	91	5.16	1.223
V4(16)	91	5.22	1.245
V5(17)	91	5.34	1.335
G6(18)	91	5.38	1.254

V6(19)	91	5.42	1.136
S8(20)	91	5.38	1.052
V7(21)	89	5.25	1.246
G7(22)	90	6.00	1.017
V8(23)	91	5.08	1.284
Valid N (listwise)	86		

Table 0-3 Correlations for the 23 item MRS (Parents)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.000																						
2	.212	1.000																					
3	.172	.118	1.000																				
4	.159	-.014	.530	1.000																			
5	.006	.079	.085	.198	1.000																		
6	.449	.152	.084	.144	.000	1.000																	
7	.218	.170	.572	.510	.019	.213	1.000																
8	-.104	.256	.214	.087	.249	-.003	.251	1.000															
9	-.028	.252	.385	.205	.253	.140	.216	.689	1.000														
10	.044	.008	.300	.336	.091	.082	.411	.275	.197	1.000													
11	-.060	.105	.228	.142	.290	.070	.082	.393	.481	.114	1.000												
12	.590	.146	.119	.190	.180	.706	.210	.015	.108	.255	.097	1.000											
13	-.056	.050	.094	.132	.372	.094	.002	.219	.221	.036	.220	.185	1.000										
14	-.143	-.121	.257	.212	-.068	.067	.096	.056	.297	.290	.142	-.113	-.035	1.000									
15	-.054	-.009	.134	.167	.327	-.004	-.044	.230	.321	-.026	.350	.000	.248	.091	1.000								
16	.421	.072	.161	.200	.265	.560	.188	.188	.269	.218	.250	.649	.171	-.018	.214	1.000							
17	.321	.056	.007	.182	.150	.402	.173	.010	.158	.224	.144	.528	.105	.057	.246	.664	1.000						
18	.113	.067	.466	.425	.099	.035	.457	.258	.312	.434	.205	.149	.045	.336	.189	.175	.152	1.000					
19	.340	.198	.009	.153	.094	.659	.256	.035	.181	.207	.118	.618	.145	-.014	.019	.528	.537	.158	1.000				
20	-.043	.304	.184	.128	.305	.341	.256	.253	.400	.175	.340	.322	.347	.003	.222	.342	.218	.147	.433	1.000			
21	.281	.132	.077	.200	.229	.456	.134	.166	.179	.297	.048	.549	.145	-.116	.217	.531	.636	.077	.610	.322	1.000		
22	.057	.118	.535	.287	.049	.001	.366	.122	.322	.302	.024	-.076	-.014	.440	.110	-.011	.031	.468	-.005	.094	.025	1.000	
23	.331	.113	.039	.186	.134	.532	.331	.216	.257	.257	.054	.477	.193	.053	.081	.443	.391	.171	.642	.377	.339	-.053	1.000

Bartlett's test of sphericity and the KMO were calculated to evaluate the strength of the linear association between the 23 items. Bartlett's test of sphericity was significant (χ^2=888.090, p<.0001) indicating that the correlation matrix was not the identity matrix. The KMO statistic (.728) was "middling" (Kaiser 1974). The item-to-total scale correlations were all >.239. Cronbach's alpha for the 23 item scale was .850. These statistics indicated that a factor analysis was appropriate.

Factor analysis was carried out on the 23 item scale. Since the original form of the scale found 3 factors, the number of factors was restricted to 3. Varimax rotation was used. As can be seen in Table 0-4all items loaded on the expected factor apart from Item 9 which loaded on both Growth and Struggle but since it loaded more strongly on Struggle, the factor to which it was originally assigned, this grouping was retained. Cronbach alphas were calculated and found to be strong for each subsection of the scale (Value = .889, Growth = .803, Struggle = .734).

Table 0-4 Identified Factors

Rotated Component Matrix[a]

	Component		
	1	2	3
V1(1)	.629		
S1(2)			
G1(3)		.772	
G2(4)		.631	
S2(5)			.603
V2(6)	.795		
G3(7)		.705	
S3(8)			.667
S4(9)		.382	.699
G4(10)		.576	
S5(11)			.671
V3(12)	.862		
S6(13)			.557
G5(14)		.539	
S7(15)			.600
V4(16)	.746		
V5(17)	.702		

G6(18)		.729	
V6(19)	.819		
S8(20)	.365		.570
V7(21)	.705		
G7(22)		.735	
V8(23)	.663		

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 5 iterations.

Conclusions

The factor analysis indicated that the MRS was suitable for use with the population in question.

Appendix 4 Cognitive Interviewing Schedule

I would like your help today in finding out how children you age think about these questions before I give it to lots of other children to do. I didn't write the questions so you can say whatever you like about them and it won't upset me. Although I am going to ask you to answer the questions as if you were doing the questionnaire yourself I am interested in how you choose your answer, not what the answer is. There are no right or wrong answers. Any time you want to stop just tell me and you can go back to you class. I am recording our voices on these recorders so I don't have to write down what you say now – I can write it down at home later from the recording. Then I will erase the recording. Have you got any questions? Are you happy to help me today?

Section 1 General questions about maths

OK so this questionnaire is about maths. Can you tell me what 'maths' means to you?

When do you do maths?

Do you enjoy doing maths? What do you enjoy/don't you like about it?

Do you think you are good at maths? How do you know if you are good at maths?

Section 2 Questions on the Scale Items

I am going to read you some statements and I want you to mark on this scale how much you agree with them by drawing a circle round one of the pictures.

{Show the scale}

Two thumbs up means you agree a lot, one that you agree a little bit, none that you are not sure, a thumb down that you disagree and two thumbs down that you disagree a lot.

OK so I will now read the statements and I want you to circle the picture that shows how much you agree with each one. I will ask you some questions about what you think as we go along but if there is anything you want to ask or say at any time about the questions just tell me.

1. Maths will help me when I grow up.

Why did you decide that? Was this question hard or easy to answer? Why?

2. It is OK to find maths hard.

Could you tell me this question in your own words? Do you know what difficult means? Would you use another word instead of hard?

3. If you can't do maths now you will never be able to.

What do you think the words 'you can't do maths now' mean? What does 'you will never be able to' mean? Was it easy to decide how to answer this?

4. Anyone can learn maths.

Why did you make that choice?

5. Everyone finds maths hard sometimes.

Why did you pick that option?

6. I will need maths when I grow up.

Why did you decide that you will/won't need maths? What is this question asking you?

7. If someone is not in the good maths groups they won't be able to learn much maths.

What did the words 'the good maths groups' mean to you here? Why did you choose that option?

8. Children who are good at maths find some of the questions hard.

How can you tell if a child is good at maths? Why did you make that decision? How hard was it to answer this question?

9. People who have jobs that use maths sometimes find maths hard.

Can you give me some examples of jobs that use maths? Was it hard or easy to answer this question?

10. People are either good or bad at maths.

Why did you decide this?

11. Everyone gets things wrong sometimes when doing maths.

Why did you choose this option?

12. Maths will help me.

Why do you think that?

13. You are born good or bad at maths.

Was this hard or easy to answer?

14. People who are good at maths might not get all the answers right.

How did you decide the answer to this question?

15. I need to do maths to help me do what I want.

Why do you think that?

16. Knowing lots of maths helps me do hard things at school when I am not in a maths lesson.

Can you tell me what this question means in your own words?

17. Some people can't learn maths.

Why did you make this decision?

18. When you do maths you learn ways to think that help you be good at other things.

Can you tell me what this question means in your own words? How did you decide what to answer here?

19. You have to get things wrong to be good at maths.

Was this easy to answer? How did you make your decision?

20. Only clever people can do maths.

What does 'clever people' mean?

21. It will be hard to do well when I grow up if I am not good at maths.

How did you make a choice for this question?

22. People in my class sometimes find maths hard.

How did you decide this?

23. Thinking the way I do in maths helps me with things I like to do.

Can you tell me what this means in your own words? Is this hard or easy to answer?

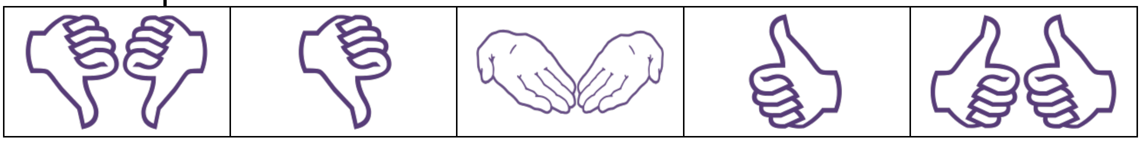
Have you got any comments about the questions?
I have been thinking about using some different pictures at the top of the scale. Would any of these be easier to answer? How hard was it to make sure you circle went in the right box?

Appendix 5 Original 20 item Version of the BCMRS

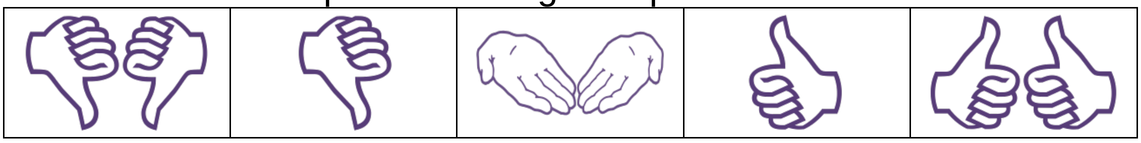
Maths Questionnaire

Put a circle around the picture that shows how much you agree with the statement.

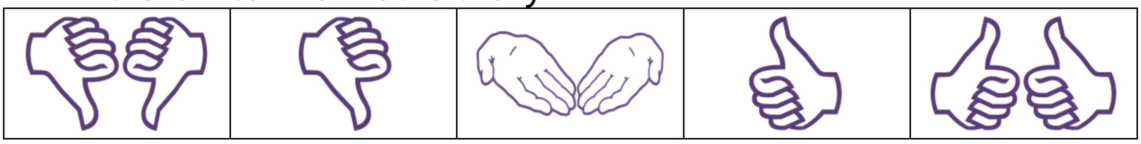
Practice question:



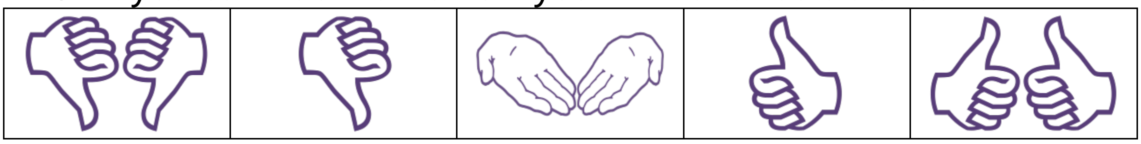
1. Maths will help me when I grow up.



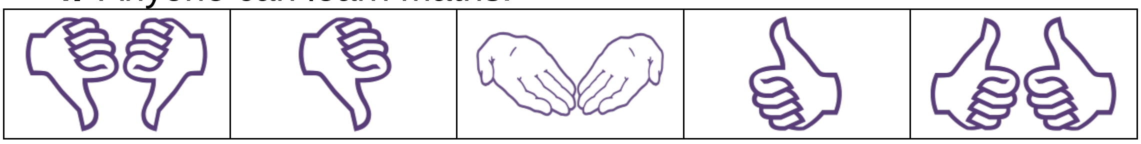
2. It is OK to find maths tricky.



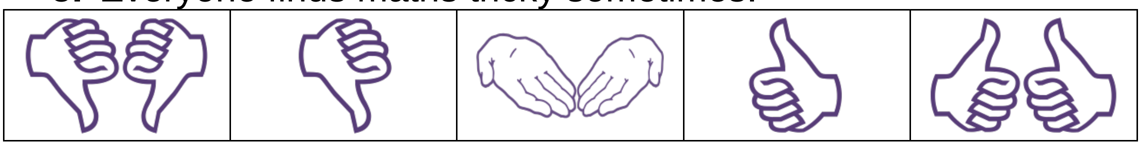
3. If you can't do maths now you will never be able to.



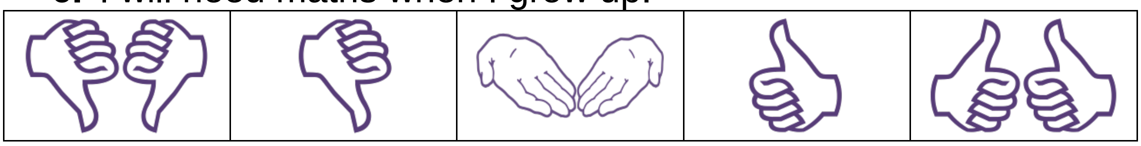
4. Anyone can learn maths.



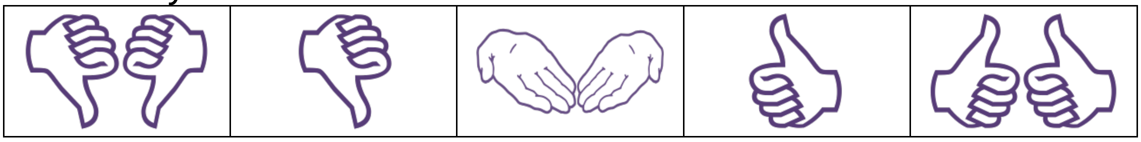
5. Everyone finds maths tricky sometimes.



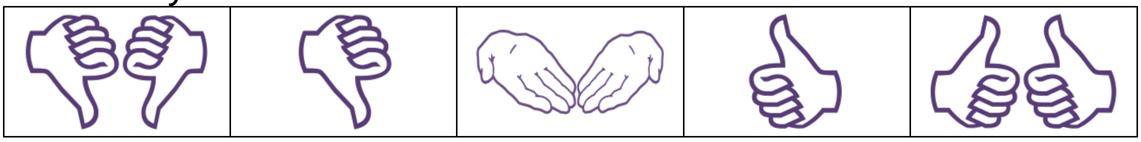
6. I will need maths when I grow up.



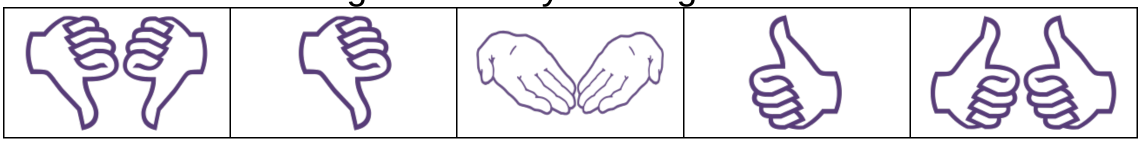
7. Children who are good at maths find some of the questions tricky.



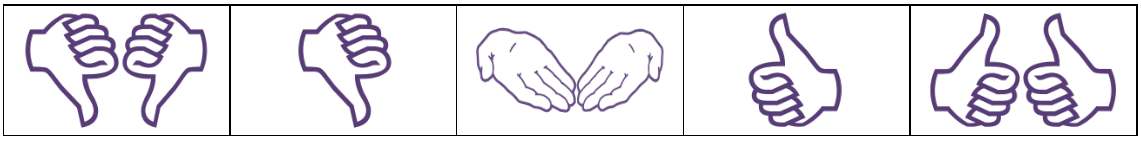
8. People who have jobs that use maths sometimes find maths tricky.



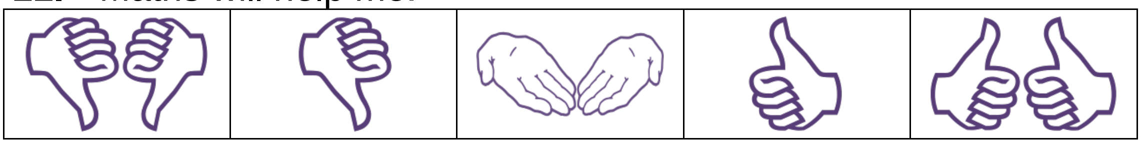
9. You can't change whether you are good or bad at maths.



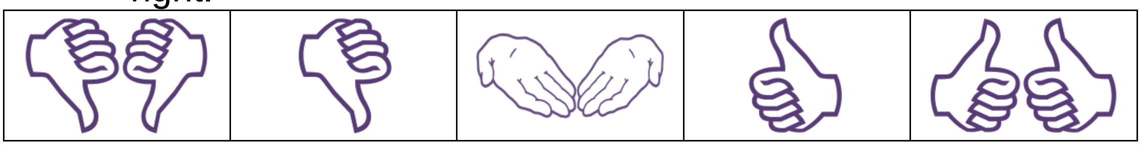
10. Everyone gets things wrong sometimes when they are doing maths.



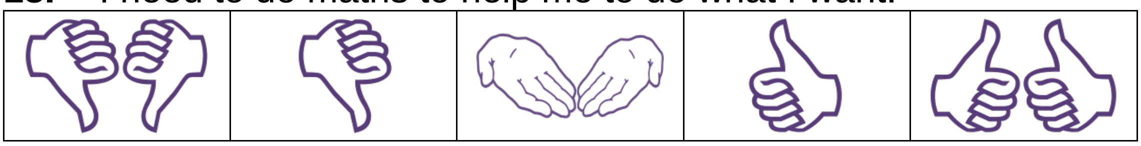
11. Maths will help me.



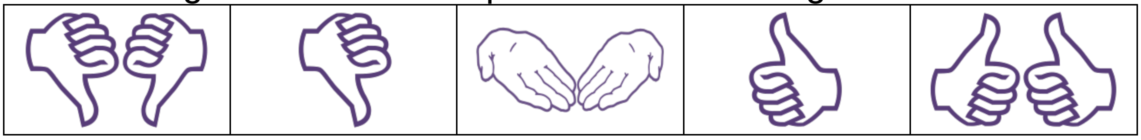
12. People who are good at maths might not get all the answers right.



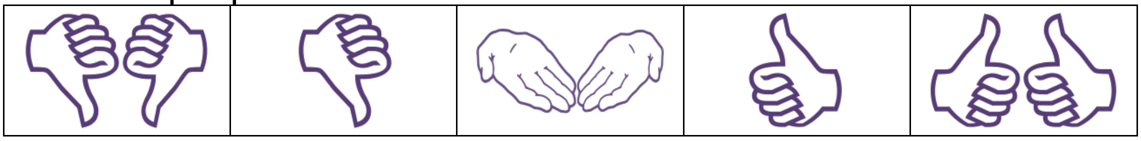
13. I need to do maths to help me to do what I want.



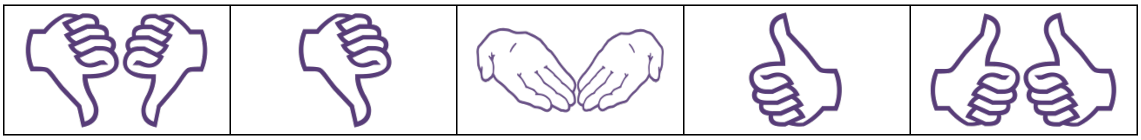
14. Knowing lots of maths helps me do other things at school.



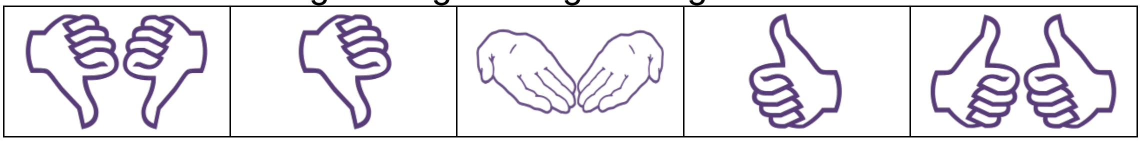
15. Some people can't learn maths.



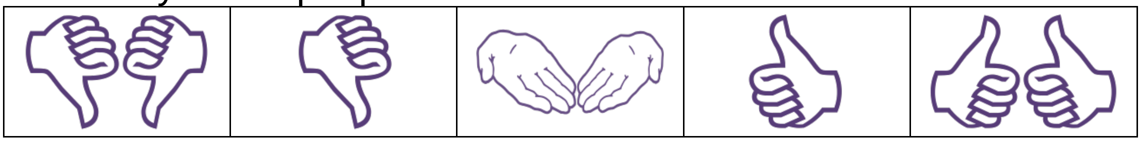
16. Knowing lots of maths helps me do things when I am not at school.



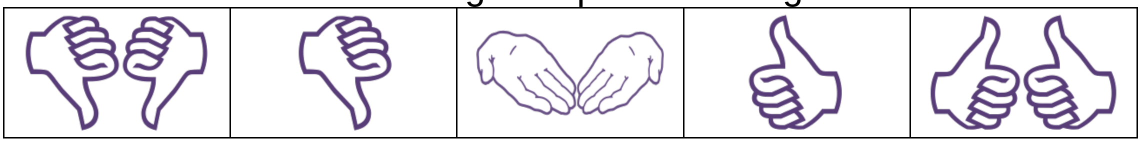
17. You have to get things wrong to be good at maths.



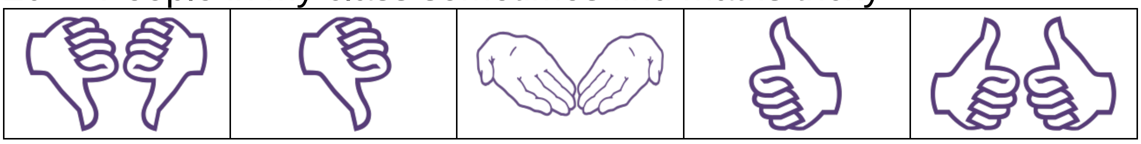
18. Only clever people can do maths.



19. I won't do well when I grow up if I am not good at maths.



20. People in my class sometimes find maths tricky.



Appendix 6 Final Version of the BCMRS

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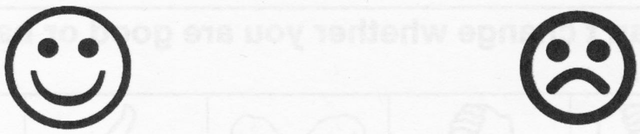
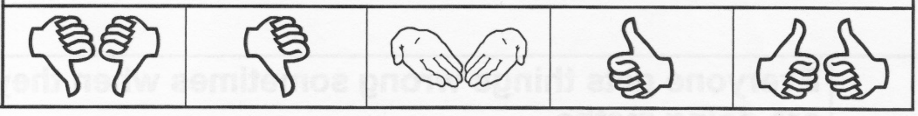
Baker Children's Mathematical Resilience Scale

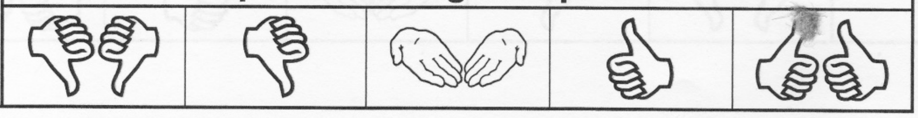
Please colour in a face to show whether you agree to take part in the research. A smiley face means you agree and a sad face that you do not want to take part. Only colour in one face.



0 — **Practice Question**

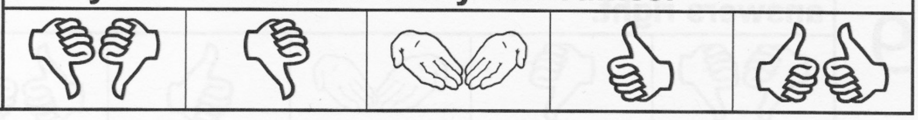


1 — **Maths will help me when I grow up.**

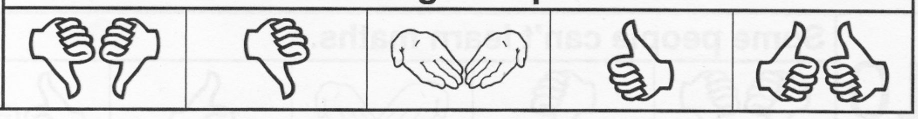


2 — **If you can't do maths now you will never be able to.**

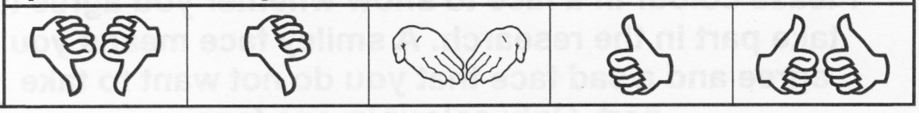
3 — **Everyone finds maths tricky sometimes.**



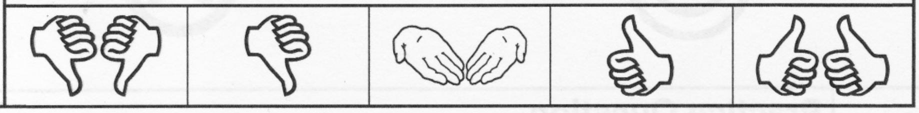
4 — **I will need maths when I grow up.**



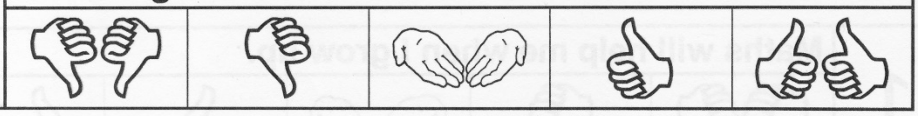
5 **Children who are good at maths find some of the questions tricky.**



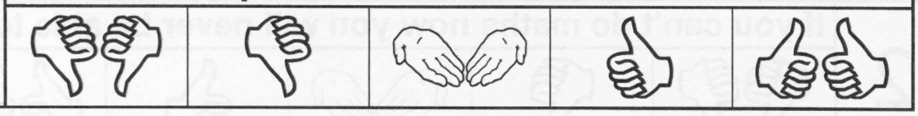
6 **You can't change whether you are good or bad at maths.**



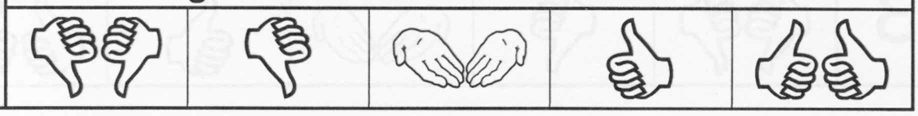
7 **Everyone gets things wrong sometimes when they are doing maths.**



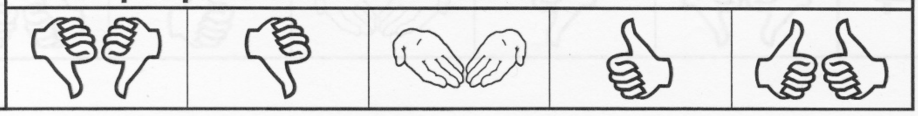
8 **Maths will help me.**



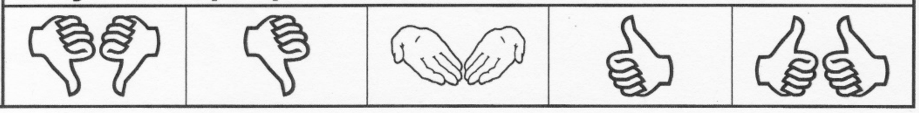
9 **People who are good at maths might not get all the answers right.**



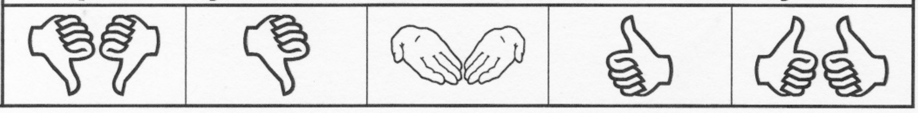
10 **Some people can't learn maths.**



11	Only clever people can do maths.



12	People in my class sometimes find maths tricky.



Developed by Katie Baker 2018

Appendix 7 Script for Chapter 5 Experiment

Pointless Mathematicians Task

If you have seen Pointless on the television you will know that the aim is to come up with an answer that no-one else has thought of in order to win a prize. That is exactly what you are going to try and do today. You have as long as you want to come up with an answer that no-one else has thought of. Write all your answers on the piece of paper. Once you have written down all the answers you can come up with we will check and if ANY of them are ones that aren't on our list you will win. But beware – once we have checked you can't write down any more so make sure you have thought of all you can before you check.

Your category is: sums with an answer of 8.

Go.

Appendix 8 Transcripts Coded by Strategy Used Ordered from Low to High MR

Total MR Score	Age	Highest Strategy Used
1.6	6	Number bonds
1.75	9	Number bonds with negatives
1.9	9	Number bonds
2.25	8	Number bonds and times table facts
2.7	6	Number bonds
2.8	8	Number Bonds
2.85	7	Number bonds
2.95	8	Number bonds
3	6	Number bonds and times table facts
3.05	9	Number bonds
3.1	8	Number bonds and times table facts
3.2	7	Number bonds and times table facts
3.2	10	Mixed operation
3.3	11	Mixed operation
3.4	9	Most complex sum
3.45	6	Number bonds and times table facts
3.45	7	Addition with non-integers
3.5	8	Number Bonds
3.65	8	Number Bonds
3.7	6	Number bonds
3.75	7	Number bonds
3.75	13	Most complex sum
3.85	6	Number bonds and times table facts
3.85	8	Most complex sum
3.9	9	Most complex sum
3.9	9	Number Bonds
3.9	9	Number bonds and times table facts
3.9	10	Most complex sum
3.95	8	Addition with non-integers
3.95	10	Most complex sum
4.05	8	Number bonds and times table facts
4.1	6	Most complex sum

4.1	7	Most complex sum
4.1	9	Number bonds and times table facts
4.1	9	Number bonds with negatives
4.2	10	Number bonds and times table facts
4.2	12	Mixed operation
4.3	10	Most complex sum
4.35	8	Number bonds
4.35	9	Mixed operation
4.4	5	Number bonds
4.4	8	Most complex sum
4.4	9	Mixed operation
4.45	7	Number bonds and times table facts
4.5	9	Most complex sum
4.55	8	Number bonds and times table facts
4.75	6	Most complex sum
4.75	9	Mixed operation
4.75	9	Number bonds and times table facts
4.85	9	Seed sum
4.9	7	Number bonds and times table facts
4.9	10	Number bonds
4.95	7	Most complex sum
4.95	9	Addition with non-integers
5	6	Number bonds
5	7	Number bonds
5	8	Most complex sums
5	8	Most complex sums
5.1	11	Most complex sums
5.15	11	Mixed operation
5.25	10	Seed sum
5.25	12	Most complex sums
5.5	12	Most complex sums
5.5	12	Most complex sums
5.6	9	Number Bonds
5.6	11	Most complex sums
5.75	7	Number bonds and times table facts
5.8	11	Addition with non-integers
5.8	12	Most complex sums
6	10	Most complex sums

6	10	Most complex sums
6	10	Number bonds
6	11	Addition with non-integers

Appendix 9 Means for Chapter 6

Table 0-5 Mean Scores on the BCMRS in each of the three terms (Standard Deviations in brackets)

	Time 1					Time 2					Time 3			
	Growth	Struggle	Value	Total MR		Growth	Struggle	Value	Total MR		Growth	Struggle	Value	Total MR
Below (n=4)	-5.25 (1.89)	7.50 (3.79)	3.75 (2.22)	1.44 (.42)	Below (n=3)	-6.67 (2.31)	8.00 (3.46)	6.00 (0.00)	1.93 (.12)	Below (n=2)	-2.50 (2.12)	5.00 (7.07)	3.50 (.71)	1.54 (1.71)
Working Towards (n = 13)	.38 (4.99)	4.62 (4.81)	3.38 (2.66)	2.15 (1.10)	Working Towards (n = 8)	2.50 (3.16)	3.38 (4.69)	3.00 (3.70)	2.30 (2.38)	Working Towards (n = 4)	-3.75 (2.63)	5.50 (3.42)	3.00 (6.00)	1.16 (2.56)
At Expect. (n = 43)	-2.40 (4.17)	4.37 (5.09)	5.50 (.76)	1.55 (1.46)	At Expect. (n = 27)	.93 (4.93)	4.26 (4.73)	2.78 (3.70)	2.01 (2.41)	At Expect. (n =22)	2.05 (5.11)	3.27 (5.41)	4.05 (2.92)	2.51 (1.81)
Greater Depth (n = 8)	-3.00 (3.89)	8.38 2.00)	5.50 (.76)	2.76 (.84)	Greater Depth (n = 3)	3.00 (2.65)	5.67 (1.53)	4.00 (3.46)	3.22 (1.97)	Greater Depth (n = 13)	3.77 (2.62)	3.69 (5.95)	2.23(4.4 9)	2.42 (2.72)
All Children (n = 74)	-2.27 (4.35)	5.15 (4.70)	3.91 (2.63)	1.76 (1.33)	Total (n=71)	-.52 (4.97)	4.11 (4.85)	3.72 (3.05)	1.93 (2.02)	Total (n = 72)	.61 (5.05)	4.96 (4.97)	3.56 (3.43)	2.33 (1.96)

Appendix 10 Intervention Documents

Reflective Diary of Participant Number

Please fill in a diary about the session this week and how you have worked with your child on mathematics at home. You may want to answer the questions below but feel free to use the diary in any way that suits you. For example some people choose to fill it in everyday while others reflect on the whole week on a day that suits them. The diary can be word processed or hand written. The diary is entirely voluntary, any information you give will be useful.

Date of Session	
Title of Session	
Questions about this week's session:	
What activities did you enjoy in this week's session?	
What key points have you learnt from this week's session?	
Did the session help you to understand anything about working with your child that you didn't understand before?	

Has the session changed the way in which you have worked with your child this week or how you are planning to work with them in the future?
Were there any aspects of the session you did not like or did not understand?
Have you had any other thoughts or feelings as a result of the session?
Questions about maths activities with your child:

Use the sections below to record any mathematics you have done with your child this week. This could include maths exercises, practical maths such as cooking or measuring or conversations about maths.
What did you do?
Was it homework or something you did independently of school?
Is it something you would have done before the course or was it inspired by the course?
Did you and your child enjoy it?
Did you use any of the techniques from the course?

Did you encounter any problems? How did you overcome them?

End of Course Questionnaire

Has the course changed the way you help your child/ren in mathematics?

Completely	In Some Ways	Not At All

Please explain your answer in the box below:

Which aspects of the course did you find helpful (tick all that apply)?

Zones of Learning Model (Week 1)	
Growth and Fixed Mindset Model (Week 3)	
Mathematical Resilience Model (Week 3 and 4)	
Explanation of the National Curriculum expectations (Week 4)	
Written Methods of Addition and Subtraction (Week 1)	
Written Methods of Division and Multiplication (Week 2)	
Ideas about how to practice maths everyday by playing games etc. (Week 4)	
The ability to talk with other parents about working with your children on maths.	
Other (please specify)	

Please comment on the following in the space provided:
The ease of setting up the time and place for the course
The size of the group
The atmosphere once you arrived at the course.
The delivery of the course by the leader
The written materials
The activities you were required to do
The explanations of the written methods
The length of each session

The number of sessions

Would you recommend the course to other parents in Year 1?

Yes	No

Do you think there are any barriers to Year 1 parents attending these courses? What do you think could be done to overcome these barriers?

Are there any areas of the course that you feel could have been improved?

Any other comments about the course:

Appendix 11 Rating Sheet for Intervention Sessions

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Observer:... School:.. Session:....................................

Rating Scale: Parenting for MR Sessions

Date:...

Instructions: Assess the session on a scale from 0 to 4 and record the rating on the line next to the question. If you think the observation falls between two of the descriptions, select the intervening odd number (1, or 3). Additionally, provide supportive comments to evidence the rating given. If you feel the descriptions for a given question do not apply to the session you are rating, disregard them and use the more general scale below:

0	1	2	3	4
Poor	Barely adequate	Adequate	Good	Excellent

1) Exposure

0 Minimal parent exposure to intervention activities, most of time spent off-task (e.g. chatting about off-task subjects)

2 evidence of parent exposure to intervention activities, some time spent off-task (e.g. long time spent between activities)

4 clear evidence of parent exposure to intervention activities, minimal time spent off task

2) Planning

0 minimal evidence of researcher planning of intervention lessons (unable to navigate or unfamiliar with materials)

2 some evidence of researcher planning of intervention lessons (e.g. able to locate activity/resources)

4 clear evidence of researcher planning intervention lessons (e.g. quick to move to activities,clear introduction to activity)

3) Instructional Guidance

0 no introduction to activity or reminder of task ahead

2 basic introduction to activity and/or reminder of task

4 clear introduction of activity, reminder of task and/or feedback

4) Opportunities to succeed (activities adapted to group)

0 no awareness of experiences of parents, no adaptation of tasks

2 some awareness of experiences of parents, some adaptation of tasks

4 clear evidence awareness of parental experience across tasks, tasks adapted to suit the group

5) Group Cohesion

0 no attempt to encourage parents to work together as a group, allowing some pupils to dominate

2 some encouragement to work as a group –

4 active management of group dynamics, e.g. enforcing turn taking and sharing,

6) Pacing and efficient use of time

0 Researcher made no attempt to time activities. Session seemed aimless.

2 Session ran more or less to time, but timing of activities within session not as planned

4 Session ran to time, timing of activities within session as planned

7) Behaviour

0 constant disruption and off task behaviour going un-managed

2 little disruption, parents mainly on-task and/or attempts at behaviour management

4 parents clearly engaged, kept on track and/or effective behaviour management

8) Links to MR made explicit

0 tasks were delivered with no reference to links to parenting for MR

2 some tasks delivered with reference to parenting for MR

4 tasks delivered with reference to relevant MR context in all cases

9) Overall rating and comments: How would you rate the overall session?

0	1	2	3	4
Poor	Barely adequate	Adequate	Good	Excellent

TOTAL SCORE: /36 **OR AMENDED TOTAL SCORE: /**

Coventry University

Appendix 12 Ethics Documentation

Certificate of Ethical Approval

Applicant:

Katie Baker

Project Title:

What is the best way to teach parenting for mathematical resilience? Pilot stage

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

12 April 2016

Project Reference Number:

P38734

Certificate of Ethical Approval

Applicant:

Anna Joyce

Project Title:

Coventry Young Researchers 2016

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

16 February 2016

Project Reference Number:

P41583

Certificate of Ethical Approval

Applicant:

Katie Baker

Project Title:

The experiences of parents when working with their children on mathematics homework.

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Low Risk

Date of approval:

16 June 2016

Project Reference Number:

P44171

Certificate of Ethical Approval

Applicant:

Katie Baker

Project Title:

The Development and Evaluation of Interventions to Help Parents Promote Mathematical Resilience in Their Children

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

13 December 2016

Project Reference Number:

P45624

Certificate of Ethical Approval

Applicant:

Katie Baker

Project Title:

Online Survey of Parents Views of Maths Interventions

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

18 April 2017

Project Reference Number:

P52578

Coventry University

Certificate of Ethical Approval

Applicant:

Katie Baker

Project Title:

Monitoring the Mathematical Resilience of Children in Year 1

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as High Risk

Date of approval:

28 June 2017

Project Reference Number:

P59098

Certificate of Ethical Approval

Applicant:

Katie Baker

Project Title:

Follow up Data Collection for Project P45624

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

08 June 2018

Project Reference Number:

P71961