In the starting blocks: Scoping the experiences, vulnerabilities, and potentials of adults with dyscalculia in Aotearoa New Zealand

Researcher: Dr Damon Whitten

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Acknowledgments

A word of thanks to the participants.

The individuals who took part in this study showed courage and generosity in sharing their stories, challenges, hurts, and personal victories with the interviewer. It was a somewhat daunting task considering they were being asked to sit with a stranger and talk about maths! Yet, the primary motivation for their participating was to contribute to making life better for other people with mathematical difficulties. Thank you. I shall endeavour to use your experiences and insights to make life better for other people with dyscalculia.

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ISBN Online: 978-1-98-856253-7
ISBN Print: 978-1-98-856254-4

November 2024

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Introduction

The increased attention on neurodiversity in the last several years is encouraging, yet, dyscalculia, a key neurodiversity, remains little understood, misunderstood, and under researched. Dyscalculia is a difficulty with numbers, arithmetic, recalling facts, estimating, and numerical problem solving, each essential skills for the modern world. As mathematical demands increase across domains such as technology, employment, health, finance and daily life, difficulties with numeracy create serious life challenges and lead to multiple vulnerabilities across a range of domains. However, there is also the potential that such challenges and vulnerabilities may lead individuals to develop alternative sets of skills that have significant value. At this time there is a paucity of research to shed light on these issues. While anecdotal evidence abounds among the adult numeracy community, little research captures the lived experiences of adults with dyscalculia, and certainly not within Aotearoa New Zealand.

The whakataukī, 'He aha te mea nui o te ao? He tangata, he tangata, he tangata!', reminds us to keep a focus on what matters. What is most important in life? It is people, it is people, it is people.

This study explores the extent to which dyscalculia interferes with people's lives. What do we already know? We know that three trends are making life more difficult for adults with dyscalculia. First, the demands for numeracy skills are rising, driven by changing technologies, knowledge economies, demographic changes, and the rapid growth in the need to understand and make decisions based on numerical information (Ehlers & Kellermann, 2019; New Zealand Productivity Commission, 2020).

Second, adults with lower numeracy skills find themselves vulnerable to a range of health, economic and social risks. These vulnerabilities include higher unemployment, lower income, poorer mental health, poorer physical health, lower engagement in formal and informal training and less engagement with civil society (Grotlüschen, Mallows, Reder, & Sabitini, 2016; OECD 2019a; OECD, 2019b). Given that these are concerns for adults with low numeracy, what might the ramifications be for adults with dyscalculia?

Third, arising from the literature is the toll on personal identity and self-concept, beliefs about self-worth, emotional responses to numeracy and the ramifications this has for achievement and general wellness. The experience of school is highly formative and, in many cases, negative for learners (Whitten, 2013, 2018). There are far poorer life outcomes for adults with low numeracy, and concerningly many of these relate to social engagement and mental health (Bynner & Parsons, 2006). These three factors create an increasingly challenging environment for an adult with dyscalculia.

Given this backdrop, this paper is designed to do three things. First, it provides an overview of key areas of dyscalculia research to provide a starting point for researchers and practitioners within the Aotearoa New Zealand tertiary sector. The literature review and areas for future research provide a map of potential local research projects in the adult dyscalculia domain. Second, this paper will initiate the development of a knowledge hub for dyscalculia that individuals, educators, and organisations can access. Third, it provides a contextual view into the lived experiences of adults with dyscalculia in Aotearoa New Zealand.

This study explores the experiences, vulnerabilities, and potentials of adults with dyscalculia in Aotearoa New Zealand. It explores the following questions in regard to adults with dyscalculia: What was the experience of school like, and did it have lasting effects on confidence or self-esteem? What strategies were adopted, was help provided, were there people who encouraged, were there people who were discouraging? How do these experiences reach into adult life? What challenges exist in employment or training environments, what strategies are adopted and how are these navigated? What strengths have people developed? What have they learned and what would they pass on to others in similar circumstances. The results are an insight into the durability of the human spirit.

There are a range of views about the terminology used in the neurodiversity space, underpinned by a historical context of 'othering' and stigmatising language (Hood & Hume, 2024). Of key importance is the use of inclusive and non-stigmatising language. This study adopts an identity-first approach and thus uses the phrase 'adults with dyscalculia' as a descriptor.

1 Literature review

As early as 1919 Henschen noted that some individuals with high intelligence appeared to have difficulties working with numbers, in what he called 'number blindness'. Years later in 1974, Czech researcher Ladislav Kosc formalised the term 'dyscalculia' to describe a condition he noticed in which otherwise highly competent people had great difficulty working with numbers (Kosc, 1974). Again, years later prominent researcher Brian Butterworth studied otherwise healthy, intelligent individuals who unexpectedly had great difficulty processing numbers and he identified specific cognitive functions related to this (Butterworth, 1999). Each of these researchers reported working with individuals who were hardworking and intelligent, but whose difficulties with mathematics caused significant disruption and stress within their lives. Since then, a large community of researchers has worked to describe the origins, causes, correlates, and potential solutions to developmental dyscalculia.

Defining dyscalculia: What does it mean to be a 'dyscalculic adult'?

A brief internet search on the key word 'dyscalculia' will reveal a wide variety of definitions and descriptions of dyscalculia. It is widely described as a learning disability or learning difficulty in maths and has at times been referred to as the 'dyslexia of maths' (Roman Empire Agency, 2024). It is described as "a disorder that affects a person's ability to understand number-based information and maths" (Cleveland Clinic, 2024). The Dyscalculia Network define it as "a specific and persistent difficulty in understanding and dealing with numbers, which can lead to a range of difficulties with numbers" (Dyscalculia Network, 2024). Estimates of the proportion of the population who may experience dyscalculia are generally in the 5-7% range (Gross-Tsur, Manor & Shalev, 1996; Rubisten & Henik, 2009; Schulz et al., 2018).

The neurodiversity community includes dyscalculia within its purview, describing it as a specific learning difference (SPL) characterised by persistent difficulties in understanding and manipulating numerical concepts (Sewell, 2022). The neurodiverse paradigm views dyscalculia as a unique manifestation of human cognitive variability rather than emphasising deficit views. Instead, dyscalculia is understood as a variation in cognitive processing that is intrinsic to certain individuals, contributing to their unique cognitive profiles. The neurodiversity framework emphasises strength-based approaches, an area this research will explore and build on.

There is also a substantial historical body of research from the medical/clinical paradigm that has focused on the development of precise nosological categorisations and definitions of dyscalculia. This research has incorporated neurological, cognitive, and psychological approaches and has been focused on carefully categorising the domains, causes and correlates of dyscalculia. Leading diagnostic manuals, such as the Diagnostic and Statistical Manual of Mental Disorders (DSM-V), situate dyscalculia as a 'neurodevelopmental disorder' and define it as 'a specific learning disorder with impairment in mathematics' (APA, 2022). Similarly, the International Classification of Diseases (DC-11) (WHO, 2017) categorise dyscalculia as a 'developmental learning disorder with an impairment in mathematics'.

Within these categorisations there are further diagnostic criteria designed to differentiate dyscalculia from other mathematical difficulties or low numeracy skills. One of the earliest criteria for dyscalculia is the notion of 'persistence', that is, that the difficulty with mathematics persists into adulthood and throughout life (APA, 2022). Thus, dyscalculia is defined as a chronic condition that persists into adulthood. A typical diagnosis of adults with dyscalculia is that it presented in the early school years and continues to interfere with mathematical performance (Kaufmann et al., 2020).

A second key criteria of dyscalculia is that of 'seriousness'. That is, that the difficulties with mathematics are serious enough that they significantly inhibit mathematical learning and achievement. For example, the dyscalculia inclusion criteria for most school-based studies stipulate that the individual's mathematical skills are well below expected age-level and hamper their ability in school, the workplace, or daily life (Caviola & Lucangeli, 2015; Everatt, Mahfoudhi, Al-Manababri & Elbeheri, 2015; Ramaa, 2015). However, there is a substantial margin in the literature regarding how far below age related levels children ought to be to meet the criteria. A recent meta review by Kroesbergen, Huijsmans and Frisco-van den Bos (2023) found a wide range of mathematical levels used across studies, from a low of the 5th percentile to a high of the 46th percentile. Currently no consensus exists, although all agree that a diagnosis of dyscalculia includes that the mathematical level is significantly below age matched peers.

The third diagnostic criteria for dyscalculia is that of 'specificity'. The DSM-V and the ICD-11 criteria stipulate that the difficulty with mathematics be domain specific and not a result of other challenges or setbacks, such as non-domain learning difficulties. Thus, the difficulty with mathematics is not a result of (or caused by) other conditions such as foetal alcohol syndrome, dyslexia, or dyspraxia, (Kaufmann et al., 2020). Other neurodiversities may be present (e.g. dyslexia or dyspraxia) however are not the direct cause of the mathematical difficulty. The 2013 DSM-V dyscalculia diagnosis criteria required a 'discrepancy' between the individual's academic performance (reading, writing and IQ) and their mathematical performance as evidence of specificity. In layperson's terms, to meet the criteria the individual needed to perform well at everything, except mathematics. Testing for this has since been abandoned because the tests are composed of sub-tests that include reading, writing and arithmetic, meaning that other neurodiversities would lower the results of these tests (Kaufmann et al., 2020). Other neurodiversities frequently co-occur with dyscalculia, such as dyslexia, dyspraxia or ADHD (Cereño & Pogoy, 2022). For example, some studies find that up to 60% of adults with dyscalculia also experience dyslexia (Chivers, 2001). See co-morbidity in the following section.

The DSM-V and the ICD-11 also include sensory and educational exclusionary criteria for the presence of dyscalculia (APA, 2022). For example, sensory difficulties such as vision or hearing difficulties, or environmental conditions such as impoverished or ineffective instruction (poor teaching or lack of schooling), would need to be considered before a diagnosis of dyscalculia. While these issues may exist, they must be eliminated from being the cause of the mathematical difficulty. A common methodology for inclusion of school children in a dyscalculic cohort is that they are achieving typically across most domains (e.g. reading fluency and writing), have no sensory difficulties, and have attended school regularly, while being significantly below age-matched peers in mathematics (Kroesbergen, Huijsmans & Frisco-van den Bos, 2023).

A primary point for our Aotearoa New Zealand adult context is that these definitions of dyscalculia specify that difficulties with numeracy/mathematics are not a result of impoverished instructional strategies, or sensory challenges, but rather are neurological in origin. However, poor schooling experiences, disrupted social conditions, hearing or sight difficulties may co-occur, and often do, in foundation learning environments (Whitten, 2018). Many adults have difficulties with numeracy, for example, the 2016 Adult Life Skills Survey found almost 20% of the NZ adult population were at level one or lower (MoE & MoBIE, 2016), and it is likely a subset of these are adults with dyscalculia. The most common estimates of the population rates are 6-7%, although this will be higher among foundation level learners (Schulz et al., 2018).

A final component of defining dyscalculia is distinguishing between developmental dyscalculia (DD) and acquired dyscalculia (AD). Developmental and acquired dyscalculia differ in timing and origins. Acquired dyscalculia arises from brain injury or neurological illness which undermines an individual's ability to process numbers (McCloskey, 1991). In contrast, developmental dyscalculia is congenital in nature, present from early childhood (Göbel, Terry, Klein, Hymers, & Kaufmann, 2022). For the remainder of this study, dyscalculia will refer to developmental dyscalculia.

To summarise, to be officially diagnosed with dyscalculia the individual needs to meet certain criteria within a clinical paradigm. Although these criteria are developing, a clinical nosological diagnosis of dyscalculia includes that the mathematical difficulties are serious, persistent, and specific. Individuals with developmental dyscalculia are characterised as having serious difficulties performing fluent mathematical computations, in the absence of sensory difficulties, or causative intellectual difficulties or educational deprivation. However, sensory difficulties, neurodiverse conditions and/or deprived educational opportunities may also co-occur with a dyscalculia diagnosis.

Cognitive differences associated with dyscalculia

By far the largest subject of inquiry into dyscalculia has been the cognitive domain. A review of the literature finds a body of research exploring how children and adults with dyscalculia differ from typical developing peers. Children and adults with dyscalculia differ in how they process magnitude and quantity, carry out arithmetic, retrieve number facts, and solve problems. Reviewing each of the differences falls beyond the scope of this study, however. The following section reviews four specific number-related domains that individuals with dyscalculia commonly experience difficulties with. These four are, non-symbolic processing of magnitude and quantity, arithmetic difficulties, fact retrieval, and problem-solving[1].

Non-symbolic processing
Sample tasks:

1. Glance at the dots in Figure 1 and then say aloud how many dots there are as fast as you can.
2. Look at Figure 2, and as quickly as possible state which coloured dots there are more of.

[1] Additional information on how number is processed can be found in Appendix 1

A key finding in human psychology is that the human brain has a non-symbolic system that processes magnitude, quantity, length, and time, without the use of language or numbers. Humans can distinguish between small quantities before learning to count using numbers (Skagerlund, Karlsson & Träff, 2016). For example, preverbal babies can recognise the difference between small quantities such as 1 and 2, and 2 and 4 (Starr, Libertus, & Brannon, 2013; Xu & Spelke, 2000), and verbal pre-schoolers can rapidly name how many objects are present in a small set (<4) without directly counting them (Halberda & Feigenson, 2008). For example, typical adults can state how many dots are in the box below without directly counting them.

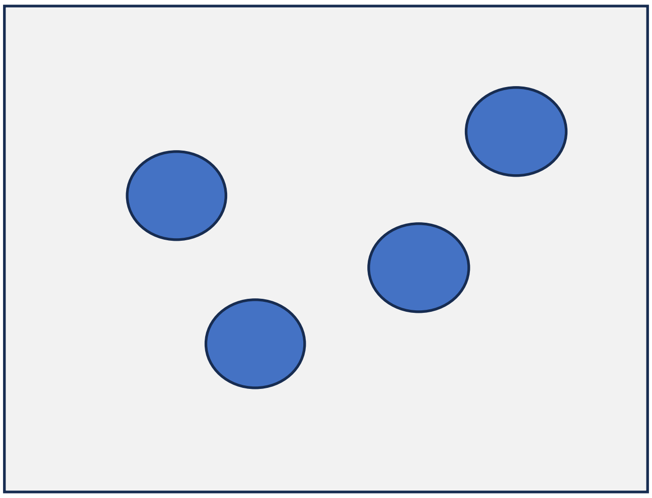

Figure 1: Subitsing task example

The cognitive system responsible for this is called the 'analogue magnitude representation' or the 'Approximate Number System' (ANS). Common tasks used to tap the ANS are rapid comparison tasks in which a box with dots of two different colours are shown to a participant (See Figure 2), or two circles with different amounts of dots in each are presented. The participant must decide rapidly which coloured dot is more numerous, or which set has the most dots. These tasks are completed without counting the dots and often framed as 'which side/colour has more dots?'. Participants typically push a button that represents a colour or left/right. Typically developing children demonstrate faster response times and accuracy than children with dyscalculia (Reeve & Gray, 2015; Zhou & Cheng, 2015). Performance on this task relates to children's current and future maths performance (Bonny & Lourenco, 2013; Libertus, & Feigenson & Halberda, 2011; Mazzocco, Feigenson, & Halberda, 2011).

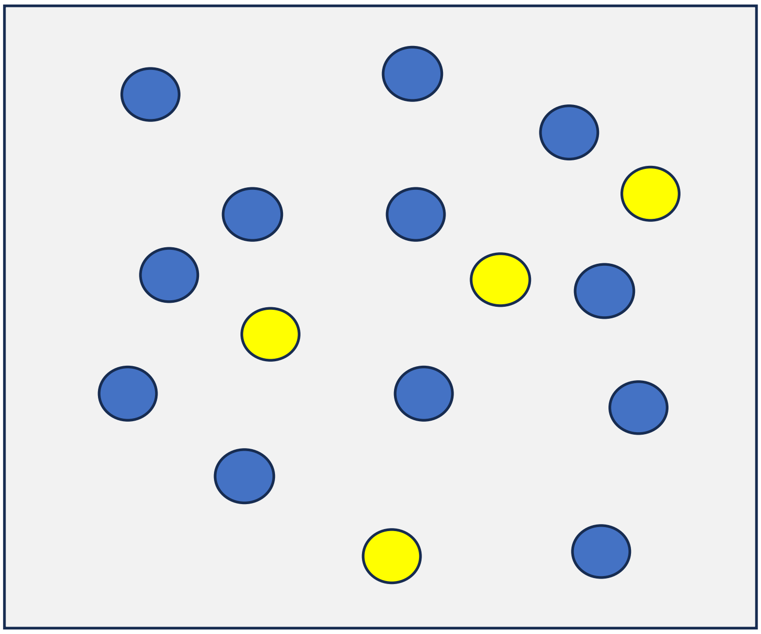

Figure 2: Which coloured dot is there the most of ?

A second task that taps the ANS is 'subitising' in which a small number of dots (<5) are flashed briefly in front of a participant (see Figure 1). The participant's task is to quickly state the quantity of dots without sequentially counting them. Typically developing children name the quantity of dots quickly and can subitise in the range of 1–4 elements. Children and adults with dyscalculia are found to take longer to name the quantity, and have a smaller subitising range, 1–3, rather than 1–4 elements (Gliksman & Henick, 2019).

The third task is 'enumerating', in which diversely spaced dots in a set are counted (see Figure 3 for example task). Typically developing children count the dots quicker and more accurately than their dyscalculic peers. This has been found true for adults with dyscalculia as well who take longer to count elements in a set and are less accurate (Cohen, Gliksman & Henick, 2019).

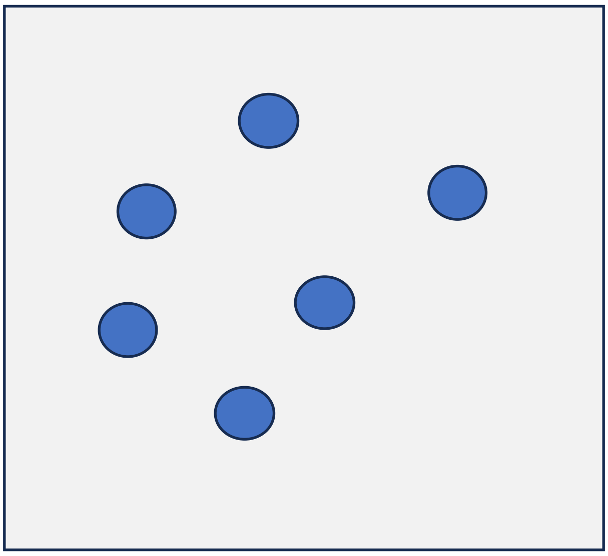

Figure 3: Enumerating task

The research on children and adults with dyscalculia processing non-symbolic quantities differently is well established, being replicated across multiple studies (Chard, Clarke, Baker, Otterstedt, Braun & Katz, 2005; Furman & Rubinsten, 2012; Reeve, Reynolds, Humberstone & Butterworth, 2012). However, the use of the 'dot tasks' described above has resulted in mixed results, with some suggesting the results are a product of how the stimuli are presented (Szucs, Nobes, Devine, Gabriel & Gebuis, 2013) and others arguing that the tasks actually measure inhibition control (Gilmore et al., 2013). Despite these remaining questions, adults with dyscalculia are found to have difficulties with the ANS across multiple tasks, and this interferes with recognition and estimations of magnitude, quantity, and length (Ashkenazi & Henik, 2010; Kaufmann et al., 2020). There is some, but a lesser amount, of research to suggest that the ANS of adults with dyscalculia also interferes with accuracy of time duration (De Visscher, Noël, Pesenti, & Dormal, 2018). However, as will be seen below, difficulties with time is a self-reported issue for adults with dyscalculia.

Differences with fact retrieval
Sample task: Finish the following sentences:
Five fives are ..?
Five sixes are ..?
Five sevens are ..?

Many of the readers were likely to have solved the timetables above from memory. "Five fives are twenty-five" is a common memorised 'fact' that many of people learned through repetition. For most people, the more they recite and practice their times tables, the more they can be remembered, and then rapidly recalled from memory to solve number problems (Ophuis-Cox, Catrysse & Camp, 2023). This is referred to as 'fact retrieval' because the number fact is retrieved from the memory.

The second difference found with adults and children with dyscalculia is with fact retrieval, such as recalling memorised single-digit arithmetic or multiplication facts (Chan & Ho, 2010; Geary, 1993; Woodward & Montague, 2002). For example, many people can automatically recall that 8 and 5 equal 13 without the need to mentally calculate, and many adults can recall memorised times tables such as 5 x 7. Difficulties with memorisation and automatic recall of such number facts are a characteristic of dyscalculia (Kaufmann et al., 2020). Rather than recalling number facts from memory, adults with dyscalculia have been observed using calculation strategies such as finger counting to solve them (Kaufmann et al. 2011).

Finger counting strategies place demands on working memory which interferes with other aspects of problem solving, ultimately making it less effective and successful (Kaufmann et al., 2020). This use of direct counting, rather than rapid recall of known facts, appears to account for the slower response times in the non-symbolic magnitude tasks described above (Cappelletti & Price, 2014). Several neuroimaging studies find that adults with low mathematics achievement recruit cognitive pathways associated with mental calculation when asked to solve addition problems in which the operand is below 25 (e.g. 5 + 4). Typically achieving adults recruited pathways associated with recall (Grabner, Ansari, Koschutnig, Reishofer, Ebner, Neuper, 2009; De Smedt, Holloway & Ansari, 2011). This suggests that individuals with low mathematic achievement solve small number problems through mental calculation rather than immediate recall. This is also cited as part of the reason why adults with dyscalculia have difficulties with more complex numeracy problems. Their cognitive resources are expended on mental arithmetic which reduces the attention able to be allocated to more conceptual features of a problem (Kroesbergen, Huijsmans & Friso-van den Bos, 2023).

Unlike the non-symbolic ANS system described above fact retrieval is considered to be mediated by a verbal word frame (Dehaene & Cohen, 1995). Neuroimaging research finds that the neural correlates used when recalling number facts are not the same as those used for non-symbolic processing (Dehaene, Piazza, Pinel, & Cohen, 2003; Grabner, Ansari, Koschutnig, Reishofer, Ebner, & Neuper, 2009). This suggests that recalling a 'fact' from memory may be primarily a language task, rather than a numerosity task (see Appendix 1).

Arithmetic difficulties

Sample task: Try and solve the following equation in your head, 27 + 44 = __?

The third specific difficulty for adults with dyscalculia is calculation such as multi-digit addition (27 + 44), subtraction, multiplication and division. The American literature refers to this as 'arithmetic' defined as counting, adding, subtracting, multiplying, and dividing. The term will be used throughout the document for consistency.

Children and adults with dyscalculia have difficulties with number conceptualisation and number sense (Dehaene, 1997; Vigna et al., 2022). This manifests as difficulties with arithmetic, with whole numbers (Vigna et al., 2022), place value understanding (Eckstein, 2016) and the understanding of decimals, fractions and percentages (Siegler, Fuchs, Jordan, Gersten & Ochsendorf, 2015). The difficulties with non-symbolic magnitude described above are theorised to be causally related to poor arithmetic skills. Some researchers suspect that imprecise mental representations of magnitude and difficulties accessing representations from number symbols play some role in hindering the development of arithmetic skills (Bugden & Ansari, 2015).

Studies on the arithmetic skills of children with dyscalculia have typically tested fundamental operations, such as arranging sets of numbers in descending order, subtracting and adding single- and multi-digit numbers, subtracting according to place value, single and then multi-digit multiplication, and dividing numbers without the need for a remainder. Multiple studies find that these children have greater difficulty than typically performing children or socially disadvantaged children (Ramaa, 2015).

Research finds that children and adults with dyscalculia also have difficulties with rational numbers such as fractions, decimals, and percentages (Siegler et al., 2015; Siegler & Pyke, 2013). Understanding rational numbers such as fractions is viewed as essential to mathematical development because it enables the learner to move beyond whole numbers into more complex mathematics. For example, understanding rational numbers enables individuals to make sense of half an orange, 50 cents, or 20 centimetres, and interest rates, deposits, and discounts. Furthermore, gaining an understanding of fractions is important for the development of proportional reasoning, a mathematical skill that has strong relationship with workplace tasks (FitzSimons, 2010; FitzSimons, Mlcek, Hull, & Wright, 2005). The difficulties with whole numbers lead naturally to difficulties with rational numbers, leading to difficulties with a wide range of daily and workplace tasks.

Problem solving
Sample task: Five rugby teams have entered a one-day tournament. How many games will there be if each team plays each other team once.

The fourth specific difficulty associated with dyscalculia is the use of mathematical reasoning to solve problems. The challenge for adults with dyscalculia is that this type of activity requires the use and coordination of arithmetic, retrieved facts, and procedures to solve problems. Additionally, successful problem solving requires the understanding of concepts, ideas and relations, the use of complex procedures and conditional relationships (i.e. if/then conditions) and integrating each to make decisions and solve problems (Geary, 1993; Schoenfeld, 1992, 2011). Children and adults with dyscalculia have difficulties with the above. This may be due to difficulties with some reasoning performance (Morsanyi & Szucs, 2015), but is also likely to be due to the difficulties coordinating and then carrying out operations with number concepts, such as arithmetic and fact retrieval, which interfere with more complex reasoning tasks (Cirino, Fletcher, Ewing-Cobbs, Barnes, & Fuchs, 2007; Jitendra, Dupuis, & Lein, 2015).

Working memory
Differences in working memory performance is also a feature of dyscalculia and dyslexia (Karagiannakis & Cooreman, 2015). The most influential model of working memory is that of Baddeley (1992). In this model the working memory is conceptualised as a short-term storage system that can briefly hold and manipulate information. It is controlled by the central executive, which allocates attention to several unique processing systems. These include the phonological loop, which stores sounds such as speech and is related to learning number facts for fact retrieval. Another system is the visuospatial sketch pad, which holds visual and spatial information and is used to interpret and organise spatial representations of objects, such as decimal positions or placing numbers on a number line (Karagiannakis & Cooreman, 2015). Several studies find that children with dyscalculia have difficulties in all three domains – executive function, phonological loop, and visuospatial sketchpad (Geary, Hoard, Nugent, & Byrd-Craven, 2007). However, there are mixed findings as to which of the three components are associated with dyscalculia. Some have found that children with dyscalculia have difficulties only with the central executive (Passolunghi & Siegel, 2004), while others have found difficulties with the visuospatial sketch pad and central executive, and others the phonological loop and central executive (Gathercole & Pickering, 2000). What appears evident is that children and adults with dyscalculia are likely to have differences with some aspect of the working memory, either one, some, or all three aspects, yet which aspect is less clear.

Comorbidity
Comorbidity refers to the presence of other neurodiverse conditions. Research finds that many adults with dyscalculia have other neurodiverse conditions such as dyslexia, dyspraxia, or attention deficit hyperactivity disorder (Cereño & Pogoy, 2022; Vigna et al., 2022). For example, some studies find that up to 40% of adults with dyscalculia also experience dyslexia (Chivers, 2001; Wilson, Andrews, Struthers, Rowe, Bogdanovic & Waldie, 2015). Additionally, these co-occurrences of neurodiverse conditions make diagnosis, such as those described in official diagnosis of dyscalculia, difficult.

In summary, adults with dyscalculia differ from the typical population across the three 'codes' of numeracy. Differences are found with the analogue number system, fact retrieval, and arithmetic. Although there may only be some cognitive difficulties with problem solving, difficulties with fact retrieval and arithmetic interfere with problem solving by drawing cognitive resources. Additionally, there are often co-occurring neurodiversities and differences in how the working memory is used.

Adult dyscalculia disadvantage and vulnerabilities

In this section the literature pertaining to the disadvantages and vulnerabilities of adults with dyscalculia is reviewed. A number of domains are explored, including health and financial life outcomes, workplace challenges, and affective factors such as identity, beliefs and mathematical anxiety. Following this, we turn to what could be found from self-reports from adults with dyscalculia, and, in the final section, review and explore the adults' potential strengths and positive adaptions.

Identity, beliefs, and emotions

A large body of research finds that the experience of struggling with mathematics during school years can, and often does, lead to the development of negative beliefs about mathematics, oneself, and the ability to learn (Allan & Schnell, 2016; Goldin, Epstein, Schorr & Warner, 2011; Whitten, 2018). This may be because proficiency in mathematics is often viewed as a measure for intelligence (Blackwell, Trzesniewski, & Dweck, 2007). Once consolidated, these beliefs are considered cognitively stable in adulthood (McLeod, 1992), difficult to change, and highly influential on behaviour (Op't Eynde et al., 2007; Radovic et al., 2018; Schoenfeld, 2011). The beliefs lead to poor self-concept, low confidence, and causal attribution of success or failure to external factors (Espina, Marbán, Jose & Sáez, 2024; Grootenboer & Marshman, 2016). These beliefs also connect to how a learner views themselves as a 'doer' of mathematics, termed a 'learner identity' (Latterell & Wilson, 2017; Radovic et al., 2018; Sfard & Prusak, 2005).

Mathematical identities are based on the experiences, interactions, and interpretations of events that occur within the social context of mathematical instruction (Grootenboer, Smith & Lowrie, 2006; Hossain, Mendick & Adler, 2013; Radovic et al., 2018). They are not seen as static but are under constant revision and construction (Latterell & Wilson, 2017; Sfard & Prusak, 2005). This was described by Wenger as "a layering of events of participation and reification by which our experience and its social interpretation inform each other" (1998, p. 151). For example, ongoing difficulties with understanding and participating in school mathematics, derogatory comments from other learners about "not getting it" and being identified by the teacher or parents as failing, may all contribute to a negative mathematical identity.

Sfard and Prusak (2005) argue that mathematical experiences and interpretations become adopted narratives or, in other words, that identities are the stories that learners hear and tell about themselves. These narratives can be authored by others, such as other learners or teachers, or may be institutional narratives that might include diagnoses, qualifications or ability groups. They are also theorised to be authored, and therefore reified, by themselves. It is argued these identities act as constraints or affordances to an individual's participation in mathematics (Boaler & Greeno, 2000; Darragh, 2013; Sfard, 2012), and, therefore, adult numeracy practices. This is because learning mathematics is viewed by many as the actualising of one's identity through participation (Hannula et al., 2016). This suggests that adults with dyscalculia may have developed negative identities about themselves that shape how they view themselves and how they continue to engage with numeracy tasks. Furthermore, these identities may have been shaped by the narratives of others, as well as themselves. They may also be evident in the stories that adults with dyscalculia tell about themselves.

It is well established that mathematics evokes strong and often negative emotions in many people, and more so in those who struggle with mathematics (Espina et al., 2024; Hannula et al., 2016; Whitten, 2018). While descriptions vary, emotions reported include anxiety, fear, panic, anger, apprehension, sullenness, humiliation, shame, embarrassment, resentment, guilt and boredom (Bibby, 2009; Goldin et al., 2011; Vigna et al., 2022). The feelings vary in intensity, ranging from mild and manageable to more severe emotional and physiological responses that appear to overwhelm the learner and disrupt engagement (Ashcraft & Moore, 2009; Evans, 2000). These emotions are typically aroused when an individual is expected to engage in mathematical thinking in social situations (Evans, 2000; Evans, Morgan & Tsatsaroni, 2006; Hannula, 2012; Whitten, 2018). When such learners are expected to engage, they often enact avoidance strategies designed to avoid repeating negative learning events (Turner, et al., 2002; Whitten, 2018).

Maths Anxiety

A further domain that has received much attention is that of maths anxiety because of its negative effect of performance and motivation (Ashcraft & Krause, 2007; Ashcraft, Krause & Hopko, 2007; Lewis, 2013). Espina et al (2024) found that half of the published research on affect and dyscalculia explored the prevalence and effects of math anxiety. Students with dyscalculia show significantly higher levels of maths anxiety than typically developing peers (See Espina et al. 2024 for references). However, Mutlu (2019) found that maths anxiety is the same for learners with dyscalculia as it is for learners struggling with mathematical performance, suggesting that maths anxiety is high in both groups.

The negative effects of maths anxiety are well established, with maths anxiety associated with decreased cognitive performance, referred to as the 'cognitive drop' (Ashcraft & Moore, 2009), and interference with the working memory. Working memory difficulties are already associated with dyscalculia yet, as maths anxiety increases, it impacts negatively on executive function, and verbal and visuospatial working memory (Mamerella, Caviola, Giofré & Szucs, 2017), making it an extremely negative cocktail of affective factors.

In summary, adults with dyscalculia are more likely to have had negative mathematics learning experiences and developed a range of negative beliefs and mathematical identities. These lead to constrained engagement with numeracy as well as negative emotions and, in many cases, maths anxiety.

Physical and mental health outcomes

The key characteristic of dyscalculia is its negative impact on numeracy development. A substantial body of research finds that adults with low numeracy skills have lower health outcomes than adults with higher numeracy skills (see Peters 2020 for an overview). Adults with lower numeracy are found to take more prescription medication, are more likely to have at least one chronic disease, have a greater number of comorbidities, smoke cigarettes, and generally report worse health (Bynner & Parsons, 2006; Garcia-Retamero et al., 2015; Martin, Haas, Schonlau, Derose, et al., 2012). Some of these outcomes may be the result of systemic disadvantages associated with low-socioeconomic status, for example due to the costs of insurances and medication, and less access to information on the internet (Peters, 2020). However, many of the health studies have controlled for a range of demographics such as socioeconomic status (Lubinski & Humphreys, 1992), body mass index, trust in physicians, and satisfaction with their role in decision making (Garcia-Retamero et al., 2015). Even though adults with low numeracy may suffer from systemic disadvantage such as lower socio-economic issues, lower numeracy skills have been found to directly influence poorer health decisions and outcomes (Peters, 2020; Curdt, Schreiber-Barsch, Angermeie, 2023).

Lower health outcomes for adults with low numeracy skills are partly attributed to lower comprehension of numerically framed health information, leading to less informed decision making (Peters, 2020; Zikmund-Fisher, Smith, Ubel, & Fagerlin, 2007). For example, adults with higher numeracy skills are more responsive to statistically presented data (Lipkus, Peters, Kimmick, Liotcheva & Marcom, 2010; López-Pérez, Barnes, Frosch, & Hanoch, 2017). Health information presented in a statistical format has been criticised for failing to be comprehensible to adults with lower numeracy skills (Gigerenzer, Gaissmaier, Kurz-Milcke, Schwartz & Woloshin, 2007).

Lower health outcomes are also attributed to poorer management of health conditions such as cancer or diabetes due to lower numeracy skills. Several studies have explored the numeracy required to manage diabetes which includes tasks such as calculating carbohydrate intake, understanding data from food labels, and interpreting blood sugar levels (Cavanaugh, et al., 2008; Marden, Thomas, Sheppard, Knott, Lueddeke, & Kerr, 2012; Zikmund-Fisher, Exe & Whittman, 2014). These tasks require high numeracy skills, in fact Peters (2020) estimated that only 9% of Americans could do all of the tasks posed by diabetes. Low numeracy skills are directly linked with poorer diabetic health (Cavanaugh et al., 2008; Marden et al., 2012).

Mental health is found to be worse among adults with low numeracy skills although the causes are less direct and less understood. Bynner and Parsons' (2006) analysis of longitudinal data found that adults with lower numeracy reported more symptoms of depression. When asked questions taken from the Malaise scale (Rutter, Tizard & Whitehouse, 1970), adults with low numeracy skills were twice as likely to report that they felt they "never got what they wanted out of life". Additionally, four times as many adults with low numeracy reported feeling as though "whatever they did had no effect on what happened to them". While the causes are not understood, it does suggest that adults with dyscalculia may be vulnerable to negative health outcomes.

Financial outcomes

There is a strong relationship between low numeracy skills and financial deprivation (Bynner & Parsons, 2006; Curdt, Schreiber-Barsch, Angermeie, 2023; Grotlüschen, Mallows, Reder, and Sabatini, 2016). Research based on the 2014 Programme for International Assessment of Adult Competencies (PIAAC) data described numeracy skills as 'woven into the social and economic fabric of society', and therefore embedded into social and economic outcomes (Grotlüschen et al., 2016). This emerges in the data regarding employment; adults with low numeracy skills were found to be more likely to be unemployed, when employed were earning lower rates of pay, often on casual contracts, and were often the first to be laid off (Bynner & Parson, 2006; OECD, 2019b).

Research was also found regarding the financial decision making of low versus higher numeracy skilled adults, which suggests that higher skilled adults make better use of data and engage more in mathematical thinking. Findings include that adults with stronger numeracy skills are more likely to invest in stocks and bonds, plan for retirement, and accrue wealth (Estrada-Mejia, Vries & Zeelenberg, 2016; Smith, McArdle & Willis, 2010). Conversely, lower numeracy skilled adults were less likely to shop around for long-term deals, more likely to be the victim of predatory loans, and make late payments on loans (Sinayev & Peters, 2015). Several studies controlled for demographics, education, cognitive ability, literacy, memory, and executive function, suggesting that differences in personal wealth are not only the result of socio-economic disadvantage/advantage but also differences in numeracy proficiency (Banks & Oldfield, 2007). The relationship between numeracy proficiency and financial outcomes are complex, yet adults with dyscalculia appear vulnerable to lower financial outcomes (Gal, Grotlüschen, Tout & Kaiser, 2020).

Workplace Challenges
There is literature to suggest that numeracy use in the workplace is becoming more frequent and more complex (Maass, Geiger, Ariza & Goos, 2019; McCloskey, 2007; OECD, 2019b). The demand for higher numeracy skills is driven by evolving technology, globalisation, the shift to knowledge-based industries, and an increasing business focus on quality and efficiency (Confederation of British Industry [CBI], 2015; Expert Group on Future Skills Needs [EGFSN], 2015; Tu et al., 2016). The workplace is expected to become more data-driven, outsourced, and lean, increasing the demand for individuals with multi-disciplinary technical, mathematical, management, and design skills (Störmer et al., 2014). The demand for lower-skilled workers is expected to decrease, along with reduced training opportunities, creating a potential social and economic divide (Marr & Hagston, 2007; Störmer et al., 2014). Thus, adults with dyscalculia may find themselves vulnerable to obtaining, and then maintaining, employment.

Workplace numeracy demands vary in the types of mathematics required to complete them. McCloskey (2007) describes a range of quantitative domains that present in adult life such as, quantity and number, measurement skills, dimensions and shape, patterns, function and relationships, data and chance, change, estimation, calculation skills and number sense. He argues that mathematical skills are embedded across workplace tasks. Examples of workplace tasks include the need for proportional thinking, such as mixing petrol and oil for 2-stroke engines (Whitten, 2023), mixing chemicals for weed spray (Fitzsimons, Mlcek, Hull, & Wright, 2005), working out the amount of paint required to cover the square area, or giving change back to a customer (McCloskey, 2007).

Fitzsimons (2010) argues that workplace numeracy tasks are far more than the application of mathematical skills to tasks. Their complexity also lies in the way they are socially-culturally situated in on-going workplace practice that is context specific and dependent. In addition to having varied outcome needs, tasks often involve a high degree of emotionality because workplace competence impacts status among peers. Difficulties completing workplace numeracy tasks in the workplace are associated with shame and embarrassment (Whitten, 2018). For example, adults make comments such as "Yeah, you don't want to actually look dumb" (Whitten, 2018, p.103) or "(not being good at numeracy) … somehow implies untrustworthiness…" (McCloskey, 2007, p. 426). These comments indicate that there are psychological costs to low numeracy in the workplace and a potential risk to workplace reputation and status.

Engagement with training and further education
The international PIAAC data provides an overview of how adults with high or low numeracy and literacy participate in formal or non-formal training. Adults with low numeracy skills are found to participate less in formal and informal training opportunities (Grotlüschen et al. 2016). Adults with low numeracy and/or literacy proficiency are found to participate 44% less than those with higher proficiency, and are substantially less likely to participant in open or distance learning, on-the-job learning, seminars, workshops, or private lessons. Moreover, adults with lower numeracy and/or literacy are three times less likely to engage in formal training opportunities. A significant cause of this is not necessarily low numeracy, but barriers to training such as not meeting the pre-requisites, unaffordability, and unexpected obstacles. Therefore, caution should be applied here because socio-demographic characteristics play a large part in the findings. The research in the present study will explore adults with dyscalculia's intentions, motivation, and feelings toward engaging in training.

Numeracy as a gatekeeper

Numeracy acts as a gatekeeper to various domains of activity. Much has been made about the mathematical skills required to enter a course, university, or work in a particular vocation. For example, we know that many adults choose not to pursue a preferred career because of the numeracy demands (Douglas & Attewell, 2017). However, much of this research has explored the impact of dyscalculia or numeracy skills at a higher level. What is less explored in the research is the impact at lower levels. For example, level 1 numeracy skills are a prerequisite to gaining NCEA level 1, 2 and 3.

At the time of writing the NZ qualifications framework includes three numeracy unit standards that must be completed for learners to gain a level 1 certificate (NZQA, 2024). The unit standards include:

- 26623 Use number to solve problems
- 26627 Use measurement to solve problems
- 26626 Interpret statistical information for a purpose

Each of these units include aspects that adults with dyscalculia have difficulties with. Unit 26623 requires learners to solve 3-digit arithmetic problems, a specific difficulty associated with dyscalculia. Furthermore, this unit requires learners to make calculations with decimals, fractions, and percentages. Learners can use calculators to solve problems but must explain the reasonability of their answer which requires number sense and estimation skills.

The measurement unit requires the use of estimation of length, weight, and volume and use of measurement tools such as measuring tapes or cups. Again, these are the areas of difficulty an adult with dyscalculia will have. The statistics unit requires interpretation of data, yet the ability to do so is predicated on reading data in various forms. This is not meant as a criticism of the units, but clearly the requirement to achieve this to gain the most fundamental qualification severely disadvantages adults with dyscalculia.

To summarise, adults with dyscalculia are highly vulnerable to a range of negative outcomes, including social exclusion, poorer mental and physical health, financial difficulties, and difficulties meeting workplace numeracy demands. In addition to this, the formation of negative beliefs about oneself as a learner may lead to avoidance of learning opportunities, and negative emotions, such as maths anxiety, may lead to poorer learning experiences when learning is undertaken. Vulnerability is not seen as a dichotomy but rather as a continuum. Adults with dyscalculia may not be excluded, but are certainly vulnerable to exclusion, and as the above sector details, the vulnerability runs across health, financial, and personal identity domains.

Hearing from adults with dyscalculia

Surprisingly, there is little research on the lived experiences of adults with dyscalculia from an adult's own perspective, a key gap in the research that this study seeks to remedy. What research that could be found is included below.

Research that has asked adults with dyscalculia to share their challenges has found that school was a formative and difficult period for them (Blackburn, 2003; Drew, 2015; Hosseini, 2020; Trott, 2015; Vigna et al., 2022; Whitten, 2018). Many of these challenges relate to negative emotions, isolation, and despondency with mathematics that extend into adulthood. For example, one adult recounted an early school experience of not being able to recite times tables in class, “Hot tears would run down my cheeks and I’d creep away feeling stupid, angry, miserable and very, very alone” (Blackburn, 2003, p.1). Whitten (2018) found that school experiences remained deeply emotional and persisted well into adulthood, with one 46-year-old man breaking into tears recalling an argument with a teacher in primary school. Adults also reported feeling isolated. Whitten recorded a young man talking about his last day at school, “I just walked out so mad, sat on the rugby field and had a ciggy. Everyone else was in class. Just me, and I never went back.” Whitten also found that many adults finished school making the decision that maths was not for them:

> “And here’s me getting dragged up from town to town to town, and every different school has a different way of teaching. Well, I’ve been trying to get my head around all these different ways of teaching, and I just gave up. I just totally gave up on everything. Maths, I didn’t, I had no time for maths. Straight up, I had no time for maths.” (p.188).

Vigna et al., (2022) found that adults with dyscalculia recalled a range of negative emotions while at school, such as tension, frustration, and anger. They also reported psychosomatic symptoms, such as stomach aches and insomnia due to stress.

Adults with dyscalculia report difficulties with everyday numeracy tasks. These tasks include adding the price of items when purchasing, checking whether the amount of change is correct, or working out a discount on a purchase price (Trott, 2015; Frye, 2020; Vigna et al., 2022). Hosseini (2020) also found that several adults with dyscalculia reported having difficulties counting, paying and receiving cash in transactions. One person reported using her debit card to avoid using and making cash despite the fees. In another case Trott (2015) reported that one adult always paid with a purple twenty-pound note, so that she did not have to make an amount with change. She reported her embarrassment amongst her friends which caused her to stop socialising with her friends. Vigna et al. (2022) also found that adults with dyscalculia had significantly higher error rates in a task that involved checking that returned change was correct, time management and estimation. Others reported leaving all financial decisions to their spouses due to difficulties (Hosseini, 2020).

Adults with dyscalculia often report difficulties reading analogue clocks, and having difficulties with time management (Drew, 2015; Trott, 2010, 2015). Frye (2020) found that some adults with dyscalculia misjudged how much time it took to drive to a location. Hosseini found that several adults found estimating time difficult. For example, one participant reported the process to catch a 4:00 flight. “If my flights at 4:00PM, I count backward… I have to be at the airport by 2:00 PM. I have to get dressed by 1:00 PM.” (Hosseini, 2020, p. 189). Moreover, Vigna et al. (2022) found adults with dyscalculia had significant difficulties with time estimation.

In summary, what we find from adults’ own voices is a series of challenges that interfere in real ways with their daily lives, across social and economic domains. Following is a review of strategies and strengths that adults with dyscalculia develop.

Strengths that may emerge from dyscalculia

Little research could be found on the strengths that adults with dyscalculia may develop in response to numerical challenges. However, there is some evidence that in some cases adults may develop agency skills, adopt and maximise technologies, and develop mental resilience and alternative creative skills.

One area of potential strength for adults with dyscalculia is the development of alternative strategies to meet numeracy demands, without having to mathematise. Mathematising refers to transforming numeracy situations/problems into mathematical solvable situations. Whitten (2018) found that lower skilled adults in numeracy classes used 'proxy agency' to meet classroom and task demands, dividing up tasks into different domains of responsibility. For example, adults divided up tasks based on various strengths in the group; higher mathematically skilled adults mathematised (turned the problems into mathematical equations), while lower skilled adults took responsibility for entering calculations into the calculator or filling in worksheets. Whitten observed that these adults, although not mathematising, still met the demands of the class, which were to solve problems as a group. In Bandura's (2006) terms, these adults were exercising their own agency through the proxy agency of intermediaries, as one would do employing an expert to complete a task. While Whitten noted that this does not result in effective numeracy learning, it did facilitate the goal, which was to solve the numeracy problems. A question raised in the study is, although proxy agency may not be effective in a learning environment, is it useful in a non-learning environment in which completing the task is the only goal? For example, is trading a numeracy task for a non-numeracy task, with a numeracy expert, a useful workplace skill? Is this strategy used by adults with dyscalculia?

There is research that suggest that many adults with dyscalculia can come to understand numeracy concepts and use numeracy in daily life, although they take longer to do so, require expert support, and sometimes develop understanding through atypical means (Trott, 2015). For those adults that do come to understand various numeracy skills needed for work and life, this suggests considerable persistence, resilience, and mental toughness. Research was found that suggested neurodiverse individuals who become successful by overcoming learning differences often did so by developing coping strategies to overcome challenges (Greenbaum, Graham & Scales, 1995; Heiman & Kariv, 2004). These individuals report that it is through a significant amount of effort and the belief in their ability to achieve that contributed to their overall success both academically and in the workplace (Ebo, 2016; Greenbaum et al., 1995; Heiman & Kariv, 2004; Madaus, 2006).

Finally, although not specific to dyscalculia, Shessel and Reiff (1999) identified five areas where adults believed they had benefited positively from having difficulties learning. They reported it had helped them to be a better person, allowed them to think creatively, increased their sensitivity to others, made them better professionals, and developed a desire to help others.

Technology

There is very little research exploring how adults with dyscalculia use technology to overcome challenges with numeracy. What little could be found was self-report data in which some adults with dyscalculia reported using calculators where possible, navigation tools such as GPS, online calendars (with reminders) to manage time, and several adults reported using software to help with large addition tasks such as Excel (Hosseini, 2020; Trott, 2015).

Conclusion

There is a large amount of research exploring the cognitive aspects of developmental dyscalculia. Although the studies are mostly conducted with children, adult studies suggest similar challenges, primarily challenges in the recognition of magnitude and quantity, arithmetic performance, fact retrieval, and a subsequent negative flow on effect to problem solving. Additionally, dyscalculia often co-occurs with other neurodiverse conditions and with differences in working memory performance.

There is a substantial body of research that finds negative outcomes for adults with low numeracy skills, and adults with dyscalculia. These outcomes include negative learner identities, beliefs and emotions, concerning mental and physical health outcomes, and disparate economic outcomes. Furthermore, employment challenges are also a serious factor, including difficulties completing tasks, the social implications of this, and unstable employment conditions.

There is far less research exploring the lived experiences of adults with dyscalculia and the challenges they face and the strengths they may develop. The experiences that are available reflect serious daily challenges that have serious impacts on social and economic outcomes. It is evident that having difficulties with numeracy in a world in which numeracy is embedded into the fabric of society is more challenging than most would appreciate. However, there is evidence to suggest that, in the face of challenges, many adults with dyscalculia develop a range of strategies and availing mindsets that offer advantages. However, there is simply not enough information to form a picture. This study seeks to fill some gaps by exploring the experiences, vulnerabilities, and potentials of adults with dyscalculia in Aotearoa New Zealand. It explores the unique challenges faced by adults with dyscalculia in the tertiary sector. What challenges do adults with dyscalculia experience and what strategies do they use to meet, mitigate, or avoid numeracy demands?

Sub questions:

- In what ways are adults with dyscalculia vulnerable to exclusion or difficulties in various contexts?
- What specific challenges do adults with dyscalculia have in daily life and the workplace?
- How do these challenges interfere with their desired outcomes?
- What strategies do learners use to cope with numeracy needs?
- What social, technological, or other resources do learners draw on to bridge learning needs?

2 Methodology

Participants
Participants were recruited via a request to organisations and neurodiversity networks for adult learners (>18) that had dyscalculia or had considerable difficulties with mathematics or numeracy throughout their lives. See example video clip: https://www.youtube.com/watch?v=rPMHmpeTrcQ

The request included that participants had persistent mathematical difficulties that were evident at an early age and continued to cause considerable difficulties throughout their lives. Thirteen individuals were interviewed for an average of one hour and ten minutes each.

Several people were not included following the interviews due to not having persistent difficulties with numeracy throughout their lives, rather their numeracy issues emerged in response to higher numeracy demands such as algebra in high school or statistical analysis as part of employment.

The participants came from a variety of backgrounds and ages. Three were male and 10 were female.

Table 1: Participant names and age range

Age range 20-30	Age range 31-45	46 +
Rawiri	Claire	Harper
Nigel	Sara	Karen
Alice	Julie	Mila
Penny	Kayla	George
	Paige	

Method
A semi-structured interview was used to explore participants' experiences, while being flexible enough to allow unexpected areas to be explored. Interviews were conducted in private with an approach consistent with Cicourel (1964), in that such interviews are a social event rather than a data transfer event. A focus was placed on rapport and trust, reducing nervousness or anxiety, and minimising the possibility of either party misinterpreting the other. Consistent with Chu-Fuluifaga and Ikiua-Pasi's (2021) talanoa approach the largest part of the interviews involved the participants sharing stories beginning with early experiences and moving toward current experiences in work and daily life. The interviews were relaxed and took the form of a conversation, with the interviewer asking questions and prompting for more information.

Participants were informed that, upon their agreement, the interview would be recorded, transcribed, and that names would be changed to a pseudonym. Additionally, audio recordings would be deleted following data analysis and all identifying content removed. Pseudonyms are used throughout this study.

Instruments

A semi-structure interview form was used that included the following sections:

1. Learning history including early childhood experiences, primary, intermediate, and high school experiences.
2. Affective responses, including, history of numeracy/ dyscalculia, evaluation of self-confidence, emotional responses, maths anxiety, beliefs about self and numeracy, attitude toward numeracy, family life, supportive/encouraging influences (parents, teachers, friends), school views and reflections as an adult.
3. Daily life and workplace challenges, including easy and challenging tasks, context, description of tasks, specific challenges, relationships with staff. Attitude to training opportunities, peers, new challenges, cultural influences.
4. Daily/weekly challenges of dyscalculia including; home, social settings, life tasks, approaches to challenging tasks, examples of clever thinking, overcoming challenges and advice to others.
5. Attitudes towards further training, approaches to independent or supported learning, hobbies, things you love, things you are good at, and how are setbacks dealt with.
6. Strategies used in daily life, strategies used to manage workplace tasks, mitigations, tools and technology, workarounds, and what strategies are used to learn new things. What have you learned, and what advice would you give to yourself as a child?
7. What would be useful, including educational support, technological support, resources, other.

These sections were moved through in a non-linear way but with an attempt to cover all areas.

3 Findings

Four broad themes emerged across the interviews. These were school experiences and the effect this had on learner identity, challenges with adult life, strategies and strengths and reflections on life with dyscalculia. These are reported on below.

School experiences

School experiences featured frequently in the participants' recounts, with vivid recollections of events, and frequent references back to school throughout the interviews. Four themes emerged within the topic of school: growing awareness of difficulties, trying to get by in class, blame, abandonment and the development of a negative learner identity.

Early awareness of difficulties
Most of the participants became aware that they were having difficulties with numeracy in their early school years. The difficulties usually became apparent during class activities and related to counting, adding, and fact retrieval tasks such as learning times tables.

> Nigel: Well, I think we were starting to learn how to add. And like, it took me a while, because the teacher would explain 2 plus 2 is 4. Like, and I would, I don't know for some reason, I just could never get it. Like, 2 plus 2, 2. Yeah, I'd always just have trouble with it, and I'd always have to count it out on my fingers.

Nigel noticed that the others in the class were not having difficulties.

> Nigel: The other kids got it quite easy. And it seemed, myself and another kid, we just couldn't. Yeah, some reason. It just didn't click.

The recalled events often related to having to answer questions in front of others in the class.

> Penny: And you would have to show, um, math. Things like the teacher would do like 'eight plus five', 'two plus two'. And I would be like, oh my god, this is going to be so embarrassing when it comes to me.

Difficulties with multiplication facts (times tables) were frequently referred to as an area where participants became aware of differences between themselves and others.

> Harper: But I couldn't, like even like the times tables. Yeah. You know, they used to sit in class and like chant them. Yeah. And people just chanted them by rote and others just like struggling to keep up.

> George: Back in the day you had to say the times tables and it was a competition. So no hiding cause if you didn't know it, everyone knew it.

Avoiding attention in class

All of the participants that attended school described their behaviours in class as designed to hide their difficulties with mathematics to protect against embarrassment and damage to status amongst their peers. The classroom environment they described was hostile to their self-esteem, confidence, and status, and the process of avoiding notice by others appeared to be a primary concern. Participants described employing strategies designed to minimise their public participation in mathematical events, such as reciting the times tables, or in later years, avoiding class altogether.

The strategies used to minimise public participation included pretending to understand, remaining quiet, sitting at the back of the class, avoiding eye contact with the teacher, copying work, or doing all work at home so that no one noticed the difficulties. For example, Harper described acting as though she was understanding to avoid attention from students and the teacher:

> Harper: And I was just like, I don't get it. And I kind of knew that I had to pretend to at least get it, in order to not look stupid.

Julie described being 'standoffish' because she was trying to avoid being asked a mathematics question by the teacher:

> Julie: Don't pick me. Don't pick me. Don't pick me. Yeah. Yeah. So, I'm the standoffish kid in the class. So, I never used to say anything. I just used to just, just not do anything.

When Mila was a teenager, she purposely misbehaved to be removed from class:

> Mila: I knew to wait until we were a good way through the class, and then start.
> Interviewer: And what did you do?
> Mila: Oh you know challenge him [the teacher], be difficult, and he'd send me out for the rest of the class.

Rawiri talked about making it through several years of high school without his teachers knowing he was not understanding the content:

> Rawiri: I don't think they ever found out.

In contrast to Rawiri's experience of not being noticed, Nigel recalled the moment when the teacher found out he was not, and had not been, understanding the mathematics. He described the moment of being caught copying off another student as his 'worst moment' in school. It is worth sharing the story here in full because it sums up much of the participants classroom experiences:

> Nigel: I hate to bring up a word 'cheating'. I was caught cheating in a maths test. When I came down to a maths test, I just, I panicked. And I'd always try and look over to the person next to me. And I'd get their answers.
> Interviewer: And what happened?
> Nigel: And I got caught once because theirs was exactly like mine. All of the problem solvings and everything. Yeah. Oh, god. I was about 13.

Following this, Nigel had to spend one-on-one time with the teacher over the next few days. He described this as 'a nightmare' because, despite the tuition he still couldn't make sense of the mathematics. Sitting with the teacher, and despite the teacher's efforts, not making progress was deeply embarrassing and awkward.

Others described sitting quietly, hoping to avoid detection for fear of being labelled as intellectually inferior to the other children, while also beginning to think of themselves as lesser. Terms such as 'stupid' and 'dumb' were used repeatedly.

> Penny: And I feel so guilty because I was like, oh my god, I'm so stupid. So that's what you think of yourself.

> Sara: [To avoid being embarrassed in class] I used to take it all home. So then I didn't have to do anything in class. I just sat there but didn't do anything.

Unsurprisingly, no participants that went to school enjoyed the experience.

> Julie: Yeah. I hated school, so I didn't want to be there.

> George: I just wanted out of the there from the moment I arrived.

Being blamed for not doing well in maths

In the context of specific events within school many of the participants described being treated as though they were to blame for not understanding specific aspects of mathematics. In many cases they reported feeling as though they were to blame.

> Julie: I had this principal at the time. And he just, yeah, it was so embarrassing… He was yelling at me because I couldn't get the maths. I couldn't, I couldn't do it. It was the long division. And I just couldn't get it and he was going, and then next minute I know he was yelling and screaming at me in front of everybody. Yeah. So it made me feel like crap.

The participants talked about the concern of getting into trouble due to not understanding or completing work.

> Karen: You know, like worrying about being told off because I wasn't doing my work. You should be doing this. Yeah. You know, I just, you just had real fear.

> Kayla: When I look back on it I had incredibly high levels of anxiety. And I would just put up a mask, a coping mask. And if the teacher would come around and ask you a question I would say "yes I can do that" but I'd sit there for hours agonising over it.

Likewise, participants recalled getting in trouble because the teacher felt that they were not trying.

> Penny: Like they sort of just maybe like got frustrated with me because they thought I wasn't trying, which felt really like, um, frustrated because like I was. But I just couldn't use that part of my brain to think as quickly as the other kids.

> Penny: She [the teacher] was really hard on me with it. Yeah. And like, I would just, I would just cry and just, I just wanted to go home.

Claire recalled getting asked to leave class because she had not completed her homework:

> Claire: I don't think it helped that he (the teacher) would kick me out. So, I'll get to class and he'd be like, "why didn't you do your homework?" and I'm like, I don't want to do it and he'd be like, you know, "go!" (leave the class).

In other cases, their parents would tell them off for not trying hard enough.

> Karen: But we're very old school and his way of trying to teach me to learn was simply to write stuff down and I forgot something. "Wrong!", and he'd whack me.

> George: Yeah they sort of saw it like you just weren't trying, playing up, and not doing what you are supposed to.

Nigel recalled a one-on-one tutoring session and how he perceived it as his fault that he wasn't "getting it":

> Nigel: That's getting more awkward. He explained it a second time and a third time. Nope. And then you get frustrated at that thing. Because, because you're not getting it. And that's my fault.

The expression by authority figures that the learner was to blame engendered feelings of shame in many participants. Shame appeared to be a result of comparisons with either other siblings, or against a perceived expectation of performance.

> Claire: I think my experience of math has been kind of covered over with like shame as well because so many family members all got on great, got 'As' and did so good.

Abandonment (feeling of being left behind)
A third theme emerging from school experiences was the feeling of being abandoned, 'given up on' or 'left behind' by the teacher, the class, and the school institution. For example, Karen described the teacher giving up on her, and because she was quiet, leaving her alone:

> Karen: So again, trying to be that quiet person. And they kind of left you. When I think about it now, they kind of left you if you were quiet. They kind of left your life really. Yeah. You just, you got left.

Rawiri described skipping class, and how this became more frequent as he became aware he was not going to succeed in that environment:

> Rawiri: Yeah, just not wanting to be a school. Yeah. So, it's not just me, it's like, I'm over school in general.

Mila described that the teacher had tried to help her, but after a certain amount of time it hadn't "worked", so now the teacher largely ignored her in class:

> Mila: I sat in the corner and he didn't even really make eye contact.

The implication was that the teacher was purposely sparing her from engagement because the teacher was aware of her difficulty.

The development of a negative learner identity
All of the participants used self-deprecating language to describe how they believed others perceived them, and self-deprecating to describe how they perceived themselves in school. Comments made were reifying, significant, and endorsed through the stories they told. For example, Paige stated that she is 'not smart' when reflecting on how she thought of herself during school:

> Paige: I'm going to hate on me because I'm not smart, you know, it's just, it's a lot of like, self-doubt, your little voice, like putting you down and yeah, yeah, like that.

> Julie: And I always thought I was dumb. Yeah. And I was in [low level maths class] at high school. Yeah. Which was for the dummies.

> Mila: I mean they never said, 'cabbage maths', but we all knew it.

> Karen: It brought feeling of being scared, being dumb.

Participants often referred to comments made to them by significant adults. For example, Harper recalled this comment from a teacher directed at her and her friend. This was a highly emotionally charged memory:

> Harper: Yeah. He would say, if you guys were sheep dogs, we would have shot you by now.

Harper made further comments about sitting down and being taught maths by her father:

> Harper: And so, he would just explain things like the same way over and over. Like that's going to help and just get louder and louder. And I would just absolutely lose it and burst into tears… I just know that I'm stupid at maths, so that's fine.

Other comments revealed how participants viewed themselves:

> Paige: Like, I just thought I was stupid. I, my whole upbringing, I thought I was stupid."

> Alice: I'm absolutely rubbish at maths.

> George: I knew I was a dummy, we just got kicked out in the end.

In several of the interviews, the participants' perceptions of themselves as 'dumb' was so extreme it led them to reduce their social connections and interaction with other people. This was to avoid other people judging them:

> Julie: I don't like talking to people really. I know. I know I can, I, I, I'm shy to start off with you, see. But, um, I'm very weary. Yeah. I like, I'm sort of standoffish.
> Interviewer: What are you weary about?
> Julie: I don't know. I, I, whether it's me thinking, oh, they'll realise they're talking to a dumb person.

Interestingly, a key motivation for almost all of the adult participants interviewed was to prevent children with dyscalculia experiencing the same things as they did:

> Julie: There's something that needs to be done in schools and that. And to get the kids help because I struggled through school and I hated school. And yeah, it just needs to be more out in the open because hardly anybody knows about it.

> George: We want this next generation to be taught better. You know, to get away from this 'you're not one of the smart ones' stuff.

Challenges in adult life

All of the participants described significant challenges caused by difficulties with numeracy in adult life. This included difficulties with mathematics limiting their job and career options, doing numeracy in the workplace and daily life, and the social difficulties associated with this.

Decisions about career and job choices
The participants were asked whether their difficulties with mathematics had influenced their decisions about what work they would like to do, or what career paths they would have taken. Almost all of the participants expressed that they had not done what they wanted due to the numeracy demands.

> Paige: Yes, very much so. Very much so. It stopped me from doing a lot of things. I wanted to be living overseas, doing nursing and stuff like that and I just, yeah, nah, not a go. And that's something that I've wanted to do since I was a little like becoming a nurse… Um, I didn't think I was smart enough.

> Nigel: Well, I would probably be a nurse by now. Yeah. I've forgotten that [meaning given up on it]. So rather than being a nurse, I've gone and done this.

The participants were asked whether, with support they could learn the maths required for the various jobs. Alice had expressed a desire to work with animals and be a vet. She had decided that a nursing vet was more realistic and then discussed her hesitancy about pursuing vet nursing:

> Alice: … it does make me hesitant to go. Like, my friends with maths are kind of thinking about doing like vet nursing, but it's just too much study, too much math.

Alice was asked whether she thought she could learn the maths needed to work out dosages for medicines:

> Alice: I'm getting better at ways to learn it, but yeah, probably put a little bit, and I think I'd always, I'd always just struggle. You know, just with that stuff like that. If I was better in maths I might put the pressure on myself to do something like that.

Julie described how different her life would have been if she was good at maths:

> Interviewer: If you were good at maths do you think you would have done different things?
> Julie: I'd be blown away. I'd be doing everything. I'd be good. Yeah. I'd work in a shop. Yeah.
> Interviewer: Why do you not work in a shop now?
> Julie: Because of maths. And the money and that sort of thing. It's the money. It's giving the change out. Yeah. And I know each of the machines can do that. Yeah. But I still get confused with the buttons, of putting the numbers in and all that sort of stuff.

Julia went on to explain her preference for not working was due to the associated stresses and challenges:

> Julie: And I get anxiety. Yeah. Yeah. Yeah. My anxiety goes, pshh. Through the roof. I'd rather just be at home.

George described how the trades had been an option based on school performance:

> George: The only thing I could do was labour work, you know lift, build, bash and all that. But even the trades now you need maths. I would have done construction, something around building.

All of the participants had a preferred career path or job that they would have pursued had they been confident of meeting the numeracy demands.

Completing numeracy tasks in the workplace

All the participants expressed difficulties completing numeracy tasks within their former or current workplaces. Two themes emerged, first the complexity and variety of workplace tasks, and second, the social and emotional challenge caused by difficulties with numeracy tasks.

In regard to the complexity and variety of tasks, a wide range of workplace tasks was discussed, including weighing animals and calculating dosage rates, weighing people and taring scales, measuring out liquids and/or medicines in different contexts, handling cash, using spreadsheets or other technology, calculating dry stock per square area of paddock, telling the time, reading nutrition information, working out grams of protein needed for kilograms of bodyweight, reading out and recording three-digit identification codes, and counting tasks such as stocktaking. The participants reported how these tasks caused them significant stress, and embarrassment:

> Alice: Dairy farming, like everything is numbers. It took me a long time to be confident to match cow numbers and sheets. And I still get it mixed up. So you might have a cow 207 on the U tag and I'll go 'seven oh two'. I'll actually get my numbers the wrong way round. ... Then I'll have to go back and fix it, so that's taking me a quite a long time.

> Paige: Even when I was dairy farming, I used to have to look several times at the numbers because when we were tagging the cows, the numbers would swap around on me. Yeah. All the time. Yeah. And I'd have to reread, recheck, read up, you know, and even then I'd muck it up sometimes.

> Kayla: I can't do spreadsheets. Scared the living daylights out of me... And if I'm asked to do a spreadsheet, I will have a little mini meltdown and I'll just agree and go oh yeah I can do that. Yeah. But I can't.

Karen described difficulties with cash handling working behind the counter in a bar:

> Karen: When it comes to just dollars, you know, if you give me $10, I can give you $5. But if there's something like 35 cents, they're not going to get right change. Okay. And that's really hard.

> Paige: It was when customers dumped twenty dollars' worth of fuel and coins down on the counter in front of me. And I'd be taking about five, six minutes standing there, counting it again and again because I wasn't sure if I had it right.

These tasks created significant social and emotional difficulties for the participants in terms of embarrassment, status, and respect. All the participants expressed feeling that their difficulties with numeracy could, and often did, lead to other people thinking less of them. The impact of work colleagues thinking that they were 'dumb' was a painful and recurring theme. Participants talked about how other employees formed conclusions about their general intelligence based on their performance on numeracy tasks.

For example, Nigel recalled having to measure out liquids and an occasion of getting caught measuring incorrectly:

> Nigel: And I gave the wrong amount. Okay, I did get quite a slap on the hand for it.

Nigel went on to explain the embarrassment and shame associated with being asked why he measured out the incorrect amount and having to explain that he had ongoing difficulties using the measuring devices, despite everyone else having no problem. His comment, 'I did get quite a slap on the hand', was expressed with crestfallen emotion. The recalling of the story in the interview was upsetting for him.

Difficulties completing workplace numeracy tasks led to people attempting to hide their difficulties, which may have led to isolation in the workplace. For example, Paige shared how she kept a social distance from others at work because if they were to see that she struggled with various tasks they would look down on her:

> Paige: Because, yeah, it does affect you. You kind of don't get close to a lot of people at work too because you're like, oh, you're way better at this than me if you find out how, how bad I am. Like, yeah. Are you going to look down on me, you know?

Participants expressed how difficulties with workplace tasks affected their workplace autonomy and status.

> Julie: Oh, yeah. I was struggling all the time. Yeah. I've had to keep somebody to double-check me. Is that embarrassing or what. Yeah, it was. Yeah, I feel embarrassed.

> Harper: And my boss tried to teach it to me quite a number of times. And then essentially just gave up, and, and presumed that I had it. When I really didn't have it…

Harper found the pressure too much:

> Harper: … And I just went, "I quit!". And I quit. I just basically, seriously, I just sent out an email and it was a complete utter shock to them.

Workplace tasks were a source of anxiety for all of the participants.

> Paige: Like, you know, I even look at some of my, um, co-workers sometimes and I think, f**k, why can't I be like, oh, I shouldn't really swear, but why could I not be like you? You know, why can't it come easy to me?

In summary, the workplace presented a formidable environment for adults with dyscalculia in which to manage the numeracy tasks embedded into all roles. Even more challenging was managing/coping with the toll this took on personal status, autonomy, and work enjoyment.

Challenges with daily numeracy tasks
In addition to difficulties with the numeracy in workplace tasks the participants had significant difficulty with a range of daily tasks. These difficulties were described as frustrating and time consuming. For example, Nigel described trying to purchase two new tyres for his bike, but not being able to remember the numerical size:

> Nigel: I had an incident where I had to get new tyres for my bike. And I got, I thought I had done it right where my calculations were right and it turns out that two tyres later. Yeah. I just kept getting the wrong tyres.

Nigel bought the wrong tyres, spent money, and had to make multiple trips to the shop.

> Nigel: So it was like [the tyre size] one point zero eight oh, times twelve point eight oh. Yeah. And I'd go into the shop with that in my head and be like, I'll read the things on the box and I'll be, this one right? And then you just give up and you buy both and you go, well, if one doesn't work, you got the other.

Many of the participants talked about the difficulties they had reading analogue clocks:

> Harper: I can't read clocks with arms on them.

> Paige: Clocks! Still struggle with analogue.

> Claire: My cousins could tell the time real easy. At some point I was given a watch which I wore. And people would ask what's the time and I'd end up just showing them the watch.

Working out prices and discounts was also a challenge:

> Nigel: Filling up with gas, the litres. Mum asks me to calculate how much to put in the car. I'm like what. $2.98 a litre is something? I always get it wrong.

> Penny: What I struggle with in life is when I'm shopping. And it's like a 20% off or 50% off. And I'm like, oh, it's just like (puts her hands up), and then I look at the price and I'm like, so what's that percentage? And I read numbers wrong as well. That's another thing I do.

Seven of the participants expressed that paying for items using cash was stressful and embarrassing.

> Nigel: I hate paying in change. Yeah, that sucks. I try not to do it. Yeah, all. Someone's standing there. You've got a bunch of change in your hand and then you're like, they asked me to count it out. No! I'm like… 10, 20. Oh, it's like math's class.

Nigel described the demeaning situation in which a shopkeeper became impatient with the time it takes to count the change, takes the change and counts it themselves because it takes too long:

> Nigel: And then they just take it because you're taking so long counting out and they're like, 'give it here'.

The theme of embarrassment arose in the context of daily tasks. Not only were occasions of difficulty embarrassing but had ramifications for friend groups. Nigel mentioned the ongoing decisions about friend groups, stating that if a friend doesn't appreciate that although he has difficulties with numeracy he is still highly intelligent, it can be a difficult relationship to maintain.

> Nigel: I think… I'm more self-conscious about who I pick as friends. Yeah, okay. Because I don't. I don't want to be friends with someone who thinks I'm dumb.

Strategies, creative thinking, and attitudes to further training

The third theme was the strategies participants used to manage numeracy tasks, examples of clever thinking that participants engaged in, and general strengths that people had developed.

Strategies used to complete numeracy tasks
Many of the adults described strategies that they used in the workplace and daily life to manage or mitigate difficulties with numeracy. The numeracy tasks were divided between those with the discretion to delegate to another person and those that had to be completed by the adult with dyscalculia, such as a routine workplace task. Not many strategies were mentioned, but some examples were; breaking tasks into smaller parts, asking other people for help or learning support, getting people to double check work, or using technology.

When participants were unable to delegate various numeracy tasks to another person, such as some workplace tasks, they reported trying to break tasks into smaller parts to complete. For example, Paige recalled the challenge of counting high quantity items during stocktakes, such as packets of cigarettes. She would lose track of her count often:

> Paige: You get quite high, and you'd be like, oh! [meaning she forgot the count]. So what I actually do is I'd have a piece of paper and I'd count one certain area and then I'd write it down and then I'd count the next and then the next. That type of thing. Sometimes I'd even break the one area down into multiples of four or five or two titles or something. I'd just like separate them into bundles and then as I count them I'd write it down and then I'd put that back into the box. I knew that I counted it and then I counted the next bundle or that was out kind of thing.

Alice discussed her practice of double checking her work, or in her words 'triple checking' or 'quadruple checking':

> Alice: And if I do anything with the numbers, I'm always like absolute triple checking or like quadruple checking everything because I just would just miss a number out you know like something like that, so you've got to make strategies.

Alice also referred to repeating numbers aloud to the other person to act as a double-checking practice:

> Alice: And also saying out loud too. Like if you're calling them out, like Dad might call out like 370 and I'll go 'three seventy". I'm absolutely making sure that I have it right like because sometimes I'll "three zero seven".

The most frequent strategy for completing tasks that could be delegated to others was drawing on the expertise of others to help with numeracy tasks. These people were work colleagues or friends. For example, Harper discussed 'calling in reinforcements' when having to work through challenging numeracy tasks:

> Harper: My first reaction is, avoidance, totally. And my second reaction is to call on help, because I have got very many big brain friends, thank God. I think so you struggle to do something whatever it is. So you call in reinforcements.

> George: I usually get someone else to do it. They can do it twice as quick, so might as well.

Developing a network of friends who understood the person's difficulty with numeracy, who respected the idea that different people have different strengths, was important. Such people in the workplace were used by several people to double check their work in an informal way to avoid mistakes. Several participants built this into their workplace practice as a backup on their work.

> Mila: I'm happy to be the first as long as it goes further up the food chains or someone else checks my work. Well, they have to check my work.
> Interviewer: You have someone check your work?
> Mila: I've learned over the years to get someone I trust to do this.

Many of the participants reported using various forms of technology to support them. These included iPhones, timers and calculators. One participant in particular, Sara, utilised a wide range of technologies and was quick to adopt new technologies, applications and software as it became available. Rather than disliking Excel, as did most other participants, Sara used it for a variety of functions:

> Interviewer: What sort of things do you use Excel for?
> Sara: Anything, and everything. I love Excel. That's my best, best of all. Percentages, adding, subtracting. Yeah.

Sara described using automatic functions and writing formula. She also described using timers that can be set using voice commands:

> Sara: It's like a little screen that you'd say, that you say, 'hey, Google, just set an alarm or set a timer on here'. I could say, '11 o'clock', it'll just calculate the meeting and it'll come up.

This level of use of technology wasn't as high among the other participants but they all used forms of technology to help with numeracy related tasks. For example, Harper described using Excel not as a mathematical tool, but as an organising tool:

> Harper: I'm just like, yeah, love Excel. Yeah, because Excel's got sums and stuff in it. So I keep track of things on Excel. But that's more to sort of say, yes, I've got the invoice for this and yes, I've got the proof of purchase for this and that. So it's not actually checking the math side of things, it's not arithmetic. It's not adding that numbers so much. It's also that kind of pressure of when you're looking at things like, sometimes if you've got too much to think about, you know what I mean? Like the brain freeze is higher. you've ticked off a certain portion of things and you can look at your Excel spreadsheet and this is all shaded out.

The most common technology used was a Smart phone and several digital applications in particular, such as the calculator, the digital clock, and timer options.

Clever thinking and conceptual understanding

Participants were asked to give an example of a problem they solved or clever thinking they had engaged in. The results revealed sophisticated thinking skills and a high capability to get things done in the real world. Each of the participants shared an innovative solution strategy to a problem of some sort. For example, Harper shared a solution to a workplace challenge:

> Harper: When I have to do things, I work backwards. I try and leap forwards to the end result and then work backwards. So I find that kind of works.
> Interviewer: Can you give me an example?
> Harper: At my other job, we have these little life jacket things for people, and they're in different sizes. And the people will come in different sizes. And so you have to try and match the people to the size. And the size of the jackets is on a label, but actually there's about six different labels. And you've got all these kids piling in all at once. And it's just that you're trying to find something quickly. And so, seriously, I just need to be able to grab the jacket to fit the person.

Harper described an innovative approach to the problem of quickly finding the right sized jacket for the children:

> Harper: So what I've done is it's in kilos on the label. And I just kind of. I Googled average age versus kilos. And then I went through and then I took a marker in and on the actual inside of the jacket. I've written four to five years, two to three years, two to six years. So now you can just pick up a jacket and go... You look about five years. Here, have this one. Yeah. I was like, I just want to get to the point where I can just dish these out. Yeah. And I kind of was like, right, so there you go.

When asked to describe an example of clever thinking Nigel recalled how he needed to weigh a person in a wheelchair and then subtract the weight of the wheelchair:

> Nigel: I've recently learnt how to weigh the wheelchair bound people, you have to, you weigh them and you minus what the wheelchair weighs. And that's, I've found myself actually quite clever with doing that. And I learned how to, I eventually learned how to do it.

Others talked about such tasks as working out schedules to pick up children, cooking, and working out how to feed animals certain amounts each day.

The participants were also prompted to explain in increasing detail the numeracy tasks they had difficulty with to explore their conceptual understanding. Although there is limited data, most responses from the participants revealed a conceptual understanding of the tasks, but difficulties with the numbers.

For example, Alice, who had difficulties transcribing three-digit numbers, explained the concept behind a complex farm measurement with which she had difficulty:

> Alice: They work out the cover of the grass. And then you have to work out how much they're going to leave behind [cows]. And then you have to work out, so you take that away from the cover amount. And then you... And that gives you how much they should be getting in total. And you have to split that by the size of the paddock. And then you just round that block of 1,000 or something to get the number of steps or posts.

In conclusion, the participants gave examples of innovative problem solving and displayed solid conceptual understanding of situations.

Attitudes toward training and future education

Despite negative school experiences most of the participants had positive attitudes toward taking part in non-numeracy workplace training or further education. However, there was a tension between the ambition to gain new qualifications and the potential risk of not being able to learn the content. The risk was expressed as a general stress that resulted from having to learn content and meet deadlines, and also the potential for shame or embarrassment at being shown up as 'not smart' among the other students.

> Kayla: I'm looking at doing my Masters and professional practice on neurodiversity. So, it's something that really fascinates me um, but I'm too scared to sign up to do it yet because I don't know what the workload is going to be.

Paige was highly motivated to continue studying and yet was aware that some content might take her longer to learn than other people. This raised issues of potential shame or embarrassment associated with not learning as fast as others. A key concern was who the other students on the course were, and what support would be provided by tutors:

> Paige: And I'm scared to do it in case I don't retain it all. I'll muck it up. I get, yeah, I get too scared or something, I just don't know who's going to be on the course with me either.
> Interviewer: Do you think you've lost your joy for training?
> Paige: Yes and no in a way. I like researching, um, Viking and Greek mythologies and stuff like that. So if it's something that I'm really passionate about I'm into it, but it just takes me longer to do things. It's so like, this course, I had to do the foundation and then my level three for [name of job] assistant. Yeah. And I got through foundation. I just barely got through. But then I think it helped me because I already knew the atmosphere and my mate, he was doing the level three [name of qualification] and we had met on the level two foundations course. And so that helped me to go back to study because I knew he was going to be there too. So yeah, kind of, yeah, it does scare me to go and do study and training and learning.

Almost all of the participants referred to the need for strong support when engaged in study and saw it as a pivotal part of being successful. For example, Penny described how her mother was a strong and constant support who had helped her succeed in previous study:

> Penny: So she kind of understood the things that I couldn't do because, you know, she was sort of struggled in ways as well. Like, she really struggled in school as well with her dyslexia because people didn't know what dyslexia was back in then. And, she understood because she was always pushed too, like, the dummy classes because people thought she was dumb. She didn't make me feel stupid. She always made me feel very intelligent for anything, you know, any small task I'll do. She's like, yeah, you know, just a supportive person.

In contrast to the positive attitudes toward further training in non-numeracy contexts, participants were uncomfortable with the idea of engaging in numeracy learning opportunities. For example, Mila noted that she continued to avoid numeracy learning environments:

> Mila: So like even like, I'm old enough now I don't have to do it. You can't make me. So that goes with a lot of it. Like if it's required for my job, obviously I'll stumble my way through it, but it's not really part of the learning.

This related to a lack of confidence about learning the content.

> Mila: Yes. You know, like I can't, I can't help my 10-year-old with his work let alone my 15-year-old. You know, so I just I don't, I just I don't. I just assume I'm not going to get it, and I don't try to be perfectly blunt.

> Penny: Just like, you know, you're stuffed. It's just like, oh my gosh, you know, you can't do it. There's no, there's no, no way. And I just wouldn't do it, because I wouldn't want to suffer.

In summary, the participants used a variety of strategies to manage numeracy tasks. When unavoidable, some broke tasks into smaller parts and used another person to double-check their work. When avoidable, participants drew on the expertise of others to complete numeracy parts of the task. Participants provided strong evidence of clever thinking and problem-solving skills. Finally, the participants had positive attitudes toward non-numeracy training, but this was bounded by the risk of excessive stress and fear of potential embarrassment.

Reflections on life with dyscalculia

The fourth theme emerging from the interviews was the participants' positive reflections and attitudes toward themselves and life with dyscalculia. Despite the challenges presented in the previous three sections of the findings, the participants were optimistic about their goals, and each had hobbies and interests that they found joy in. The participants expressed high levels of empathy toward others with learning challenges, an awareness of their own children's progress and self-esteem, and an inclination to intervene on behalf of their children if necessary. When reflecting on life with dyscalculia, the participants discussed not letting dyscalculia influence one's self-worth and putting difficulties with maths in perspective with broader life experiences.

The participants shared that they had come to understand and accept that difficulties with numbers was a part of their lives, not their fault, and simply something to be managed. They were comfortable sharing that they had difficulties and would ask for help.

> Alice: [when I need help] I can just say now, that actually, I'm struggling. You know, and that's okay. My brain works differently. Because if you don't realise why you're like that, it's more horrible.

> Nigel: Well, maths isn't everything. It's not the be all and end all. It doesn't make the person stupid or dumb. They're smart in other ways.

Participants had matured to the point where they no longer worried about the opinions of others and expressed being more comfortable with themselves.

> Mila: But I'm also at the point now where it's like, you know, well, I just don't give a f**k. This is how it is. Sorry, I swear. I swear a lot. But yeah, like it's, I've looked like an idiot so many times before that this one time it doesn't even matter anymore.

These themes also emerged when participants were asked what advice they might give their younger selves. The comments were all uplifting, and focussed on being comfortable with themselves, and not seeing mathematical performance as indicative of broader life abilities. There were many comments regarding resilience and not being damaged by what were obviously difficult school experiences. For example, Harper's advice to her younger self was to see the experience of dyscalculia as a life lesson, and not to see mathematical ability as indicative of overall value:

> Harper: What would I say to myself? Do you know what Harper? You were okay. The rest of you was fine. And the rest of you was like 95%. So, just let it go. And that's just life's lessons. That's just learning life's lessons. Letting go is obviously one of the hardest of life's lessons.

Many comments were related to keeping a sense of perspective on the role of school in their lives.

> Harper: I think it's funny because school is built up as like this big thing that if you fail at school, that's life over. And then you actually get out into the world and you get a job and you can do the job. And you start earning money and you start paying bills and you go overseas on holiday and you start to earn.

> Julie: Just let it go. And don't stress. And don't stress. And don't give a shit about what anyone thinks. But I do, but I don't. It's hard not to, but you learn.

Nigel's advice to himself was to let him know that he can be successful:

> Interviewer: What advice would you give your younger self?
> Nigel: You can do it. Go for it. Do it. Don't worry about what other people are saying. You're not stupid you're not dumb.

Rawiri was asked if his confidence was better now than it was when he was at school.

> Rawiri: Way better. My self-confidence was down a lot in school. To a point where I didn't even want to do the work. I want to do things now. I'd say to myself, just get out and get to work. Find things you like to do.

The participants also stated that their difficulties with numbers had developed their determination to achieve various things and had increased the sense of reward when they solved problems or learned new things. For example, Alice, when asked whether she thought she had developed strengths said:

> Alice: I think so, I'm learning ways to work around it [dyscalculia]. And I've learnt to be slightly more confident in myself, and not to stress too much about it, and just try to make, just to make the best of it really. And also it gives you a bit of determination, a little bit too, because, you know, like, it's not, nothing comes easy, so you have to kind of fight for it a little bit, gives you a bit more, and you have a huge amount of appreciation for when you do get something right, rather than someone that just like does it every day, you know, easy as. I can say I did that, I worked that out!

Participants also expressed empathy for others with learning difficulties and an awareness of the need for support for them. For example, Kayla noted that if you are good at something they may have less empathy for those who struggle, but that she notices when people are not understanding what is being taught:

> Kayla: But I think if you're very good at something, you don't have a lot of empathy or patience. And there's a few of us within our team that are like whoa hang on a minute, we need to see what we can do to help these people. You know, what's that learner like? She'll [the tutor] write stuff on the board and she'll go "do you get it?" And the learners are going "No, we don't get it" and I'm sitting in the background going we need to support them better.

The participants who had children in school indicated that they were more involved in their children's education than their own parents had been in theirs. Additionally, they were quick to intervene if their children had difficulties, such as talking to teachers or employing private tutors. Furthermore, the participants with children purposely provided positive affirmations to their children.

A good example was Karen, who shared that her daughter had had difficulties counting the cash and change in her job but would not tell anyone. Karen was quick to provide support:

> Karen: My older daughter is the same. She's 18 now but started work at 14. So she works at a food place, and she was like struggling. She was like, "My god, mum, when they come in, I can't count the change". And I just went, "Honey, tell your boss. I can come with you if you want, or I can message him. Just let him know that you struggle with the change side of things. And have a calculator beside you at the, at the counter". And then her thing was, people will think I'm dumb. She eventually talked to the boss, and he got her a calculator. And she's just, she's good now. She's so good. She's been in the job 4 years. She's started when she was 14. She's 18. She's still there. And she's managing.

All of the participants described themselves as having developed emotionally and socially since school, by coming to terms with difficulties, and reflecting on their experiences.

In summary, despite difficult and painful school experiences, and continuing challenges in work and daily life, most participants had grown to recognise that numeracy was only one aspect of life, which could be overcome through resilience, drawing on the strengths of others, and maintaining a sense of proportion.

4 Discussion

The findings reveal that life with dyscalculia in Aotearoa New Zealand is a challenge, creates vulnerabilities, has serious implications for learner identity, limits employment opportunities, and takes a heavy toll on self-esteem and the emotions. While other studies have identified challenges for adults with dyscalculia in daily adult life, this study reveals a broader connection between challenges at school through to adult life challenges. It also reveals the very serious nature of dyscalculia across a multitude of domains. Given that dyscalculia research is dominated by cognitive research, this study fills in an important part of the broader picture of life with dyscalculia.

The experience of school had a profound impact on the participants. When asked why they had agreed to be interviewed, all the participants moved directly into their school experiences (except Alice who was homeschooled). The participants shared how they became aware that they were different from their peers at an early age, 'less than' in some way, and then attempted to hide this difference from peers and teachers. They described, in some cases, being blamed for not trying hard enough, then felt shame or embarrassment, and continued to feel deeply uncomfortable throughout their schooling. Threaded through these situations were personal stories of attempting to avoid being identified as not understanding, being caught, being castigated by teachers, having arguments with parents, and awkward and unfruitful one-on-one sessions with tutors attempting to bring them up to speed. These findings align with a growing body of research that the school experience of learning mathematics can be deeply distressing for many learners, but particularly for students with dyscalculia (Blackburn, 2003; Vigna et al., 2022). What we see in this study is that these learners receive the full brunt of these experiences.

The situation of a child feeling isolated in class due to not understanding the content, while the other children do, is not new (Blackburn, 2003; Turner et al., 2002), but remains deeply troubling. The participants described feeling the need to hide their difficulty with mathematics as long as possible from peers and teachers, which led to a period of 'trying to get by in class'. For example, Harper's comment, "I had to pretend to at least get it in order to not look stupid" shows her attempt to avoid others seeing the truth, that she was struggling with the content, because it would invite judgement from others. This situation, pretending to 'get it' by mimicking the behaviours of the other children, may act to push the 'true self' underground as the child attempts to present themselves as 'normal' all the while managing a range of negative emotions, and enacting behaviours designed to camouflage their difficulties. While they were working hard at appearing confident and learning, they were secretly anxious about being exposed, feeling less than the others, and waiting for the entire experience to end. What this classroom role playing does to a child is unclear and beyond the scope of this study, however it is clear it is not constructive to the goals of education. These findings shed further light on the negative emotions many children and adults have with mathematics education (Espina et al., 2024; Evans, 2000; Hannula et al., 2016; Whitten, 2018).

The effect of these school experiences certainly suggests the development of negative learner identities. Using Sfard and Prusak's (2005) model of identity, which the stories we tell are our identities, then all the participants in this study who attended school reported very poor identities upon leaving school. For example, reifying comments such as, "I just thought I was stupid. I, my whole upbringing, I thought I was stupid," reveal a person who had come to believe they were inept primarily as a result of their school experiences. Consistent with Sfard and Prusak's identity model, the participants had stories of deep emotional significance in which the participants were exposed, or found out, as not being mathematically at the level they were expected to be by peers or the teacher. As was the case with Nigel, who described his worst moment as being caught 'cheating' by the teacher (which in fact was an attempt to avoid more embarrassment), or Penny who recalled being unable to answer an addition question in front of the class. These stories provided the raw material with which they framed themselves as 'dumb' or 'stupid'. Interestingly, Alice who was homeschooled did not report feeling this way, suggesting that being homeschooled removes the comparison to peers that accompanies the classroom experience?

The negative learner identities, and the beliefs and attitudes associated with them, almost certainly lie behind the participants' trepidation to engage in further numeracy study. Consistent with international data, the participants in this study stated they were extremely hesitant to engage in further numeracy training, at least in a formal sense (Grotlüschen, et al. 2016). Most participants had a positive attitude toward further training in non-numeracy education and had high ambitions and goals.

However, their actual commitment to a course was underpinned by self-doubt, trepidation of the workload, fear of failure, and, most importantly, the fact that there are elements for numeracy in almost every vocation. This demonstrates how mathematics acts as a gate keeper to various life options. Participants were asked whether they would have pursued a different career if they had been good at mathematics and almost all of them enthusiastically said they would have, and described a preferred career or work area they had wanted to be in. These were vocations that included a reasonable level of numeracy such as being a nurse, vet nurse, or teacher. The perceived numeracy demands of the training was a barrier to engagement, with one participant summing it up, "I don't think I'd be able to do the maths". Thus, while participants want to pursue non-numeracy training the inclusion of numeracy still acts as a barrier.

The main concerns for participants enrolling in further training were the need for understanding and support of the other learners and tutors. In short, trusting relationships matter a great deal as to whether adults with dyscalculia undertake training or not. It appears that the school experiences, framed by memories of isolation, judgement, frustration, and shame, are the lens through which they see formal instruction. This underscores the need for good numeracy practice, with a focus on relationship building, trust building, whanaungatanga (a Māori concept meaning a commitment to relationship building developed through shared experiences and working together, leading to a sense of belonging), and expert skill in instructional approaches.

Safety from negative experiences must be at the forefront of any instruction, followed by all the elements of good practice, assessment, clear instructional goals, and evidence-based instruction. Organisations would benefit from implementing neurodiverse-friendly systems and communicating these to neurodiverse adults as part of marketing, to order to encourage adults with dyscalculia to enrol, as the decision to enrol appears to be a major barrier. However, once students were on the course, the organisations would then need to ensure the commitment to support was actualised. The danger of offering support and then these learners experience similar experiences to those they had at school would likely consolidate negative emotions and beliefs (Whitten, 2018). Unfortunately, not enough is known about the effects of high quality, vocationally targeted numeracy instruction for adults with dyscalculia. Nor has research explored the effect of supporting adults with dyscalculia to incorporate technological tools into their practice. These would be beneficial areas of research to pursue.

It is evident that difficulties with mathematics in school merge into difficulties managing numeracy tasks in the workplace. The findings on workplace numeracy raised two major concerns. The first is the real challenge adults with dyscalculia face completing numeracy tasks embedded into workplace roles. Consistent with the varied numeracy domains complied by McClosky (2007), workplace tasks reported by the participants included complex ratio tasks, such as calculating the amount of dry stock per square metre or working out dosage rates per kilo of body weight, less complex tasks of measuring liquids, to even less complex counting, recording counts on paper, and dealing with money. Also consistent with previous research (Vigna, et al., 2022), the participants had difficulties with all of these tasks, from transcribing three-digit numbers accurately to more complex ratio tasks. Although this is a limited study, it highlights a key difference between dyscalculia and general numeracy difficulties. Dyscalculia interferes with all number tasks (such as counting), not just those that at limits of the individual's numeracy skill.

The workplace findings also support other literature, suggesting that numeracy skills are becoming an increasing and complex component of employment (Tu et al., 2016). The participants of this study each gave multiple examples of the numeracy tasks required for their roles and emphasised that these tasks were important. There appeared to be an expectation from the workplaces that employees were able to complete these tasks personally and accurately. For example, all participants gave stories of recurring tasks, with which they had difficulties with and how these tasks were pivotal parts of their jobs. Additionally, these tasks were relatively high stakes, with serious economic or health costs associated with error such as measuring out dosage rates. Interestingly, only one person interviewed in this study stated that they got workplace support with their numeracy after being seen making a mistake (Alice). In the other cases, even after being reprimanded for an error knowingly related to numeracy, no support or training was offered or provided by the workplace.

The second serious concern emerging from the workplace was the social impact these situations had on the person. The participants repeatedly talked about the embarrassment associated with having difficulties with numeracy tasks, needing to rely on others, and in several cases receiving reprimands for making mistakes. Comments such as “I was struggling all the time. I’ve had to keep somebody to double-check me. Is that embarrassing or what?” reflect the social difficulty maintaining personal respect while also having to rely on others for help with workplace tasks. These findings build on those of researchers Blackwell, Trzesniewski and Dweck (2007) who note that people often view mathematics as indicative of general intelligence, leading to embarrassment or shame when they struggle with tasks that they assume others can complete. Our perceptions of others’ thoughts about us are highly influential, impacting our sense of self-worth (Dunn & Creek, 2015). Thus, adults with dyscalculia perceive, rightly or wrongly, that their peers are judging them as intellectually inferior when they struggle, and this appears to erode self-worth, and certainly erodes workplace happiness and satisfaction. Many researchers have stressed that an individual’s sense of self-worth and personal significance is essential to having a positive sense of location relative to others (Dunn & Creek, 2015; Habermas, 1984). This study suggests that dyscalculia has a serious impact on workplace satisfaction if employees with dyscalculia are not supported in the workplace.

Workplaces would benefit from recognising neurodiversity, such as dyscalculia, and implementing processes that enable employees to identify that they may need support with various tasks. Support should include awareness raising for all employees to remove the association between difficulties with maths and general intelligence, thereby reducing the social cost of identifying oneself as dyscalculic. Furthermore, support, workarounds, and training ought to be provided where requested. This study suggests that difficulties with numeracy tasks are taking a high toll on the employee’s workplace wellbeing.

The findings shed some doubt on the strength building capacity of dyscalculia adversity in the domain of strategies and technology. One participant, Sara, used a wide range of technology to support her numeracy skills and was a quick adopter of new technologies. She referenced using voice activated technologies, timers, measuring applications and even used Microsoft Excel. However, the other participants spoke little about using technology to compensate for or overcome numeracy challenges beyond reading time in a digital format. This suggests there is much potential for the use of technology to support adults with dyscalculia. Two areas may be worth researching; one, new technologies for adults with dyscalculia, and two, methods of disseminating these to the dyscalculia community (see recommendation bullet point six for more details).

There were very few strategies used by the participants to manage numeracy tasks. The participants reported some strategies, such as breaking tasks into smaller easier parts, and drawing on the expertise of others when someone was available. Yet, there was little evidence of a systematic way of dealing with numeracy tasks. A fruitful area of research may be the impact of teaching adults with dyscalculia strategies for how to approach numeracy tasks in addition to developing numeracy skills. For example, Ako Aotearoa's 'Knowing what to do when you don't know what to do' strategies might be adapted for such a purpose.

The participants showed enhanced awareness and empathy toward others who struggled within the education system or the workplace. For example, one participant said, "they need to know they are not dumb", referring to children in school. There were also indications of working participants taking a more agentic approach to their learning than when they were at school. In particular, the participants who had children were highly alert to their performance in school, and quick to intervene when they sensed support was needed. These participants made appointments with teachers, employed private tutors, and were very careful to ensure their children did not adopt negative beliefs about themselves. They used phrases designed to avoid the inculcation of negative beliefs they themselves may have suffered from as children.

An example of raised awareness and empathy was evident in the way Karen coached her daughter in her job in retail. Her daughter was highly discouraged due to difficulties counting and returning cash, enough to want to leave the job, and expressing that she felt 'dumb'. Karen encouraged her, provided positive messaging, and together they approached the manager to find a solution. Part of the solution was to use a calculator behind the till, ignore the social pressure not to use it, and push through the learning curve. Karen stated that her daughter had continued working at the shop successfully for four years. Without overstating it, if Karen's daughter had not had the support, and had left after the first few embarrassing days, she may have never developed the confidence to take more challenging roles. Karen's intervention, due to her own experiences, may have led to the development of positive beliefs, confidence, and life trajectory. That is a strength emerging from dyscalculia.

Limitations of the current study

This study was designed to identify broad areas associated with the lived experiences of adults with dyscalculia with the purpose of sharing these and identifying areas for further research. The use of interview data, while appropriate for the purpose, is subjective and cannot be extrapolated to wide populations. A variety of further research designs and methodology is recommended to advance knowledge in the field of adult dyscalculia. Further thoughts and recommendations are made below.

5 Recommendations

International research on adult dyscalculia is continuing, albeit slowly, to inform educators on how they might best support adults with dyscalculia. However, the New Zealand tertiary sector, workplaces, courses, educators, and adults with dyscalculia would benefit from context specific, targeted, research. This needs to be followed quickly by clear practice-based strategies that educators can implement. Thus, two aspects are required, a research and development process and a coordination and dissemination process. This section outlines recommendations that can be implemented in the tertiary sector, and second, research questions that arise from the findings of this study.

Recommendations for the tertiary sector

The first recommendation is the development of a New Zealand Dyscalculia Knowledge Hub that can act as a central point for coordinating the efforts of various experts, providing a central point for information, and coordinating and disseminating research.

Potential features of a knowledge hub:

- First, the Knowledge Hub would be a central site providing information to New Zealand workplaces and educational organisations. It would provide state-of-the-art information and interact with supporters and educators of other neurodiversity communities.
- Second, the Knowledge Hub would present good educational practice. These would be drawn from existing and new research, and contributions from practitioners and communities working in the dyscalculia space. There are pockets of excellent work being done across Aotearoa New Zealand that could be supported and drawn on. These communities could be supported to conduct case study research and share findings through the hub. Broader methodological studies would also be advanced. For example, Whitten (2023) provided an example of good practice being used successfully within a horticulture course. These types of case studies could be copied and built on by the wider sector.
- Third, the Knowledge Hub would store, collate, and present research for easy access by organisations, neurodiverse communities, and educators. Ideally, each study would include an ‘implications for practice’ summary ensuring value for practitioners.
- Fourth, the Knowledge Hub would present an updated list of research questions needing to be answered, and methodological support where requested. This would provide direction for new or existing educational researchers to design and conduct local dyscalculia research. There are research funds available to practising educators who may benefit from direction and support. This may also encourage the development of a New Zealand dyscalculia community.
- Fifth, the Knowledge Hub would provide specific support to workplaces. For example, advice on developing inclusive workplace designs, and specific training solutions where needed. Case studies could be developed and made available to inform companies.
- Sixth, the Knowledge Hub would provide information regarding new technologies and, specifically, how they can be used by individuals and workplaces to increase access and effectiveness for adults with dyscalculia. For example, new technologies, such as the ‘DysCalculator’ (Sharpe, 2024) could be disseminated to the sector or, the hub could provide information to equity workplace representatives on how to present information to employees in a dyscalculic friendly manner.

Recommendations for future research

This study has identified several research areas that would be valuable to explore:

— How do we encourage adults with dyscalculia into further education that is appropriate and able to meet their needs? The findings indicate that adults with dyscalculia have ambitions to undertake formal training but are concerned about the associated risks of failure and/or being shamed or embarrassed. The findings also indicate that adults with dyscalculia value safe environments, and therefore trusting relationships with peers and tutors is essential. What are the best ways to ensure these values are communicated and actualised in both workplace training and formal organisational courses?

— What types of instruction work and what don't? What types of training, approaches, and instructional strategies are most effective for adults with dyscalculia? How can these be tailored to help learners deal with their specific daily or workplace numeracy needs? As it stands, the international intervention data is idiosyncratic and there is little that can be generalised into general adult practice. Methodologically high-quality adult educational studies are notoriously difficult to undertake. Controlling for variables, including control groups and/or having homogenous samples are difficult to implement in adult settings. Yet, in the immediate term, a series of interventions with small numbers of adults would provide a beginning. For example, case studies that clearly describe a learner's needs, their specific vocational workplace numeracy demands, a methodical and progressive instructional plan, and a detailed measurement of progress would provide other educators good starting points.

— The sector would benefit from further research into the strategies that adults with dyscalculia use and how these might be improved or adapted. The findings revealed that the participants had few reliable strategies to tackle numeracy tasks in daily life or the workplace. A more extensive study into the depth with which adults with dyscalculia engage with tasks, the strategies they use, and how these might be built on to be more effective is recommended. For example, participants used technology to varying degrees, but in what ways might they use technology more effectively?

— What factors might encourage adults with dyscalculia to engage in personal numeracy study in their own time to meet the demands of workplace numeracy tasks? For example, can an Artificial Intelligence (e.g. ChatGPT) be given the contextualised numeracy task, such as using a measuring cup of the specific graduations and provide conceptual instruction and practice? If learners knew these options existed, would they use them and what level of efficacy would result?

— A recurring and yet unanswered question is how much numeracy progress can an adult with dyscalculia make when provided with high quality assessment, instruction, support, and resources? A positive and optimistic approach should be taken, based on the high intelligence of the participants in this study, the technology that exists, and evidence-based instruction. Any one of the participants in this study could form the basis of a study that takes account of workplace numeracy tasks, the learner's current numeracy skills and knowledge and quality support at an affective and cognitive level. The benefits to the people in this study would be immense.

Recommendations for policy

It would be beneficial to launch a public awareness campaign to inform the public about dyscalculia, its effects, and the challenges and strengths faced by many adults. The aim would be to reduce stigma, increase understanding, and provide public support, leading to supportive workplace and training environments. An additional aim would be to attract educators wanting to specialise in supporting adults with dyscalculia.

It is highly recommended that policy be developed to support the professional development of educators and employers in the domain of dyscalculia. Adults with dyscalculia would benefit from educators and employees being equipped to recognise and support adults with dyscalculia in training and the workplace, and to provide accommodations and support. More important, however, is the ability to link the learner/employee to effective numeracy support. To achieve this, the sector needs to develop numeracy instructional capability, that is, available specialists equipped to work with adults with dyscalculia. Professional development opportunities do exist, and are being developed (See Ako Aotearoa, 2024), however, direct policy support from the Tertiary Education Commission regarding professional development expectations would be a benefit.

6 Conclusion

The findings of this study suggest that adults with dyscalculia are vulnerable to poorer life outcomes. Although dyscalculia is specific to number, societal attitudes view mathematical difficulty as indicative of broader difficulties. Coupled with a school system that magnifies this societal effect, these individuals face significant challenges to their sense of self, and to their progress through education and employment. Talking to adults with dyscalculia about their life experiences reveals the depth of the challenges they face, the impact it has on their self-esteem, the limiting effect it has on schooling and employment, and the accumulated emotional toll. The findings of this study diminish any argument that dyscalculia is not a significant issue for the lives it influences. The adults interviewed in this study are resilient, intelligent, ambitious, creative, and have fully immersed themselves in the experiences of life. Simply put, it would benefit society in general to smooth the educational and employment path enabling them to flourish, for all our sakes. Their creativity, empathy, strength, and input into society is essential for all of us to flourish.

This study started with the Māori whakataukī, ‘He aha te mea nui o te ao? He tangata, he tangata, he tangata!’. What is the most important thing in the world? It is people, it is people, it is people.

Let’s heed the message and work to make the world a better place for adults with dyscalculia.

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Appendix

The triple code theory
It is worth reviewing an influential cognitive theory of number processing because it provides a framework for much of the dyscalculia research findings. The most influential model is the 'Triple Code Model' (Dehaene & Cohen, 1995). This model posits that the brain uses three distinct representational codes for numerical information that are each supported by three regionally and functionally distinct neural substrates. To put this more simply, the human brain has three different systems it uses to work with quantities, and each of these uses its own separate neural pathway.

The first is Approximate Number System (ANS). This system uses analogue magnitude representations to make estimations, approximate calculations, and discrete quantity representations. A key distinction here is that this system does not count one to one but makes rapid estimations of quantity. This system is used when an individual makes a rapid comparison between two quantities. For example, an individual may be asked to quickly decide whether more yellow or blue dots are on the page (see Figure 2). The individual does not count but uses their ANS to make a decision.

The second system is the Arabic Number Form which supports the processing of visually presented numbers. This system is in use when a person sees and mentally computes a calculation presented as numbers. For example, 22 + 37. The individual must know what the numerical symbols mean and then be able to mentally manipulate them as symbols. Again, this system is widely considered to be a distinct system.

The third system is the Verbal Word Frame which is in use when a person draws on verbally mediated operations like counting, naming numbers, or automatically recalling number facts. For example, the memorised phrase "five fives are twenty-five" is considered a memorised language unit. As children memorise common addition facts (5 + 5 = 10) and times tables (5 x 5 = 25) they add to their number facts knowledge.

The three 'codes', (Analogue Number System, Arabic Number Form, and Verbal Word Frame) are all used as children develop their mathematical knowledge. Below we review the cognitive differences dyscalculic children and adults experience in each of the codes.

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