Comparing digital and non-digital executive function assessments with Chinese children with autism spectrum disorder

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Abstract

Traditional assessment methods such as paper-and-pencil tasks have long been used to assess cognitive functioning. However, they may not fully reflect the unique cognitive characteristics of children with autism spectrum disorders (ASD). Digital tools with interactive and adaptive features provide an alternative by delivering a more engaging and accessible assessment that is promising. This study investigated the comparative effectiveness of digital and non-digital task modalities in assessing executive functioning (explicitly working memory, cognitive flexibility, and inhibitory control) in children with ASD. The study involved 11 children with ASD, aged 6-12 years, who completed both digital and non-digital tasks to measure their performance in these cognitive domains. The two research questions for this paper are RQ1. How does task modality affect executive function performance in children with ASD? RQ2. Are there modality-specific strengths and challenges observed in children with ASD when they are not able to perform well on these tasks? The study used a mixed methods approach, combining quantitative performance data with qualitative insights from teacher interviews. Results suggest that while there were no significant differences in overall performance between digital and non-digital modes, digital tasks exhibited strengths in maintaining engagement task completion for children with ASD.

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Chapter 1 Introduction

1.1 Overview

The shift in integration between enhanced educational and psychological assessments and digital tools is a huge breakthrough for children with developmental disorders such as autism spectrum disorders (ASD), whose cognitive abilities are sometimes misinterpreted due to the limitations of traditional assessment methods (Demetriou et al., 2019). ASDs are neurodevelopmental disorders that are characterised by social communication, persistent difficulties, restricted interests and repetitive behaviours (Demetriou et al., 2019).

These characteristics can present some obstacles and difficulties in the cognitive assessment of autistic children, as standard methods may not fully capture the unique cognitive characteristics of children with ASD. There is a growing need to explore alternative assessment models that are more responsive to the specific needs of this population. Digital tools that are interactive and adaptive are one such model, which offers possibilities. This is because they have the potential to maintain the attention of the child and avoid interaction with the child during the assessment process, thereby providing a more accurate assessment of children who might otherwise have difficulty completing traditional paper-and-pencil tasks.

1.2 Rationale for the Research

Traditional assessment methods such as paper-and-pencil tasks have long been used to assess executive functions such as working memory, cognitive flexibility, and inhibitory control. However, these traditional methods may not fully reflect the various cognitive characteristics of children with ASD, who often have difficulty maintaining attention and following instructions in non-interactive environments. Digital tools, with their interactive interfaces and adaptability, have the potential to increase engagement and provide more accurate assessments tailored to the specific needs of these children, as long as they are rightfully used and do not contribute instead to distractions or compete for children’s attention.

Despite the potential of digital tools, especially for autistic children, little research directly compares the effectiveness of digital tools with traditional, non-digital methods. Research by Chopra et al. (2021) suggests that digital tools' personalised, immediate feedback may benefit children with ASD. However, due to the lack of comparison of the performance of children with ASD in the two modalities, the present study aims to evaluate the effectiveness of a digital task modality versus a non-digital task modality in assessing executive functioning in children with ASD, which can support their cognitive and educational development.

The scarcity of comparing the performance of children with ASD on digital and non-digital devices can be attributed to the complexity and heterogeneity of autism. Autism encompasses a wide range of symptoms and varying degrees of severity, making it challenging to design studies that account for all differences (Miyake et al., 2000). Each person with autism may face unique challenges

in communication, social interaction, and cognitive functioning, which may affect their response to different types of assessments (Miyake et al., 2000). This variability calls for individualised research methods, thus complicating the generalisation of findings or the establishment of standardised methods that are applicable to a wide range of differences. As a result, research in this area remains limited and inconclusive, highlighting the need for more comprehensive studies to determine whether digital assessments have measurable advantages over traditional methods in ASD. Additionally, there is a need to further explore how these tools can be effectively integrated into educational and therapeutic settings to meet the specific needs of this population.

In conclusion, digital tools have great potential to enhance the educational experiences of children with ASD, but direct comparisons of the differences in the educational experience of ASD in the digital modality versus the traditional modality are few and far between at the moment. Comparisons based on digital and non-digital assessments and education can not only help to tailor more effective educational strategies, but also ensure that digital innovations truly meet the individual needs of children on the autism spectrum.

1.3 Aim of the Study

The primary aim of this study is to investigate the comparative effectiveness of digital and non-digital task modalities in assessing executive functions—specifically, working memory, cognitive flexibility, and inhibitory control—in children diagnosed with ASD. To address this aim, the study is guided by the following research questions:

RQ 1: How does task modality affect executive function performance in children with autism spectrum disorder (ASD)?

RQ 2: Are there modality-specific strengths and challenges observed in children with ASD when performing executive function tasks?

By comparison, the study seeks to determine whether digital tools offer a significant advantage in engagement, accuracy, and overall efficacy or if traditional methods remain just as effective. Additionally, the study will explore how familiarity with digital devices influences task performance, thereby contributing to the understanding of the role of technology in cognitive assessments.

1.4 Significance of the Study

The present study, firstly, fulfils a pressing need for more effective assessment tools that address the cognitive characteristics of children with ASD. The study aims to provide empirical evidence that can influence educational and psychological assessment practice by comparing numerical and non-numerical models. The findings may also contribute to the development of more personalised and engaging assessment methods, ultimately improving educational outcomes for

children with ASD. Additionally, the study's focus on executive functions—critical components of cognitive development—highlights its relevance to educational and assessment interventions.

1.5 Structure of the Dissertation

Chapter 1 describes the background, rationale, purpose, and significance of the study. Chapter 2 reviews the existing literature on executive functioning in children with ASD and the use of digital tools in cognitive assessment. Chapter 3 outlines the research methodology, detailing the study design, participant selection and data collection methods. Chapter 4 presents the results of the study, focussing on the comparison of the performance of children with ASD on digital and non-digital tasks. Finally, Chapter 5 discusses and interprets these results in the context of existing research, explores the implications of the results for theory and practice, and concludes by summarising the main points, identifying limitations, and making recommendations for future research.

Chapter 2: Literature Review

Section 2.1 Overview of Executive Functions

2.1.1 Definition of Executive Functions

According to Miyake and Friedman (2012), Executive Functions (EFs) are complex cognitive processes necessary for controlling goal-oriented activities and human behaviour. These abilities help people to plan, focus, retain instructions, and multitask effectively. Because of this, executive functions are often described as the brain's 'traffic control system' or 'command centre' that organises and manages a multitude of concepts and activities occurring simultaneously or rapidly (Miyake & Friedman, 2012).

EF refers to a wide range of cognitive activities, such as planning, working memory, attention, inhibition, self-monitoring, and self-regulation. Given the heterogeneity of EF across individuals, several hypotheses have been created to provide a more complete explanation of this complex notion (Miyake et al., 2000). These theories investigate EF from various theoretical viewpoints, each providing unique insights into the structure and organisation of these cognitive processes.

One of the most influential models, proposed by Miyake et al. (2000) and further developed by Miyake and Friedman (2012), identifies three core components of EF: updating, shifting, and inhibition. This framework points out that these components are interrelated, but they can be distinctly measured and influence behaviour differently (Miyake & Friedman, 2012).

As a cognitive mechanism, working memory helps to process temporarily and store information required for a variety of cognitive tasks, which helps people to remember and process information in real-time, which in turn helps to perform critical tasks such as learning, decision-making, problem-solving and language comprehension (Spencer, 2020). Working memory is a dynamic and adaptive system because, in contrast to short-term memory, working memory can update its content in response to changes in task demands or environmental conditions (Spencer, 2020). Working memory is significant to children's development and is closely related to children's thinking skills and academic success (Spencer, 2020).

Working memory was first conceptualised by Baddeley and Hitch (1974) as a system of multiple temporary information storage systems. The phonological loop, episodic buffer, central executive and visuospatial sketchpad are examples of these stores (Baddeley, 2000; Baddeley & Hitch, 1974). As the control centre for working memory, the central actuator oversees the entire system by directing and coordinating the actions of its components (Baddeley, 1992). The phonological loop comprises an articulatory rehearsal process that preserves verbal and auditory information and a short-term storage system for it (Baddeley, 1992). In order to manipulate and temporarily store visuals and spatial relationships, such as the placement of pieces and spatial interactions in a game of chess, one can use the visuospatial sketchpad (Baddeley, 1992). Finally, the episodic buffer, which was first described in later research, functions as a working memory subcomponent as well as an integrative mechanism that bridges the gap between working memory and

long-term memory by assembling data from long-term memory into a logical sequence (Baddeley, 2000).

Updating is a critical component of working memory in executive function. It essentially entails the ongoing process of observing and encoding new information pertinent to the task at hand and altering the information already in working memory by substituting more recent, relevant information for older, irrelevant information (Morris & Jones, 1990). According to Nyberg and Eriksson (2015), this updating capacity enables people to maintain the information they hold in working memory in an adaptable manner, ensuring it stays pertinent to their current tasks. In daily life, updating is essential. For example, it helps one remember the key elements of a conversation while ignoring minor or irrelevant facts, which makes the exchange flow naturally and logically.

The ability to withdraw from one activity and re-engage in another, or "task switching," is a fundamental aspect of executive functioning and is often called cognitive flexibility (Miyake et al., 2000). According to Miyake et al. (2000), shifting ability is essential in dynamic contexts where task needs might alter suddenly. It is essential for efficiently managing cognitive resources when faced with several simultaneous demands. For example, when preparing a multi-course dinner, a chef needs to manage several courses simultaneously, such as salad, dessert and main course. To optimise time, many of these tasks overlap, such as chopping salad toppings while baking a dessert. Cognitive flexibility is important to manage these different tasks without making mistakes, since it relies on shifting attention between various culinary activities. Cooks must frequently interrupt one task (e.g., baking a dessert) to switch to another (e.g., chopping a salad topping) as needed.

Inhibition is key to regulating behaviour, thoughts and emotions by intentionally suppressing automatic, dominant or instinctive responses (Miyake et al., 2000). This cognitive control process is essential because of the ability to adjust an individual's behaviours and responses in a given situation, which enables us to act thoughtfully and not just react according to instinct or habit. In short, there is a clear need for inhibition when the innate response may not be the most appropriate one. For example, during a meeting, if the display of a mobile phone lights up, the innate response may be to pick up the phone and check the alert message, which is a habitual behaviour. It is critical to restrain this behaviour in a timely manner, as it is inappropriate to check a mobile phone message during an important meeting. Thus, inhibition is critical for social transactions, efficiency, and overall cognitive health.

The model of executive function proposed by Miyake (2000) consists of three fundamental components: updating, shifting, and inhibition. These features collectively provide a complete framework for comprehending the complex interactions among the cognitive processes that support informed human behaviour and decision-making. The paradigm enables more thorough examinations of the separate but interconnected cognitive control functions of these three components, therefore offering valuable insights into the operational mechanisms of executive function.

Miyake's (2000) model of executive functioning emphasises the essential elements of these functions, and subsequent research has sought to build on this by examining inhibition, working memory and cognitive flexibility in a developmental context. Scholars have expanded on this tripartite paradigm, most notably Diamond (2013), by examining how these executive capacities emerge and change from early childhood onwards. Diamond's (2013) comprehensive study elucidated the developmental trajectory of these functions and provided insight into the important interplay between cognitive abilities and environmental inputs.

Furthermore, Dobell (2020) expanded on this concept by emphasising the plasticity of executive functions (EFs), asserting that these cognitive processes are highly adaptive and are primarily shaped by the environments in which children find themselves. Dobell (2020) builds on the basic ideas put forward by Miyake by further emphasising the adaptive nature of executive functions, mainly how children use these processes to achieve personal goals and adapt to their environment. By changing the emphasis on these adaptations, Dobell developed a better understanding of early childhood extroverted abilities, arguing that these abilities are independent cognitive processes and dynamic talents that emerge in response to the physical, social, and educational environments in which children find themselves.

According to Miyake's (2000) categorisation, executive functions comprise three basic components: updating, shifting and inhibiting. These components are independent and interrelated, each contributing uniquely to complex cognitive processes while overlapping. However, Doebel's (2020) research emphasises the adaptive nature of executive functions and their dependence on the surrounding environment, i.e. how environmental factors and personal goals influence children's use and growth of executive functioning. Doebel (2020) argues that EFs are not static abilities but rather adaptive talents that develop in contact with the environment and are influenced by the demands of tasks that are significantly influenced by the demands of the task. Children use these adaptive executive processes in order to accomplish personal goals, from academic tasks to social interactions. Therefore, cognitive processes and their interaction with the environment must be taken into account when studying executive functions.

In short, Miyake's (2000) model provides a systematic framework for understanding and measuring different executive processes.Doebel's (2020) approach considers the adaptability of executive functioning in relation to environmental conditions and personal goals.Doebel (2020) argues that perceptions of executive functioning have shifted from seeing it as a static ability to seeing it as a tool that children actively use to achieve certain goals, particularly in terms of adapting to and managing goals in the environment. Both of these approaches are critical to a deeper understanding of how executive functions are enhanced and refined across life stages and environments.

2.1.2 Development of Executive Functions

The evolutionary development of executive functioning (EF) is an intricate and multifaceted phenomenon that occurs at different stages of childhood and adolescence. While Miyake's (2000) model focuses on adults, Doebel's (2020) model is more comprehensive and emphasises the need to develop executive functions from a child's perspective. Therefore, it is critical to examine the developmental pathways by which each of the basic elements of executive function (EF), including inhibition, shifting, and updating, arise and mature from early childhood to adolescence.

The foundations of EF begin to appear very early in life, potentially even within the first year, and continue to develop as the child ages, with a significant boost in EF performance observed between the ages of 2 and 5 years (Best & Miller, 2010). Moreover, EF becomes increasingly complex as children grow, eventually reaching adult levels around the age of 12 (Ferguson et al., 2021). Much of the research on children's EF development is grounded in Miyake's three-factor model, which assesses children's EF functioning through tasks measuring inhibition, working memory, and updating (Miyake et al., 2000). Therefore, this paper will examine the developmental trajectory of EF by analysing these three components.

Inhibition, the ability to control automatic, dominant, and irrelevant responses to perform goal-directed behaviours, begins to emerge in the first years of life (Friedman et al., 2011). Young children are generally perceived to have limited self-restraint and often struggle to control their emotions or achieve delayed gratification, commonly reflected in their difficulty with not doing things they want (Friedman et al., 2011). Nevertheless, the development of inhibitory control in children began about nine months of age. Although executive function (EF) is not fully developed during infancy, it is observable in some manner (Holmboe et al., 2018). The capacity to restrain the desire to divert one's gaze from a stimuli when instructed indicates an early demonstration of attentional control. Preschool-aged children between the ages of 3 and 5 see a substantial improvement in their ability to regulate impulses and defer immediate satisfaction (Hughes, 1998).

Figure 1, presented in the study by Garon et al. (2013), illustrates the development of various skills underlying executive function (EF) in young children from 0 to 60 months. The graph highlights periods of rapid development and increasing complexity in these skills, indicated by dark shading. For example, response inhibition (RI) begins to develop around 18 months and shows significant progress through age 5.

Figure 1 Developmental Trajectories of Executive Functions from Infancy to Early Childhood (Garon et al., 2013)

Similarly, Holmboe et al. (2018) found that signs of working memory also emerge during infancy. Early interactions with the environment reveal an infant's ability to temporarily retain and utilise sensory information, which can be recognised as the first manifestation of working memory. Holmboe et al. (2018) demonstrated the emergence of working memory in infants as early as nine months, using specific experimental tasks such as the A-not-B task. In this task, the infants successfully memorised the location of hidden objects within a short period, suggesting that working memory is beginning to develop and is primed for further maturation.

Working memory and inhibitory control are two processes that are closely intertwined and often need to function together (Diamond, 2013). Specifically, during inhibitory control, individuals must suppress instinctual or impulsive reactions using information retained in working memory (Diamond, 2013). For example, in a classroom setting, a student might need to remember instructions to remain quiet during a group activity, which requires inhibiting the impulse to talk to classmates. In the context of working memory, inhibitory control plays a critical role by helping the individual suppress irrelevant thoughts or distractions, thereby enhancing the efficiency of working memory (Diamond, 2013). In essence, this interplay allows the individual to focus on the task.

Unlike working memory and inhibition, shifting is a more complex EF ability, with both working memory and inhibition contributing to cognitive flexibility (Garon et al., 2013). In other words, shifting builds on these foundational EF abilities and tends to develop later than the first two (Diamond, 2013). Cognitive flexibility, which includes shifting, involves more intricate cognitive

processes that require the support of both working memory and inhibitory control to alter an individual's thought processes or change perspectives (Diamond, 2013).

Shifting begins to emerge in early childhood in simple forms, such as within-dimension switching, which can be observed in children as young as two (Diamond, 2013). As children grow, their ability to switch tasks improves, along with the complexity of the tasks they can manage. For example, children around four or five can typically complete the Dimensional Change Card Sort (DCCS) task, which requires more advanced shifting abilities (Diamond, 2013). According to Garon et al. (2013), shifting is categorised into two types: a shift of the ATT set, which begins to develop around 32 months, and a shift of the R set. In summary, cognitive flexibility—a key component of executive functioning—is a dynamic skill that begins to develop in infancy (around 12 months) and continues to improve as the child grows, allowing them to handle increasingly complex task-shifting challenges throughout their lifespan (Diamond, 2013).

2.1.3 Development of EF in ASD children

ASD is a developmental disability characterised by restricted interests, repetitive behaviours, and difficulties in communication and social interaction (Demetriou et al., 2019). The effects and severity of ASD symptoms can vary significantly among individuals, hence its classification as a "spectrum" disorder. Symptoms typically emerge in early childhood and can impact an individual's ability to function in social, educational, occupational, and other aspects of life. While ASD is marked by its core symptoms, it also presents unique impacts on each individual, sometimes including exceptional abilities in visual skills, music, art, and learning (Demetriou et al., 2019). Although understanding of ASD has improved, its exact causes remain under investigation, with genetics, environmental factors, and early brain development all believed to play significant roles. What is certain, however, is that most individuals with ASD experience deficits in EFs, which are among the diagnostic criteria for autism. These deficits include impairments in working memory, planning, inhibitory control, and cognitive flexibility (American Psychiatric Association, 2013). Similar to neurotypical children, EF in children with ASD develops with age but does so at a slower pace and often in an impaired manner (Best & Miller, 2010; Vogan et al., 2018).

Due to the spectrum nature of autism, encompassing variations such as low-risk ASD and high-risk ASD, developmental pathways can vary considerably from one child to another, as suggested by the findings of St. John et al. (2016). What is clear, however, is that autistic infants often exhibit significant behavioural changes around 12 months of age, and ASD can be reliably diagnosed from around the second year of life (Christoforou et al., 2023). A comparison by St. John et al. (2016) between high-risk and low-risk ASD children found no significant differences in executive function (EF) and motor skills at 12 months but a significant divergence by 24 months. This indicates that the early developmental period between 12 and 24 months is critical for the emergence of EF deficits in high-risk children. Although the initial development of motor skills and basic EF may appear typical,

high-risk children begin to lag behind their low-risk counterparts as they approach their second year, providing evidence of the stage at which EF deficits start to manifest in children with ASD.

Section 2.2 Executive Functions in ASD

2.2.1 ASD and working memory

Working memory, the ability to temporarily retain and process information, is often severely impaired in children with ASD (Habib et al., 2019). These working memory deficits can profoundly impact their daily functioning and learning processes, contributing to learning disabilities, difficulties with behavioural regulation, and challenges in maintaining focused attention (Habib et al., 2019). Zacharov et al. (2022) summarised the research of Edmunds et al. (2021) and Pellicano et al. (2017), which found that children with ASD performed significantly worse than typically developing children on tasks used to assess working memory, such as the Corsi Blocks, Self-Ordered Pointing Task (SOPT), Hide and Seek Task, and Boxes Task. However, research findings in this area are mixed; while some studies report severe deficits in working memory among individuals with ASD, others have found little or no difference between individuals with ASD and their typically developing peers.

Contrary to the findings of earlier studies, Zacharov et al. (2022) found no significant differences in working memory performance between children with ASD and typically developing children under short and long waiting conditions. The performance of 3.5- to 7-year-old children on the Boxes task and the Spinning Pots task, as Garon et al. (2013) examined, also indicated no significant differences in working memory between 4- to 6-year-old TD children and those with ASD. Zacharov et al. (2022) attributed the differences in findings across different studies to variations in study parameters and task designs, noting that different WM tasks may impose varying levels of complexity and cognitive demands. To address these differences, Zacharov et al. (2022) employed a sophisticated eye-tracking approach that minimised reliance on verbal communication and motor responses, ultimately finding no significant differences in working memory performance between ASD and TD groups during tasks with short and long waiting periods. This suggests that, under certain controlled testing conditions, children with ASD may perform comparably to their TD peers in working memory tasks. However, as mentioned in the discussion, factors such as small sample sizes, gender disproportionality, and the difficulty level of the tasks may have influenced the results to some extent. Therefore, it is crucial to consider neurobiological factors that may support these observations for a more comprehensive understanding.

The frontal lobes have been closely associated with working memory in previous research, mainly through studies involving n-back tasks (Han et al., 2022). A significant study using functional near-infrared spectroscopy (fNIRS) provides compelling evidence that prefrontal cortex (PFC) functional connectivity is altered in children with autism, especially when working memory demands are increased. These findings suggest that impaired working memory in this population may be linked to altered PFC connectivity (Han et al., 2022).

In the Baddeley and Hitch (1974) model, discussed in Section 1, working memory is divided into two storage systems—the phonological loop and the visuospatial sketchpad—that support a central executive system. Much of the current research focuses on the impact of impairments in these two systems on working memory in children with ASD. Based on a meta-analysis of 28 studies on ASD conducted by Wang et al. (2017), it can be concluded that individuals with autism exhibit moderate to high levels of working memory deficits, with effects on both spatial and verbal domains. In addition, meta-analyses showed that the effect of autism on spatial working memory was more pronounced than on verbal working memory, suggesting that people with autism experience more obvious difficulties in spatial tasks.

The phonological loop is part of working memory and is used to store and process auditory and verbal information, and deficits in phonological loop functioning in children with ASD can take many forms, greatly affecting their language acquisition and academic performance (Whitehouse et al., 2008). These deficits typically manifest themselves in the form of difficulty repeating non-words, problems with verbal working memory, and difficulty following complex verbal instructions effectively (Jokel et al., 2020).

For example, when children diagnosed with ASD are assigned a non-word repetition task, such as ‘blibber’ or ‘floom’, they may struggle to accurately reproduce these sounds, often replacing or excluding syllables. The significance of this task is that it is independent of recorded linguistic information. Instead, it assesses children's ability to understand and reproduce new speech sequences, and therefore tests the raw processing power of the phonological loop (Jokel et al., 2020).

In an educational setting, challenges with verbal working memory can be illustrated by the following example: A teacher might give a series of verbal instructions for a class activity, such as "First, take out your painting supplies, then draw a big circle on your paper, and finally, paint the circle blue." A child with phonological loop impairments may forget parts of these instructions, perhaps drawing the circle but not painting it, because they cannot retain all the verbal information in their working memory long enough to execute all the steps sequentially (Jokel et al., 2020).

The game Simon Says provides further evidence of the difficulties faced by children with ASD when faced with complex verbal commands: in the Simon Says game, the player must follow multi-part instructions such as ‘Simon Says, touch your nose and clap your hands twice’. Children with autism may only touch their nose and forget to clap their hands. This difficulty is due to an impaired phonological loop with a limited ability to retain and sequence multiple verbal commands, which involves storing and processing information in the correct order (Jokel et al., 2020).

In children with ASD, deficits in the visuospatial sketchpad, which is mainly responsible for processing and keeping visual and spatial information, often result in challenges with reading and writing, spatial memory, and social interaction (Zhou et al., 2023). Children diagnosed with ASD may have difficulties in accurately tracking text during reading and writing, resulting in problems such as line skipping or reading in random sequence (Zhou et al., 2023). Moreover, defects in spatial

perception can impede a child's ability to comprehend items spatially, therefore complicating the task of arranging text on a page or interpreting diagrams and maps (Zhou et al., 2023).The impact on spatial memory is often evident in difficulty locating objects and understanding their spatial relationships (Zhou et al., 2023). These impairments can directly affect tasks that require spatial working memory, such as navigating through an environment or remembering the arrangement of objects.

The impact of facial recognition difficulties on social interaction is often evident, such as the inability to accurately remember and recognise facial features, which can lead to difficulties in social communication and interaction. Difficulty in storing and retrieving accurate facial information may impede successful social communication as it also affects visual communication and emotion recognition. As detection of and response to emotional expression relies heavily on facial signals, deficits in visuospatial perception can further impede children's ability to communicate emotionally with others, thus affecting their social and emotional growth (Zhou et al., 2023). Therefore, it is crucial to understand and attend to visuospatial perception abnormalities in autistic children to help them overcome difficulties associated with their learning environment and social interactions.

2.2.2 ASD and Inhibition Control

As with working memory, the findings mentioned above regarding inhibitory control in children with ASD compared to typically developing controls are contradictory, and the research remains ambiguous (Adams & Jarrold, 2009). Some studies have found no significant differences in inhibitory control between children with ASD and typically developing controls (Eskes et al., 1990; Goldberg et al., 2005; as cited in Adams & Jarrold, 2009). However, other research (Ames & Jarrold, 2007; Bishop & Norbury, 2005; Christ et al., 2007; as cited in Adams & Jarrold, 2009) has documented apparent deficits in inhibitory tasks among children with ASD. For example, Christ et al. (2006) found that children with ASD performed worse than typically developing children on the go/no-go task and the flanker interference task. Specifically, children with ASD responded more slowly in the flanker task under inhibitory conditions and made more errors on the go/no-go task, both suggesting difficulties with selective attention and inhibitory control. However, their performance on the Stroop task was comparable to that of the control group, indicating that children with ASD do not exhibit difficulties across all inhibitory tasks.

In the Stroop task, participants must name the ink colour in which colour words are printed, or vice versa, with the stimuli congruent or incongruent with the word’s meaning (Christ et al., 2006). Christ et al. (2006) found that children with ASD performed comparably to typically developing (TD) children in terms of response time (RT) and error rate. The control group exhibited similar performance levels to children with ASD, showing no significant differences in managing the task demands.

In contrast, the Flanker task, which requires participants to focus on a central stimulus while ignoring flanking stimuli that may be congruent or incongruent (Eriksen & Eriksen, 1974), revealed that children with ASD had slower response times in the inhibition condition compared to controls. The TD controls responded faster, suggesting that children with ASD have difficulties with selective attention and that TD children have better inhibitory control and selective attention capabilities (Christ et al., 2006).

The last task used by Christ et al. (2006) was the Go/No-Go task, which assesses motor response inhibition by requiring participants to respond to certain stimuli ("Go") and withhold responses to others ("No-Go"). The results showed that while ASD children performed comparably to controls on No-Go trials, they made more errors on Go trials. In contrast, TD controls made fewer errors on Go trials and displayed similar performance on No-Go trials compared to ASD participants, indicating that children with ASD face challenges with consistent motor response inhibition (Christ et al., 2006).

Some children with ASD exhibit similar inhibitory control to typically developing children in the Stroop task yet show significant impairments in the other two tasks, possibly due to the Stroop task's limitations in effectively measuring inhibition control (Adams & Jarrold, 2009). In the Stroop task, participants must follow specific rules and respond based on either the ink's colour or the word's meaning. This process also involves reading ability, which can influence the results and may not accurately reflect proper inhibitory control.

2.2.3 ASD and Cognitive Flexibility

Cognitive flexibility is a fundamental executive function that enables individuals to adapt their thinking and behaviour in response to changing environments, rules, or demands. It involves switching between tasks or mental sets, adapting to new rules or situations, and considering multiple concepts simultaneously (Leung & Zakzanis, 2014).

The various dimensions of cognitive flexibility are continuously manifested in daily experiences. For example, in an educational environment, this skill enables pupils to transition between subject areas or themes, incorporate new information with preexisting knowledge, and adjust to novel teaching approaches or resources. Cognitive flexibility in problem-solving allows individuals to perceive problems from several viewpoints, generate innovative solutions, and adapt tactics when first efforts prove to be ineffective. Furthermore, cognitive flexibility is crucial in social settings for comprehending and reacting to evolving social signals, participating in seamless dialogues, and adjusting behaviour to various social environments. For instance, it enables individuals to adapt their conversational manner so as to suit the context of their interactions with peers, professors, or family members.

Autisticchildren frequently encounter substantial difficulties in terms of cognitive flexibility as a result of fundamental neurological disparities (Leung & Zakzanis, 2014). The challenge is

apparent in their rigid commitment to daily schedules and reluctance to adapt; for example, if a child consistently walks the same path to school, they may have considerable difficulties if a deviation is necessary. Transferring between various places or engaging in different activities can be very difficult, sometimes resulting in heightened anxiety and behavioural problems (Leung & Zakzanis, 2014). Transitioning between classrooms or shifting from playtime to scheduled learning activities might elicit significant anxiety and behavioural impairments. Moreover, a significant number of persons diagnosed with autism exhibit concentrated interests in particular subjects or items. Although these interests can offer comfort and pleasure, they may also make it challenging for individuals to participate in activities beyond these interests (Leung & Zakzanis, 2014).

The various dimensions of cognitive flexibility are continuously manifested in daily experiences. For example, in an educational environment, this skill enables pupils to transition between subject areas or themes, incorporate new information with preexisting knowledge, and adjust to novel teaching approaches or resources. Cognitive flexibility in problem-solving allows individuals to perceive problems from several viewpoints, generate innovative solutions, and adapt tactics when first efforts prove to be ineffective. Furthermore, cognitive flexibility is crucial in social settings for comprehending and reacting to evolving social signals, participating in seamless dialogues, and adjusting behaviour to various social environments. For instance, it enables individuals to adapt their conversational manner so as to suit the context of their interactions with peers, professors, or family members.

2.3 Modalities of Task Delivery

Education plays a vital role in the development of individuals and societies by equipping them with the knowledge, skills and values necessary to successfully navigate the world and make important contributions to it. The effective dissemination of educational materials and the implementation of educational activities are essential to promote learning and the active participation of students. A fundamental determinant of educational effectiveness is the pedagogical model, i.e., the methods and tools used to deliver the lessons.

Technological progress and the transformation of educational settings have led to a progressive transition in teaching methods from the conventional in-person model to several technology-driven approaches (Chopra et al., 2021). In their study, Chopra et al. (2021) classified these instructional approaches into four distinct categories: Face-to-Face Classroom Teaching, Pure Online Teaching, Blended Teaching, and Flipped Classroom Teaching. In addition to traditional classroom teaching, the other three models are modern, technology-driven instructional methods that provide more adaptability and accessibility, fostering active learning to enhance students' comprehension and retention of material (Chopra et al., 2021). Significantly, this paradigm shifts the educational process from being teacher-centred to being learner-centred. By employing cutting-edge instructional technologies, instructors can generate more interactive, captivating, and tailored learning

experiences that address the unique requirements of each student (Cheng et al., 2019; as referenced in Chopra et al., 2021).

However, there are limitations and drawbacks to these new models, including technological challenges and the lack of in-person supervision by the teacher, which places greater demands on student self-regulation and motivation (Chopra et al., 2021). Traditional classroom teaching characterised by face-to-face interaction between teachers and students remains irreplaceable in some respects. The direct interaction and timely feedback it provides, as well as the presence of fellow students and the teacher, can significantly increase motivation and engagement (Wright, 2017; cited in Chopra et al., 2021). Despite the many innovative advantages of contemporary technology-supported pedagogical approaches, the traditional educational model remains indispensable due to its direct interaction, structured environment, and comprehensive student support. Given these mixed results, it is challenging to conclude which instructional model is superior. Each model has strengths and weaknesses, and its effectiveness will vary depending on the context and implementation.

Figure 2. Categorisation of Teaching Modalities Highlighting the Shift from Traditional to Technology-Based Models (Chopra et al., 2021)

2.3.1 Pure Online Teaching

Pure online instruction refers to the use of a digital platform to provide all instructional materials, communication, and assessment without any direct human interaction (Chopra et al., 2021). The main advantage of online instruction is the convenience of accessing course materials and completing assignments at one's own preferred pace regardless of the student's location. These adaptable features allow individuals to provide a customised learning experience by tailoring the material to their preferred learning method and pace. Since online courses are usually pre-loaded, students have the flexibility to access these courses at any time, from any location, and at any time as needed. According to Chopra et al. (2021), during the COVID-19 pandemic, when most institutions of higher education adopted online teaching as their primary method of instruction, significant drawbacks emerged, e.g. students' lack of self-regulation resulted in lower course completion rates and inadequate attendance.

2.3.2 Blended Teaching

Blended teaching, also known as hybrid learning, is an educational method that combines traditional face-to-face classroom teaching with digital media (Gerbic, 2011). This model combines the strengths of both physical and virtual learning environments to create a more flexible learning experience. According to Stacey and Gerbic (2009), blended learning enhances the overall teaching and learning experience by integrating these two environments. By incorporating computers into the "content," "place," and "time" of learning, blended learning expands the environment in which students learn, thereby extending the traditional classroom experience. For instance, by combining online simulations, role-playing, interactive problem-solving activities, virtual classrooms, and social networks, blended learning provides a more diverse learning experience (Hamilton & Tee, 2013). This pedagogical approach enhances flexibility while retaining the benefits of face-to-face interaction. However, because blended teaching merges online and in-person instruction, it also inherits disadvantages, which includes the need for students to be highly self-regulated (Hamilton & Tee, 2013).

2.3.3 Flipped Classroom Teaching

Flipped classroom teaching can be seen as a subset of the blended learning model as it also integrates computer-assisted content with offline instruction in a more concrete way (Cheng et al., 2018) In stark contrast to the traditional model of education, flipped classroom teaching subverts the traditional approach of learning in class and completing assignments after class. Instead, students are encouraged to learn the content at their preferred pace before class, allowing class time to be dedicated to discussion, problem solving, and application of learned material under the guidance of the instructor (Cheng et al., 2018)

Flipped classroom instructional techniques include online delivery of much of the course material while incorporating the participatory nature of live instruction (Chopra et al., 2021). This approach allows students to take advantage of the organisational and interpersonal engagement inherent in traditional classroom teaching and also provides students with the adaptability to access digital knowledge on their own, resulting in more efficient use of resources and time and a more flexible approach to the learning process.

For example, students can complete theoretical content online before class, freeing up class time for practical applications, discussions and collaborative work. Flipped classroom teaching combines the benefits of both online and offline teaching methods, but it also faces significant challenges in implementation. The creation and management of blended learning environments is complex and requires careful planning and coordination to ensure that online and face-to-face content is well integrated and complementary to each other (Gerbic, 2011).

In conjunction with instructional techniques, learning tools are essential assets that enhance the learning process from the student's standpoint. A wide range of resources, including as textbooks, teaching aids, laboratory equipment, and other conventional materials used by students, are included within these tools. The digitization of these educational instruments can offer pupils unrestricted access to vital information, therefore greatly augmenting their motivation and learning (Svendsen & Svendsen, 2020). Røsvik and Haukedal (2017) concluded that digital technologies in higher education can be classified into two primary domains: digital tools and digital media.

Digital tools cover physical objects and software programs that enable educational and instructional activities. Academic technologies refer to computers, software, mobile devices, and e-book readers that enable students to use educational applications, access online resources, and complete assignments (Røsvik & Haukedal, 2017). Conversely, digital media refers to a range of internet platforms and technologies that enable the exchange and cooperation of information, including cloud services, social media, blogs, and wikis. According to Røsvik and Haukedal (2017), these platforms enable students to store and exchange data from any location and to interact and communicate with other students or teachers in real-time.

Adopting digital technologies in education has brought numerous benefits, including enhanced digital skills, a deeper understanding of subjects, and increased opportunities for collaborative learning. These advancements have transformed traditional teaching methods, making education more engaging and accessible for students. Nevertheless, the implementation of these technologies has also presented certain challenges, such as guaranteeing equitable and unbiased access, managing potential interruptions seamlessly, and delivering uninterrupted support and training. However, despite these challenges, ongoing technical progress will undoubtedly broaden the range of e-learning and enable the development of more innovative and efficient tutorial approaches.

Discussions of various pedagogical models (e.g. online-only, blended and flipped classroom teaching) suggest that modern educational environments are increasingly reliant on digital tools based on approaches that show potential to increase engagement, personalise the learning experience and provide greater flexibility to meet the needs of a diverse range of students. In the field of education, digital tools are widely adopted for their ability to provide interactive and visually stimulating content that engages students with the material in ways that traditional methods cannot provide. This flexibility, such as blended and flipped classroom models, brings many benefits, such as adapting the pace of content to individual learning styles and creating interactive student-centred learning environments. The advantages offered by digitalisation can also be reflected in cognitive assessment, where personalised feedback, visual cues and engagement are essential for accurate results, especially when assessing complex skills such as executive functioning in children with ASD. By using digital tools in assessment, the same principles that promote learning in educational settings can be applied to improve the assessment process, ultimately providing more targeted and effective support for children with ASD.

2.4 Digital Assessment of ASD Children

Despite the presence of both advantages and disadvantages, the e-learning formats in the current wave of teaching methods have mostly a beneficial effect on students' education. Considering children with ASD, the potential advantages of e-learning may be even more significant than those for normally developing children. Empirical evidence supports the notion that children diagnosed with ASD tend to spend a significant amount of time watching television and playing on computers compared to their normally developing peers, thereby benefiting socially and cognitively (Cardy et al., 2009; Cardy et al., 2023). As previously stated, digital learning can be customised to suit specific requirements, providing adaptable instructional settings and on-demand scheduling (Chopra et al., 2021; Cheng et al., 2018). Therefore, e-learning may be especially suitable for children with autism in several aspects. The present half of the research will examine the distinct advantages and revolutionary capacity of digital tools specifically designed for the educational advancement of children diagnosed with ASD.

Before discussing the use of digital technology in the education of children with ASD, it is important to note that these children are often favourably disposed towards a variety of technological products such as computers, mobile phones, tablets and televisions. Studies have indicated that children diagnosed with ASD generally allocate a greater amount of time to screen-based activities, including movies, games, and websites, in comparison to their typically developing counterparts (Kuo et al. 2013; Mazurek & Wenstrup 2012; Cardy et al. 2023).

A study by Cardy et al. (2023) found that children and adolescents with autism devote a significantly higher amount of time to using technology, especially tablets, compared to their non-autistic peers. In addition, Cardy et al. (2023) also highlights that children with autism primarily use tablets for entertainment and derive more benefits from the social, physical, language, and emotion regulation skills developed by technology compared to children without autism. Furthermore, the study conducted by Mazurek and Wenstrup (2012) revealed that children diagnosed with ASD have a heightened inclination towards electronic entertainment, including video games and television. Hence, the allure of electronic gadgets for children diagnosed with ASD and their capacity to maintain focus can be advantageous in choosing material or software that is captivating and does not elicit rejection or adverse feelings.

While screen use can help children with autism regulate symptoms in several areas, Mazurek and Wenstrup (2012) found that children with autism use screens for an average of 4.5 hours per day, which exceeds the 1-2 hour limit set by the American Academy of Pediatrics. Additionally, a large portion of this screen time was devoted to gaming, which increases the likelihood that these youngsters will develop harmful gaming habits (Mazurek & Wenstrup, 2012).Cardy et al.'s (2023) research suggests that extended screen time may have more beneficial effects on children with ASD and their families, which is the opposite of the concerns about too much screen time. The opposite of

concerns about too much screen time. Therefore, it is important to take advantage of technology whilst minimising possible negative consequences to fully aid the development and daily functioning of children with ASD.

Built around the assumption that children diagnosed with ASD typically hold a favourable view of technological things, this study seeks to investigate the possible advantages that digital tools can provide to this particular group. One key benefit of digital tools is their ability to tailor the learning experience to precisely address the unique requirements of every child. The unique characteristics of digital technologies may offer specific advantages for children diagnosed with ASD by effectively addressing the unique difficulties and obstacles they encounter. The described symptoms include difficulties in social interaction, rigid and repetitive behaviours, increased sensory sensitivity, difficulties in identifying emotions, and concentration deficiencies (Stiller & Mößle, 2018; Murphy et al., 2014). According to Gentil-Gutiérrez et al. (2022), these difficulties can hinder their capacity to engage with their classmates, take part in classroom activities, and efficiently handle everyday responsibilities. Yet, the emergence of digital technology presents potentially effective remedies to tackle these distinct requirements.

As emphasised in the DSM-V, a fundamental symptom of ASD is the presence of language impairments, which have a substantial impact on many facets of life, resulting in communication deficiencies and misunderstandings (American Psychiatric Association, 2013). Although a growing number of children with ASD are achieving success in mainstream educational environments due to changes in curriculum practices, their social and communication difficulties often impede their complete integration into general classrooms and can worsen their academic difficulties (Zager & Shamow, 2005; as referenced in Boyd et al., 2015).

Given the communication difficulties experienced by children with ASD, it is crucial to investigate alternate and supportive methods to facilitate their learning and integration. A viable strategy is incorporating digital technology in education, which provides a variety of focused solutions to enhance the communication abilities of children with ASD. Augmentative and Alternative Communication (AAC) systems work particularly well for persons who are unable of verbal communication (Marshall & Goldbart, 2008). Proloquo2Go is a prime example of AAC technology, specifically developed to enable supported interaction with electronic devices. This program is a symbol-based communication tool specifically developed to assist persons who are unable to speak or have limited speech ability. The program provides a customised lexicon and an intuitive interface (Sennott & Bowker, 2009).

Augmentative and alternative communication technologies, ranging from basic image boards to sophisticated speech-generating gadgets, empower children to articulate their perceptions, requirements, and emotions. By offering a platform for children to engage more completely in educational and social settings, these tools facilitate daily communication and improve learning and social engagement (Calculator, 2009). Moreover, by integrating customisable features, these

applications can be tailored to the user's specific social context and communication needs, thereby improving their ability to interact meaningfully with others (Sennott & Bowker, 2009). This adaptability highlights the convenience and effectiveness of digital applications for children with autism, allowing for personalised communication solutions.

In accordance with Bandura's Social Learning Theory (1977), the process of learning heavily relies on the observation and imitation of behaviours. From a behavioural modelling standpoint, children with ASD frequently encounter difficulties in successfully socially communicating with others. Others may modify their communication style to be more concise and comprehensible to accommodate the communication challenges of these children, therefore restricting their chances to see conventional social interactions. The AAC system, such as Proloquo2Go, offers children with ASD a well-organised setting to observe and engage in expressive communication activities (King et al., 2014). By providing visual symbols and organised vocabulary, these tools enable learning in a way that aligns with Bandura's (1977) recommendations, enabling youngsters to replicate and internalise communicative habits.

Alongside the behavioural viewpoint, Calculator (2009) examines the function of AAC in educating children with impairments from the socio-pragmatic model. This paradigm highlights the use of language to accomplish well defined communication objectives, such as seeking information or expressing opinions through deliberate social exchanges. This approach promotes the integration of language instruction into daily encounters instead of segregating it solely within therapy sessions. The proposed model promotes the acquisition of language abilities in different contexts and emphasises that successful AAC teaching necessitates the establishment of environments that provide adequate communicative justification and chances to facilitate active engagement in interactions. (Calculator, 2009).

To summarise, the AAC system is a revolutionary instrument for children with communication problems who encounter difficulties in spoken communication, enabled by technology and improved educational and social settings. Applied AAC caters to the immediate communication requirements of persons with communication disorders and offers a well-organised setting for them to observe, practice, and internalise communication practices, therefore facilitating the bridging of the social communication skills gap. Although Augmentative and Alternative Communication (AAC) provides considerable advantages, it also presents noteworthy difficulties. One significant constraint is the challenge of implementing the AAC system in various situations, and incorporating it into earlier educational environments may have been particularly challenging due to the scarcity of extensive trials for reference (Calculator, 2009).

Nonetheless, the emergence of COVID-19 greatly expedited the progress of online and hybrid education methods, as traditional courses had to be swiftly converted to online platforms, and particular lesson plans had to be modified. Hernandez et al. (2023) proposed the inclusion of the Individualised Educational Plan (IEP) as a hybrid teaching method tailored for children with ASD.

Despite the difficulties linked to blended learning, this strategy has been applied in several contexts, illustrating its versatility and potential efficacy for children with autism. The IEP hybrid approach has played a crucial role in achieving IEP objectives and enhancing educational results during difficult periods, such as the COVID-19 pandemic, with satisfactory progress documented.

Figure 3. Example of Augmentative and Alternative Communication Tools (Proloquo2Go Communication Interface, AssistiveWare, 2019)
*This figure illustrates the user interface of Proloquo2Go, a communication application designed to support individuals with communication challenges, including those with autism spectrum disorder (ASD). The interface features various buttons for spoken communication, folders for additional words, and customization options to tailor the experience to the user's needs. The top bar displays the constructed message, while the bottom bar provides quick access to search functions, a keyboard, and settings for adjusting buttons and folders.

However, to ground this discussion in the present study, it is crucial to explore how digital tools can specifically support the assessment of EF in children with ASD. Executive functioning, which includes skills such as working memory, inhibitory control and cognitive flexibility, is a vital area of cognitive development that is often damaged in children with ASD. However, in order to ground this discussion in the present study, it is crucial to explore how digital tools can specifically support the assessment of EF in children with ASD. Executive functioning, which includes skills such as working memory, inhibitory control and cognitive flexibility, is a vital area of cognitive development that is often damaged in children with ASD.

The Early Years Toolbox (EYT) provides a relevant example of digital tasks designed to assess these cognitive functions. The research of the EYT tool has highlighted the potential of these tasks to provide a more engaging, flexible and personalised assessment experience (Howard & Melhuish, 2016). This link between digital tools and EF tasks is crucial, as traditional non-digital assessments often fail to meet the specific needs of children with ASD, such as difficulties with attention and socialisation (Gentil-Gutiérrez et al., 2022).

Research on EYT tasks for assessment highlights a key advantage of EYT over traditional methods: one of the main advantages of EYT is its engaging and age-appropriate design that minimises frustration and supports sustained attention (Howard & Melhuish, 2016). This is critical when assessing the executive functioning of children with autism, who may have difficulty concentrating or completing rigorous tasks. The EYT's visually stimulating prompts help to maintain engagement, while the reduced literacy and numeracy requirements make it easier to use. In addition, the reliability and developmental sensitivity of the EYT allows for a more accurate assessment of cognitive abilities, making it particularly suitable for children with diverse learning needs (Howard & Melhuish, 2016).

Another important factor is the nature of the interaction between the child and the task. Studies have demonstrated that children with ASD, particularly those with higher levels of screen use, are more comfortable and focused when engaging with digital tasks compared to non-digital ones (Cardy et al., 2023). Digital tools such as those provided by the EYT use interactive interfaces that can hold the attention of children with ASD more effectively than traditional paper-and-pencil tasks. This aligns with the present study's objective of comparing digital and non-digital task modalities to assess their effectiveness in evaluating executive functions in children with ASD. The potential for digital tools to improve task engagement and performance makes them a promising alternative to traditional assessments.

In summary, the general trend of integrating digital tools into education and assessment is significant for children with ASD, especially when assessing their executive functioning. The digital tools developed by 'EYT' provide a more flexible, interactive, and tailored approach to cognitive assessment that is better suited to the unique needs of children with ASD. By comparing digital and non-digital modalities, this study aims to understand how these tools can contribute to a more accurate and engaging assessment of executive functioning, ultimately providing better support for the cognitive and educational development of children with ASD.

Chapter 3: Methodology

Materials and Methods

3.1 Overview

This chapter outlines the research design, participant selection, data collection methods and analysis methods used in this study to evaluate the validity of digital versus non-digital task modalities in assessing executive functioning in children with ASD. This study also included a focus group with interviews with teachers and caregivers to gather qualitative insights into the use and validity of these assessment tools.

3.2 Research Design

This study conducted a comparative analysis between digital and non-digital executive function assessments for children diagnosed with ASD in China. The main goal was to evaluate the effectiveness of digital versus non-digital task delivery methods in assessing cognitive functions, specifically focusing on working memory, cognitive flexibility, and inhibitory control, and it employed a quantitative approach to measure and compare participants' performance across these modalities.

The study employs a mixed-methods approach, combining quantitative assessments of children's performance on digital and non-digital tasks with qualitative data gathered through focus group interviews with teachers and caregivers. This design allows for a comprehensive evaluation of the tools, considering the measurable outcomes of the assessments and the perspectives of those involved in the children's education and care.

3.3 Participants

Participants in the study included 11 children aged 6-12 years, all diagnosed with ASD, who were selected through purposeful sampling from a local school. Each child participated in three tasks designed to measure working memory, cognitive flexibility, and inhibitory control, each lasting approximately 10 minutes. The study was structured into two parts, ensuring that each child was directly involved in digital and non-digital tasks to compare their performance.

The digital tasks were administered via a tablet, requiring children to interact with images and shapes through touch. In contrast, the non-digital tasks involved similar cognitive demands delivered through paper-based activities. This dual-modality approach allowed for a robust comparison of how different formats impact cognitive task performance.

3.4 Data Collection

Quantitative Data: The quantitative component consists of assessing children's performance on three cognitive tasks in both numerical and non-numerical forms. The tasks were conducted in a controlled environment to minimise external variables that could affect performance. To control for sequential effects, the order of the tasks was counterbalanced, and breaks were scheduled between tasks to prevent fatigue and maintain engagement.

The instruments used in this study included:

- **Digital Assessments**: Tasks were administered via tablets, where children interacted with images and shapes through touch interfaces. These tasks were designed to match the cognitive demands of their non-digital counterparts.
- **Non-Digital Assessments**: Similar tasks were presented in a paper-based format, requiring children to perform activities like matching, sorting, or recalling sequences with comparable difficulty levels to the digital tasks.

In this study, the categorization of assessments is divided into two main groups: digital and non-digital. These categories serve as the foundation for exploring the cognitive capabilities of children diagnosed with ASD. To achieve this, the study focuses on three key aspects of executive function: working memory, cognitive flexibility, and inhibition control. By evaluating these cognitive domains through digital and non-digital modalities, the research aims to uncover insights into how the assessment medium influences the performance of children with ASD. Each task was designed to measure a specific cognitive function relevant to the study and to ensure that the difficulty level was consistent across all tasks of the same modality. For the digital modality, all the assessments are from the Early Year Toolbox (Howard & Melhuish, 2016). For all non-digital tasks, this study employed instructions from “Administering measures from the prior learning-related cognitive self-regulation study” (Meador et al., 2013).

Task 1: Working Memory Assessment – Mr Ant (Digital) and Corsi Blocks (Non-Digital)

- **Mr Ant (Digital)**

In the study by Howard and Melhuish (2016), Mr Ant task was utilised as a critical component of the Early Years Toolbox (EYT) to assess the working memory capabilities of young children. Recognising the limitations in existing methods, which often did not fully capture the dynamic nature of how children use working memory in real-world contexts, the development of the Mr Ant task was motivated by providing a more interactive and visually stimulating assessment environment (Howard & Melhuish, 2016).

This task directly adapts to Case's (1985) original 'Mr. Cucumber's task was designed to measure spatial and visual working memory, particularly in children. This task involves a straightforward yet engaging method where participants interact with a simple line drawing of a cucumber. During the assessment, children are presented with various features, such as colourful

stickers or geometric shapes, placed on specific cucumber image locations. Participants are expected to observe and memorise the placement of these features during a presentation phase.

Subsequently, the features are removed, and participants are tasked with replicating the arrangement by placing identical or similar items onto a blank outline of the cucumber. This exercise assesses visual working memory—retaining and manipulating visual information—and evaluates spatial orientation and processing abilities, requiring participants to perceive and remember the spatial relationships among various elements. Panesi and Morra (2019) categorised this spatial and visual working memory as M capacity and found that a certain level of maturation of M-competence enables children to perform executive control tasks more accurately.

The "Mr. Ant" task builds upon foundational memory assessment techniques but introduces a more engaging and child-friendly approach by using a cartoon ant and colourful stickers instead of the traditional cucumber model; further refinement was achieved by incorporating Morra's (1994) procedural enhancements, which standardised the presentation and response protocols to increase the reliability and validity of the assessment.

As shown in the visual provided (see Figure 4), this task begins with an image of "Mr Ant", onto which various coloured stickers are placed in various positions. The task starts with a simple setup featuring a few stickers and progressively increases in complexity by adding more stickers to different parts of Mr. Ant's body. Children are initially shown the image of Mr. Ant with stickers and are asked to remember their locations over a short retention interval. Following this, they are presented with a blank outline of Mr. Ant and must replicate the sticker placement from memory. This procedure tests their memory and ability to manage spatial relationships and attention to detail (Howard & Melhuish, 2016).

The task's difficulty is systematically upgraded by increasing the number of stickers, thereby challenging the child's working memory capacity in a structured manner (Howard & Melhuish, 2016). By incorporating Morra's (1994) procedural enhancements and standardised presentation and response protocols, the Mr. Ant task ensures excellent reliability and validity in assessing children's visuospatial working memory abilities.

Figure 4. A Depiction of Early Years Toolbox App of Mr. Ant task (Howard & Melhuish, 2016)
*Figure 4 illustrates the Mr. Ant application from the Early Years Toolbox, designed to assess visuospatial working memory in children. Mr. Ant, a cheerful cartoon character, serves as the interactive element of the task, where children are shown his image adorned with various coloured stickers. These stickers are placed in different positions on his body, and the children are tasked with remembering and replicating the arrangement of these stickers after a short interval.

- **Corsi Block-Tapping Task (Non-Digital)**

The Corsi Block-Tapping Test (CBT), developed by Corsi in 1972, is designed to evaluate visuo-spatial working memory (Milner, 1971; Corsi, 1972). The test involves an examiner tapping a series of nine blocks arranged in irregular patterns on a board at a steady rate of approximately one block per second. The participant is then required to replicate the sequence in the same order. The CBT starts with more straightforward sequences, progressively increasing in length as the participant successfully recalls each sequence. The task continues until the participant cannot accurately reproduce two sequences of the same length, determining the longest sequence they can remember correctly (Arce & McMullen, 2021).

Given that brain damage can significantly affect visuo-spatial working memory, the CBT has proven to be a reliable and effective assessment tool for various psychological disorders (Paulraj et al., 2018). Besides the traditional physical CBT, several adaptations have been developed to meet diverse research needs, including the digital version of the CBT, the Walking Corsi Test (WalCT), Virtual Reality (VR) CBT, and Audio CBT(Arce & McMullen, 2021). These variations address specific practical needs and enhance research flexibility, leading to more accurate assessments of visuo-spatial working memory.

Figure 5. A Depiction of Corsi Blocks Task (Arce & McMullen, 2021)
Figure 5 depicts the Corsi Block-Tapping Task, used to assess visuospatial working memory. Nine blocks are arranged in a set pattern, and the examiner taps a sequence, which the participant must replicate in the same order. This task evaluates the participant's ability to recall and reproduce spatial sequences, providing insight into their working memory capabilities.

- **Comparative Analysis: EYT Mr. Ant task vs. Corsi block-tapping task**

In the current research, the rationale for pairing the Corsi Block-Tapping Test (CBT) with the Mr Ant task comes from several strategic considerations, primarily the potential synergy in assessing visuo-spatial working memory through both digital and physical methodologies (Corsi, 1972; Case, 1985). The decision to match these two assessments is based on preliminary findings suggesting a significant correlation between the spatial memory capacities measured by each task with a correlation of 0.45 (Howard & Okely, 2014), which indicates a moderate positive correlation, suggesting that as performance in one task increases, so does the other. Since both tasks involve spatial memory and the ability to recall and replicate sequences of locations (in the case of Corsi blocks) or positions of items (in "Mr Ant"), the correlation might reflect underlying shared cognitive abilities. This could imply that these tasks measure overlapping facets of spatial working memory.

Digital tasks, such as "Mr Ant," often incorporate elements that can increase engagement, such as interactive graphics and cartoon figures, which are not present in traditional physical tasks like CBT. By comparing these two formats, this study aims to investigate whether the increased engagement offered by digital tasks translates into better performance or whether the tangible interaction with physical objects in tasks like the CBT provides a more intense testing environment that might enhance memory retention. In addition, different test formats may result in participants adopting different cognitive processes or strategies for completing the tasks. This study will examine

whether these format differences significantly affect task performance, thus contributing to a deeper understanding of optimising test patterns for different populations or objectives.

Task 2: Cognitive Flexibility Assessment- EYT Card Sorting Task (Digital) & The Dimensional Change Card Sort (Non-Digital)

- **EYT Card Sort Task (Digital)**

Based on the description of Howard and Melhuish (2016), the assessment begins with a warm-up phase, during which children are introduced to the sorting activity through a demonstration followed by two practice trials. This initial stage is essential to ensure children understand the task and are comfortable with the sorting criteria. Following this, children are asked to sort cards based on a single dimension (colour or shape), e.g. red rabbit and blue boat. For instance, according to the specified sorting dimension, participants sort cards into two categories—one for blue rabbits and another for red boats (Howard & Melhuish, 2016).

After completing six experiments according to the initial sorting rules, the complexity of the task increases as the auditory instructions prompt children to switch to the alternate sorting dimension. This switch tested their cognitive flexibility as they had to suppress the previous rule and apply the new sorting criteria. This phase consisted of six additional trials, and all the children needed to do was adapt quickly and accurately to the new dimension.

The task moves to the boundary phase after completing the pre-switch and post-switch phases (at least five correct sorts in each phase, for a total of six). Here, the sorting rules become more complex. Cards with black borders must be sorted by colour, and cards without borders must be sorted by shape. This stage includes a mixture of three bounded stimuli and three unbounded stimuli, further challenging the child's ability to process and apply dual sorting rules simultaneously.

The EYT "card sorting" task scoring focuses on the number of correct sorts after the pre-switching phase, providing a quantitative measure of the child's ability to comply with the initial sorting rules and transition to the new rules. This demonstrates their cognitive flexibility and executive functioning skills.

The Early Years Toolbox (EYT) "Card Sorting" task draws significant influence from established cognitive flexibility assessments, specifically adapting the Dimensional Change Card Sort (DCCS) developed by Zelazo (2006). The DCCS is a well-recognized method for measuring executive function in children. It is mainly designed for preschoolers between 3 and 5 years, a developmental period noted for rapid advancements in executive functioning capabilities (Best & Miller, 2010).

Given that the primary subjects of this study were children with autism-a group often challenged by executive dysfunction (Zelazo, 2006)-the test used initially to measure typical children aged 3-5 years primarily was used in this study as the digital version of the assessment that used in the

present experiment to test shifting ability in children with autism aged 6-12 years. This digital adaptation retains the fundamental principles of the DCCS but is tailored to improve children's engagement by adding colourful graphics and animation, which are particularly appealing to young children. This task version allows for a more accessible, more engaging, and more precise evaluation of cognitive flexibility, especially adopting the cognitive flexibility test for typical younger age groups.

Figure 6. A Depiction of Early Years Toolbox App of Card Sorting Game (Howard & Melhuish, 2016)
Figure 6 illustrates a screen from a card sorting game in the Early Years Toolbox (EYT) application. The screen shows two castles, each labelled with a different symbol - a blue rabbit on the left and a red boat on the right. The task requires them to sort cards according to changing rules (e.g. colour or shape), making it an interactive task that assesses cognitive flexibility and executive function.

- **Dimensional Change Card Sort (Non-Digital)**

The Dimensional Change Card Sort (DCCS) is a widely used neuropsychological test that assesses executive functions, focusing on cognitive flexibility, in children. Initially developed by Zelazo (2006), the DCCS effectively measures a child's ability to switch between different sorting rules, providing insights into their executive cognitive processes.

The DCCS employs simple card games to make the assessment accessible and engaging for young participants. The procedure begins with the participant being asked to sort a series of bivalent cards—such as cards depicting blue rabbits and red boats—according to a specific feature, such as colour. After a series of trials, the participant is instructed to switch to sorting by another feature, such as shape. This switch tests children's cognitive flexibility and evaluates their capacity to process and implement new rules.

This methodical switch in sorting criteria is fundamental in assessing the adaptability of a child's thinking and is particularly indicative of their developmental progress in executive functioning.

As such, the DCCS is an invaluable tool for research and clinical settings, helping identify potential developmental challenges in executive function.

Figure 7. The examples of two types of card forms from (Zelazo, 2006)

- **Comparative Analysis: EYT Card Sorting task vs. The Dimensional Change Card Sort (DCCS)**

In the current research, the rationale for pairing the Dimensional Change Card Sort (DCCS) with the Early Years Toolbox (EYT) "Card Sorting" task stems from strategic considerations, particularly the potential to assess cognitive flexibility through tasks of increasing complexity synergistically. The DCCS, developed by Zelazo (2006), is traditionally employed with preschool children to measure their ability to switch between sorting rules such as colour and shape. While grounded in similar principles, the EYT "Card Sorting" task introduces additional complexities, including sorting based on the presence of borders, thereby providing a more nuanced evaluation of cognitive flexibility and executive function.

Howard and Melhuish (2016) outlined that the EYT "Card Sorting" task is an evolution of the DCCS, tailored to enhance the assessment process through digital means, including the innovative feature of border-based sorting. This adaptation makes the EYT "Card Sorting" task an advanced version of the DCCS, suited for digital application. The study conducted by Howard and Melhuish (2016) also compares the EYT with the NIH Toolbox, a comprehensive set of assessments that evaluate various functions, including cognition, emotion, motor skills, and sensory abilities. Within this framework, the DCCS is a specific tool for assessing shifting abilities.

As identified in their study, the correlation of 0.45 between the EYT and the NIH shifting tasks indicates a moderate positive correlation (Howard & Okely, 2014). This suggests that both tasks

assess similar cognitive abilities, particularly regarding cognitive flexibility and adapting to changing rules or conditions. Consequently, pairing the EYT "Card Sorting" task with the DCCS is particularly effective for contrasting digital and traditional modalities of cognitive flexibility assessments, providing valuable insights into the impact of assessment format on cognitive performance.

Task 3: Inhibitory Control Assessment- Go/NoGo Task (Digital) & The Head Toes Knees Shoulder Task (Non-Digital)

- **Early Year Toolkit – Go/NoGo Task**

The Early Years Toolbox (EYT) "Go/No-Go" task is a structured cognitive assessment designed to evaluate inhibitory control, a crucial element of executive functions. Developed according to established protocols by Howard & Okely (2015) and Wiebe, Sheffield, & Espy (2012), this task challenges participants to make rapid decisions based on visual stimuli. It is specifically tailored to measure their ability to suppress automatic responses.

The primary objective of the "Go/No-Go" task is to measure the child's ability to control impulsive responses. The task incorporates straightforward yet effective "go" and "no-go" trials, requiring children to tap the screen during "go" trials (indicated by fish) and to refrain from tapping during "no-go" trials (indicated by sharks). With its engaging visual stimuli, this design is well-suited to preschool-aged children's developmental and attentional levels.

The task commences with clear instructions for the participants. For "go" trials, participants are instructed to tap the screen when they see a fish, which represents most of the trials. During "no-go" trials, participants must resist tapping when seeing a shark. The task begins with five practice "go" trials and five "no-go" trials to ensure participants fully grasp the requirements. This is followed by a mixed block of 10 practice trials, comprising 80% "go" trials, which helps integrate and reinforce the response patterns.

After the practice trials, the primary assessment unfolds across 75 stimuli into three test blocks. Each block is interspersed with short breaks and a recap of instructions to maintain focus and ensure consistent responses. The stimuli are displayed in a pseudo-random order to prevent any block from starting with a "no-go" trial and to avoid consecutive "no-go" trials. Each trial features an animated stimulus—a fish or a shark—displayed for 1,500 milliseconds, with a 1,000-millisecond interval between stimuli. This structure tests the quickness and accuracy of the participant's responses under tightly controlled timing conditions.

Figure 8. A Depiction of Early Years Toolbox App of Go/NoGo Task (Howard & Melhuish, 2016) Figure 8 shows the image as the visual cue for the 'start' trial. In Go/NoGo, participants need to tap the screen when they see a 'start' stimulus represented by a fish and not tap the screen when they see a 'no start' stimulus such as a shark.

- **Head Toes Knees Shoulder task**

The Head, Toes, Knees, Shoulders (HTKS) task is predominantly utilised to evaluate young children's executive functioning, mainly inhibitory control. The task requires children to execute a series of physical actions in response to verbal directives, frequently instructing them to perform actions contrary to their initial impulses, thereby challenging their automatic responses (Cameron Ponitz et al., 2008).

The HTKS task involves a sequence of commands where children are asked to touch various parts of their bodies in response to verbal instructions. The initial stage of the task might ask children to touch their heads or toes when those body parts are mentioned. As the task progresses, it introduces more complex instructions, such as touching their toes when instructed to touch their head and vice versa, challenging the child's ability to inhibit automatic responses and flexibly shift their action as per the changing rules. The task typically starts with simple commands and progressively integrates more complex and counterintuitive commands.

The HTKS task assesses children's ability to control impulses and adapt to new rules. Because the task starts with simple commands and then progressively integrates more complex and counterintuitive commands, it tests children's memory and ability to process instructions and measures their cognitive flexibility and ability to control impulsive behaviours, which are the main parts of the executive function.

- **Comparative Analysis: EYT Go/NoGo Task vs. The Head Toes Knees Shoulders (HTKS) task**

The task chosen to be paired with the EYT Go/NoGo Task in this study was the Head, Toes, Knees, Shoulders (HTKS) task. The reasoning for this was based mainly on the need for accessible, reliable measures of executive function, particularly inhibitory control, in children with ASD. These tasks are well suited for younger participants and those with developmental delays, and they provide more accessible measures of executive function than tasks designed for adults, such as the NIH toolbox mentioned in the previous section. The task the NIH offers to measure inhibitory control is the Flanker Task, which demonstrates a moderate correlation with the EYT Go/NoGo task (Howard & Okely, 2014).

However, the ability to understand the demands of the task and engage with it is crucial for the study population of children with ASD in this paper. Initially designed for adult participants, the flanker task is characterised by complex manipulations of visual stimuli and requires precise, consistent responses (Eriksen & Eriksen, 1974). This level of complexity assumes that participants can follow complex instructions and respond consistently, but this is not consistent with the abilities of children with ASD, who typically exhibit a range of cognitive impairments (Karalunas et al., 2018). In addition, participants in this study were required to demonstrate maturity in cognitive functioning (e.g., attentional control) (Stins et al., 2007), a requirement that can be challenging for the ASD population. Therefore, even after the moderate correlation mentioned in the EYT Go/NoGo Task and the NIH toolbox, it was still considered that the Flanker Task was deemed unsuitable to be paired with the EYT Go/NoGo Task in the current study, considering that the Flanker Task may not be suitable for children with ASD (Howard & Melhuish, 2016).

Furthermore, although McDermott et al. (2007) adapted the Flanker Task for typically developing children, they acknowledged that children develop at different rates. Consequently, younger children within the target age range or those with developmental delays might struggle with the task. This variability can lead to performance deficits that do not accurately reflect a child's developmental stage regarding selective attention or inhibitory control. Misinterpretations of the task's demands due to varying language development skills and limited experience could further skew the results.

In contrast, the Head, Toes, Knees, Shoulders (HTKS) task is presented as a more accessible alternative for children with ASD. The HTKS task's rules are straightforward and resemble real-life challenges similar to those encountered in a school environment, making it less daunting and more relatable for children (Sabrina Ann Kenny et al., 2023). The HTKS task evaluates inhibitory control by requiring children to perform actions contrary to verbal commands—such as touching their toes when instructed to touch their head—which parallels the inhibitory control assessment in the EYT Go/NoGo task, where children must resist tapping the screen upon seeing a shark (Howard & Melhuish, 2016).

Despite their different methodologies, both tasks assess inhibitory control, comprehensively evaluating this executive function across various contexts. This dual approach enhances the

robustness of assessing children's ability to regulate impulses, making the combined use of HTKS and EYT Go/NoGo tasks particularly effective for a nuanced understanding of executive functions in children with ASD.

Qualitative Data:

The qualitative data component was designed to collect teachers' observations of children's participation in the task and their perceptions of the effects of digital versus non-digital tools.

The interview questions were designed to gather feedback from caregivers and teachers on using digital tools to educate children with ASD. The questions asked to the teachers focused on the children's behaviour during the experiment, such as their engagement and performance in conjunction with their views on using digital platforms as a pedagogical tool. For example, 'What challenges or drawbacks have you encountered when using digital learning platforms?', 'What are your observations of students' behavioural and emotional responses when using digital learning platforms?'. The questions asked caregivers focused on the percentage of electronics in their lives outside of school and the child's affinity for electronics. For example, 'Can you compare the amount of time your child spends playing with digital content to physical activity?', 'What digital content does your child enjoy, and what do you think attracts them to these choices?'

The focus group was initially planned to include caregivers as well, but due to the reluctance of caregivers (many of whom were grandparents) to participate, only two teachers were interviewed. The interviews were conducted via an online chat platform, and teachers provided feedback on the usefulness, benefits and challenges of the assessment tools used in the study.

3.5 Data Analysis

Quantitative Analysis: The quantitative data from the children's task performances were statistically analysed to compare the effectiveness of the digital and non-digital modalities. The analysis specifically focused on identifying differences in performance among children with ASD across the two formats.

Qualitative Analysis: The qualitative data from the teacher interviews were analysed using thematic analysis. This method enabled the identification of major themes and patterns in the teachers' responses, providing contextual insights that complement the quantitative findings. The analysis emphasised understanding the teachers' views on the assessment tools' practicality, benefits, and limitations, as well as their overall experiences with the children during the study.

Chapter 4: Results

Quantitative Data

The current study has employed ANCOVA and correlation matrix to examine the relationships between the performance of various tasks in digital and non-digital forms of ASD children. Since the non-digital and digital tasks are different, even when assessing the same construct, and use different scoring schemes and scales, prior to any comparison all raw data were converted to z-scores in order to enable the comparison. Z-scores were calculated by subtracting the mean from the value and then dividing the result by the standard deviation.

One peculiarity of the non-digital DCCS task is that there are two scoring systems employed. One is computed by adding all the points, and another one is the results following the instruction from Meador et al, (2013), which has a coding schema. The coding schema used by Meador et al. (2013) follows the same procedure as Zelazo (2006), and it was structured so that if children failed to pass the pre-switch stage, they were given a score of 0, indicating difficulty following the initial rules. A score of 1 was assigned if they passed the pre-switch stage but not the post-switch stage, reflecting challenges in adapting to new rules. If they succeeded in both the pre- and post-switch stages but failed at the more advanced border version, they received 2 points, highlighting difficulties with more complex rule-switching. By the end, children who passed all stages were awarded 3 points, demonstrating strong cognitive flexibility. The reason for generating an additional result (sum of the points) was to align with how the results from the raw data of the digital DCCS tasks were calculated. The EYT instructions did not include a coding schema like the one used by Meador et al. (2013), necessitating a consistent way to compare the data across both versions.

Correlation Matrix

The heatmap (Figure 9) visually represents these correlations, with colour intensity indicating the strength and direction of the relationships:

- Red represents a positive correlation, with darker red indicating a stronger positive correlation.
- Blue represents a negative correlation, with darker blue indicating a stronger negative correlation.
- White or light colours indicate little or no correlation.

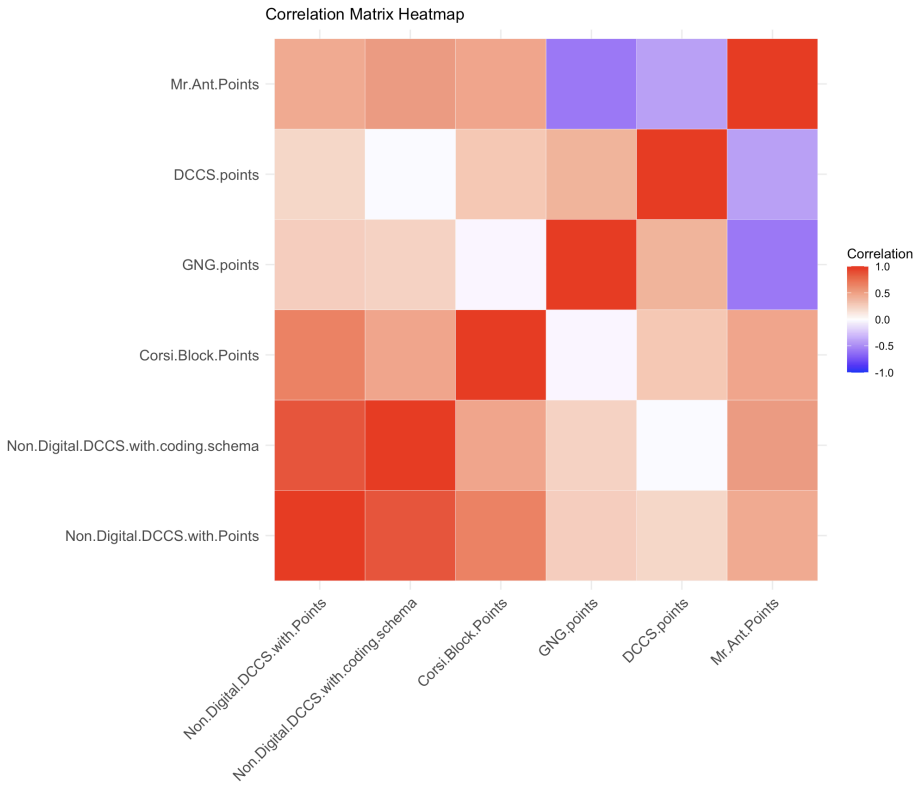

Figure 9. Correlation Matrix Heatmap

High Correlations:

- The scores from the two Non-Digital DCCS scoring methods (Non.Digital.DCCS.with.Points and Non.Digital.DCCS.with.coding.schema) are highly correlated (r = 0.858). This strong positive relationship, represented by the deep red colour in the heatmap, indicates that both scoring methods consistently measure the same underlying cognitive ability.
- Both Non-Digital DCCS scores also exhibit moderately strong correlations with Corsi Block Points (r = 0.649 and r = 0.463, respectively). These correlations, depicted by medium red hues, suggest shared cognitive components between these tasks, likely involving working memory or executive function.

Moderate Correlations:

- Mr. Ant Points showed moderate correlations with Non-Digital DCCS (r = 0.452 and r = 0.524) and Corsi Block Points (r = 0.466). These moderate relationships, represented by lighter red shades, indicate some shared cognitive constructs between these tasks, potentially related to spatial or planning skills.
- Go/NoGo Points demonstrated a moderate positive correlation with DCCS Points (r = 0.399), suggesting shared executive control processes. Additionally, a moderate negative correlation between Go/NoGo Points and Mr. Ant Points (r = -0.591), represented by a blue hue, indicates an inverse relationship between inhibitory control and spatial or planning skills.

Low to Negligible Correlations:

- DCCS Points showed low correlations with the Non-Digital DCCS scores and coding schema ($r = 0.210$ and $r = -0.017$, respectively). These near-zero correlations, indicated by lighter shades, suggest that the traditional DCCS task may tap into different cognitive aspects than the other tasks.
- The correlation between Go/NoGo and Corsi Block Points was very low ($r = -0.024$), implying almost no shared cognitive elements and indicating that these tasks assess distinct skills or processes.

ANCOVA

ANCOVA was used to compare the performance of children with ASD on tasks delivered in both digital and non-digital formats. According to the groups by cognitive flexibility, working memory, and inhibition, the analysis of ANCOVA was divided into three parts. However, for inhibition, none of the participants passed the HTKS task; therefore, only two ANCOVA analyses were reported.

Cognitive Flexibility Tasks

An Analysis of Covariance (ANCOVA) was conducted to compare the performance on the Non-Digital DCCS with Points and various levels of DCCS Points, with age included as a covariate. The overall model was not statistically significant, $F(6, 4) = 1.570$, $p = .345$, suggesting that the mode of task delivery (digital vs. non-digital) did not significantly affect the scores on the Non-Digital DCCS with Points, after controlling for age. Individual analysis revealed that neither age, $F(1, 4) = .893$, $p = .398$, nor different levels of DCCS points, $F(5, 4) = 1.633$, $p = .327$, significantly predicted the task performance. The model explained 70.2% of the variance ($R^2 = .702$, Adjusted $R^2 = .255$), indicating a substantial proportion of variance accounted for by the model despite its lack of statistical significance, possibly reflective of the small sample size.

Table 1. ANCOVA in Cognitive Flexibility Tasks

Working Memory Tasks

Similarly, an ANCOVA was utilised to assess differences in working memory as measured by Mr. Ant Points and Corsi Block Points. The model did not achieve statistical significance, $F(5, 2) = .726$, $p = .666$, implying that the delivery mode did not notably impact working memory scores. Neither age, $F(1, 2) = 1.165$, $p = .393$, nor the type of Mr. Ant Points used, $F(4, 2) = .754$, $p = .638$, were significant predictors. Despite accounting for 64.5% of the variance in scores ($R^2 = .645$), the negative Adjusted R^2 of -.243 suggests overfitting, likely due to the minimal data points available relative to the number of predictors used.

Table 2. ANCOVA in Working Memory Tasks

Qualitative Data

Interview data collected from teachers of children with ASD focused on several critical areas related to using digital tools in educational settings. The questions were designed to understand teachers' perceptions of how these tools affect student engagement, behaviour and academic achievement.

Major themes include:

1. **Student Engagement:** Teachers reported that students showed greater interest and motivation in using digital learning platforms, mainly due to the interactive nature of tools such as animations, music, and games. Even after the game was over some participants wanted to stay engaged and were angry that it was over. Moreover, teachers noted that these elements increased student attention and classroom engagement.

2. **Classroom Atmosphere and Learning Outcomes**: Teachers mentioned that digital tools created a better classroom climate, as students found traditional lecture-based instruction less engaging. Including multimedia in the curriculum helped make the content easier to understand and master, thus potentially improving learning outcomes.

3. **Challenges and Over-reliance on Digital Tools**: Despite these advantages, teachers also pointed out the risks of over-reliance on digital platforms. Some students are easily distracted by games or non-educational content. In addition, students with poor self-regulation skills may struggle with time management and concentration.

4. **Behavioural Variability**: Teachers observed that not all pupils responded equally to digital learning platforms. Many students displayed positive behavioural and emotional responses, while others were more easily distracted or frustrated by technology.

Chapter 5: Discussion

5.1 Discussion of the Main Results

The current study investigated how task modality affects executive function performance in children with autism spectrum disorder. The ANCOVA results suggest that task modality (digital vs. non-digital) does not significantly affect executive function performance in this sample of children with ASD, as no significant differences were found in performance across tasks.

The study aimed to explore the potential differences in cognitive task performance between digital and non-digital delivery modes among children with ASD, adjusting for age as a covariate. Two tasks were examined: working memory tasks (Mr. Ant Points and Corsi Block Points) and cognitive flexibility tasks (Digital and Non-Digital DCCS Points). The comparison of inhibitory control tasks, particularly between digital and non-digital formats, was hindered by the inability to process data for the non-digital HTKS (Head-Toes-Knees-Shoulders) task, which is because none of the children in the study were able to complete the HTKS task, leading to insufficient data for this measure of inhibition with non-digital group.

The findings from the ANCOVAs suggest that the delivery mode of the tasks—whether digital or non-digital—does not significantly affect cognitive task performance in children with ASD after accounting for age. This lack of significant difference aligns with the hypothesis that when tasks are designed to measure similar constructs, the medium in which they are delivered might not alter their efficacy in assessing cognitive abilities. However, the results must be interpreted cautiously due to the small sample size and potential model overfitting.

Analysing the correlation matrix heatmap suggests a complex interplay of cognitive abilities among the tasks. High and moderate correlations between tasks like Non-Digital DCCS, Corsi Block, or Mr. Ant suggest overlapping cognitive domains such as executive function and working memory. In contrast, the low and negative correlations point towards distinct or possibly competing cognitive processes being engaged by different tasks.

Also, for the inhibition group, no participants succeeded in HTKSs for the non-digital part, so there is no comparison between HTKS and Go/NoGo tasks as the assessments of ASD children's inhibition ability. However, the research question is trying to explore between non-digital assessments and digital assessments in ASD children, the failure in one task might not be able to generalise any statistical comparison, but by comparing two tasks together, success in one task and failure in another can be seen as a comparison, which directly demonstrates that the digital version better meets the needs of the ASD children in the context of this experimental design and environment. In other words, at least participants were able to pass the practice trial in the Go/NoGo task on iPad, but they could not pass that with the HTKS task.

Considering the situation that one non-digital task failed, this leads to the second research question in this study: Are there modality-specific strengths and challenges observed in children with

ASD when performing executive function tasks? This is because intuitively, all children completed the task in the digital group, but not the non-digital group. Therefore, if one were to look at this question directly from a quantitative perspective, the result would be that in the inhibition Tasks no child successfully completed the HTKS task, while some participants were able to engage with the Go/No Go task on the iPad, highlights that the digital format might be more accessible and engaging for children with ASD, particularly when assessing inhibition. This provides direct evidence of a modality-specific difference in performance. However, as discussed above, failure of the task was not directly related to participants ability to perform the task, as the factors involved in this are not directly related to participants' ability to perform the task. However, as discussed above, task failure cannot be directly linked to participant ability as there are many influencing factors involved, including the experimental design, the experimenter, and the state of the children with ASD themselves that may affect the results. However, in addition to the quantitative data, a focus group interview was set up in the present study to further understand the details of the study beyond the students.

Through interviews with the teachers, both teachers expressed that the students were more attracted to digital tools, as evidenced by the fact that students with ASD were often more engaged and motivated when digital tools (e.g., animations, interactive tasks, and games) were incorporated into their learning process. Including the enhancement of the atmosphere of the lesson, as mentioned in their responses, and the sense of achievement that students felt after completing the tasks were all features those teachers suggested digital modality brought to the lesson and to the students.

However, the teacher's interview also mentions the negative effects of using electronic devices, including the focus on irrelevant content and unfamiliarity with new things all affecting students' performance to varying degrees, as using electronic devices requires some necessary knowledge. Although digital tools can increase attention and engagement, they can sometimes cause distraction if not managed properly, which could explain why some children excel on digital tasks but not on non-digital ones.

In response to the second research question, whilst the ANOVA results showed no significant differences between the modalities, the combination of quantitative data and qualitative insights from the suppression group suggests that digital tools may have a specific advantage in engaging children with autism during the performance of functional tasks. This was particularly evident during tasks such as 'Go/No Go'. The interactive and participatory nature of digital assessments appears to be more responsive to the needs of children with autism than non-digital tasks.

It is important to note that the assessments used in this study cannot be considered definitive measures of actual executive functioning abilities in children with ASD. Although the tasks used, such as Mr Ant, Corsi Block and DCCS, are designed to measure critical executive functions such as working memory, cognitive flexibility and inhibitory control, the results obtained from these assessments may not fully reflect the complexity of executive functioning in children with ASD. One

important reason is that task performance can be influenced by factors other than purely cognitive abilities. For example, familiarity with digital tools, task format, and environmental factors can all influence children's performance on these tasks. In particular, correlation matrix heat maps showed moderate to high correlations between specific tasks, suggesting overlap between cognitive domains such as working memory and cognitive flexibility. However, this overlap complicates the interpretation of the results, as task performance in one domain may be partly driven by ability in another domain. Thus, these assessments may reflect a combination of cognitive skills rather than isolating a particular ability.

In addition, challenges associated with specific tasks, such as participants' inability to complete the non-numeric HTKS task, further highlight the limitations of these assessments. The inability to complete this task suggests that it may not be appropriate for the specific cognitive or behavioural characteristics of children with ASD. Of course, it may also be that it is not just the task that is unsuitable for children with ASD; the localisation of the task, as well as the interaction style used by the researcher, may be an influencing factor. This underlines the point that standardised tasks are not always a true reflection of executive functioning ability, especially when they do not take into account the unique challenges faced by this population, such as difficulties with language processing, attention and social interaction, which was one of the starting points of this study.

This also echoes the results obtained in the focus group interview of this study. The complexity of assessing children with ASD is also highlighted by the issues that were predominantly mentioned in the teacher's interview concerning feedback from all participants. According to the teachers, pupils' engagement and performance were often influenced by external environmental factors, personal interests and the structure of the digital tasks. Some students responded positively to digital tools and were less cooperative when engaged in non-digital tasks, affecting task comprehension and completion. However, they also mentioned that the disadvantage of digital modality is that students can be easily distracted by non-educational content or lack the self-discipline needed to stay focused during task completion.

In addition, teachers emphasised that students' attention is affected by how content is delivered and the interactive nature of the tool. Digital platforms with interactive features (e.g., games and simulations) were reported to increase student engagement. However, traditional tasks, such as non-digital HTKS, lack these features and, therefore, may not capture the attention of children with ASD. Teachers also noted that some students may have difficulty adapting to digital tools, further suggesting that both digital and non-digital interaction methods can significantly impact academic performance.

This reinforces the point that standardised tasks do not necessarily truly reflect the executive functioning of children with ASD, especially when they do not take into account their unique needs, such as challenges with attention and adaptability to new formats. As highlighted in the feedback, digital tools can be beneficial by providing more engaging forms of interaction that better cater to

students' interests and strengths. However, these tools also need to be implemented carefully to avoid distraction, emphasising that any assessment tool, digital or non-digital, must be tailored to the specific needs and cognitive characteristics of children with ASD.

5.2 Limitations of the Study

The relatively small sample size of 11 participants limits the generalisability of the findings. This study's results may not fully represent the broader population of children with ASD since the participants are from one particular school in the local area. Future studies should consider increasing the sample size to enhance the statistical power and reliability of the findings.

Another critical limitation relates to the research setting. The study was conducted in a particular education school where students could only participate for a limited period. This limitation, combined with the need to minimise disruption to the children, seriously affected the familiarisation process between the researcher and the participants. Familiarity with the students may have impacted the results, as the children may have shown more positive attitudes and cooperation with those they knew and trusted. Not having enough time to establish rapport with participants was cited as one of the reasons why no participants completed the HTKS task. Had there been sufficient time to engage with the participants, the design of the experiment may have mitigated the challenges they faced in completing this task.

Additionally, the initial goal of this study was to engage caregivers and teachers in focus groups to analyse the effectiveness of the assessment tool qualitatively. However, due to practical constraints, in particular the unwillingness of many caregivers, often grandparents of the children, to participate, only two teachers were interviewed in the focus groups.

5.3 Future Research Directions

This study revealed the effectiveness of digital and non-digital task models in assessing executive functioning in children with ASD but also identified several areas for further research. Future research should aim to address the limitations of this study and extend the findings to deepen understanding of how best to support the cognitive and educational development of children with ASD.

As a study used to test children with ASD, how infinitely more relevant it is to the actual situation is also something that needs to be considered. The main points here are the experimenters and the experimental equipment. From the point of view of the experimenters, it would be ideal to increase the level of familiarity with the participants, as teachers and students spend much time together at school and, therefore, have a high level of familiarity with each other. A follow-up experiment could be designed to approach this level of familiarity more ideally if it were a long-term experiment. On the other hand, the participants' familiarity with the equipment must be taken into account, as the students need to use it daily in their studies. Proficiency with the experimental device

(in this experiment, an iPad) can affect the child's state to varying degrees; for example, participants may be better integrated into the task itself with familiarity with the device because they are not overly distracted from the task by curiosity based on their knowledge of the device.

On the other hand, the impact of unfamiliarity with the device may be seen in the fact that participants may need to spend more effort on familiarising themselves with the device, may not be confident in the task they are engaged in due to unfamiliarity or may be attracted to something new, leading to an over-expected focus. Each of these different scenarios may have influenced the conclusions ultimately reached in this study. Therefore, this paper considers longitudinal experiments one of the main directions for subsequent development. How to ensure that children with ASD are at the same starting line is something that needs to be addressed in the experimental design.

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Appendix

Appendix A: Sample Interview Questions for Teachers and Caregivers

Interview Questions:

For Parents:

1. Do you think your child is more interested in electronic devices than in non-electronic devices?
2. How would you describe your overall experience with digital study platforms compared to traditional non-digital methods?
3. How have digital tools influenced communication between your child and their teachers or peers?
4. Which type of study platform do you think engages and motivates your child more effectively? Can you provide specific examples or scenarios?
5. How do you think digital tools can be improved to better engage your child?
6. How accessible and user-friendly do you find the digital study platforms? Are there any technical issues that have impacted your child's learning experience?
7. What features or improvements would you suggest to make these platforms more accessible and effective?

For teachers:

1. How have students responded to the digital study platform compared to traditional teaching methods?
2. Have you noticed any differences in student engagement or participation in class?
3. From your perspective, how has the digital platform influenced students' academic achievements?
4. Are there any particular subjects or areas where students perform better or worse with digital tools if school has used digital tools before?
5. What are your observations regarding students' behaviour and emotional responses when using the digital study platform?
6. Have there been any issues with student focus or motivation related to digital tool usage?
7. How has the introduction of the digital platform affected your teaching methods and classroom management?
8. Do you find it easier or more difficult to teach with digital tools, and why?
9. What challenges or drawbacks have you encountered with digital study platforms? How do these compare to the challenges faced with traditional non-digital methods?
10. What are your thoughts on the implementation and integration of the digital study platform in your teaching?
11. Have you encountered any technical difficulties, and how were they resolved?

Appendix B: Interview Transcripts with Teachers

Teacher A:

1. Students are interested in digital learning platforms, such as pictures, animations and music, which can attract their attention in class.
2. It has been noted that students may find simple lectures uninteresting and have low motivation; the class atmosphere is better with multimedia participation.
3. can enhance students' learning efficiency and help improve their academic performance.
4. No specific tests have been done, but overall it should be better. 5.
5. eyes will be more focused and emotions will be higher because students like it.
6. attention span would improve and motivation would increase, but sometimes it would be easy to overdo it, such as wanting to continue after a certain part of the game is over, and some might lose their temper because of it.
7. Increasing the diversity of teaching methods and classroom management will be more convenient, such as the countdown time, inserting ancient poems, etc. are very helpful for the classroom and teaching.
8. Make teaching more convenient.
9. Challenge: sometimes over-reliance on digital platforms.
10. Can help teaching and learning to be better implemented and integrated.

Teacher B:

1. Overall positive attitude. Students will be more interested in learning and perform more actively in class. Game sessions, like those in Shiv, provide a more interactive learning experience, and student participation is very

high.

2. Students' participation in the classroom varies according to environmental influences and personal factors. Some students are easily affected by the sounds and movements around them, and some are not interested in the teaching content, all of which will cause them to be inattentive in class and prone to desertion.
3. Mathematics is an abstract and logical subject, which is very difficult for our students. It is difficult for students to understand if they only rely on the traditional teaching mode. Through the digital platform, with the help of animation demonstration interactive games and other ways can make the mathematical knowledge more vivid and concrete helps to deepen students' understanding and memory, so as to enhance the ability.
4. Overall, I will still perform better. Digital tools can provide a personalised learning experience to help students understand better. In addition, some of the games and simulation software on the platform are lively and interesting, which increase students' interest in learning and then perform better in class. However, there are also some poor performances, such as games and social media applications that are not related to classroom teaching and learning, which may distract students from concentrating.
5. There are still differences in students' behavioural and emotional responses. Some students respond positively to learning digital platforms, showing high interest and willingness to engage in learning, and feeling a sense of achievement after completing the learning tasks. Other students do not show a positive response and are easily distracted and unable to engage in their learning when using digital tools, and also become frustrated when there is a lack of competence.
6. Students do encounter some difficulties and challenges when using digital tools for learning. For example, students' attention can linger on apps that are not related to their studies, leading to distraction. Students who lack self-discipline may struggle to manage their study time and effort effectively. Some other students may have difficulties with the use of digital tools and be less adaptable, which can also affect motivation.
7. The impact is still significant. In terms of teaching methods, digital platforms can integrate various multimedia resources, such as video, audio and animation, to make the teaching content more vivid and interesting. In addition, the digital platform can provide real-time interactive functions, which help to improve communication between teachers and students and cooperative learning among students. In terms of classroom management the communication tools provided by the platform enhance the connection between teachers and

students' parents, and facilitate the release of notices and the answering of questions. Teachers can use the platform's data analysis and other functions to fully grasp the learning situation of students, so as to teach in a targeted manner. In addition, teachers can easily upload and share resources to ensure that all students have access to the same teaching materials, reflecting fairness.

8. Relatively or still easier. Digital tools can provide a wide range of online resources and multimedia content, making it easy for teachers to access and integrate high-quality teaching and learning materials. The data analysis function of digital tools can help teachers understand students' learning styles and progress so that they can better individualise their teaching. The tools have timely feedback functions to help students correct errors and deepen their understanding in a timely manner. In addition, digital teaching is not restricted by time and place, making learning more flexible. Of course, there will be some difficulties. For example, if there are network problems during teaching, the teaching process will be affected, and if teachers and students lack the necessary technical knowledge and equipment, digital teaching will be greatly resisted.
9. In the process of using, there are certain requirements for hardware and software, and if there is a technical failure, there is no ability to solve it quickly. There are also implications in terms of student socialisation and emotional interaction. Lacking the structure and supervision of a traditional classroom, students need to have greater self-discipline. For some e-learning programmes, the lack of a teacher to focus on the key points makes it difficult for students to grasp the key knowledge. While digital platforms offer more opportunities for personalised learning than traditional teaching, the direct feedback and timely adjustments of traditional teaching are sometimes more direct and effective. Non-digital teaching methods do not require a technological foundation and are more friendly to students who are not familiar with technology.
10. Digital learning platforms help to improve teaching efficiency by enriching resources and helping students to gain a more effective and comprehensive understanding of knowledge. It breaks down spatial constraints and enables teachers and students to synchronise teaching and learning without being in the same location, for effective communication and cooperation, enhancing interaction and collaboration. In addition, learning on digital platforms fosters the ability of students to learn independently. Students can access course materials repeatedly for revision or deepening of understanding, which helps the accumulation and application of knowledge in the long term. However, it also puts certain requirements on users, requiring the use of old with certain technical skills, as well as teachers and students to be able to adapt to the new teaching mode.

Appendix C: Raw Data

The participants' date of births are concealed in this section as this study assumes that such information could potentially be used to identify individuals.

1. Raw scores from all the tasks

ChildID	DOB	Age	Sex	Non-Digital DCCS with Points	Non-Digital DCCS with coding schema	Coris Block Points	HKTS	GNG points	DCCS points	Mr.Ant Points
8	##########	128.00	male	0.508	0.721	-0.845	0.000	-0.102	-0.221	-0.233
6	##########	111.00	Female	-0.163	-1.261	-0.169	0.000	-0.818	0.127	-0.765
7	##########	114.00	Male	-0.163	-0.270	0.338	0.000	0.511	-0.918	-0.499
5	##########	95.00	Male	-0.386	-0.270	-0.845	0.000	0.614	0.127	-0.499
4	##########	96.00	male	0.284	0.721	-0.169	0.000	0.409	-0.570	-0.499
15	##########	131.00	Male	0.508	0.721	1.183	0.000	-2.353	-0.918	2.162
14	##########	130.00	male	1.849	1.712	1.183	0.000	1.125	-0.221	0.831
12	##########	125.00	male	-1.951	-1.261	-0.845	0.000	0.000	-0.570	
11	##########	96.00	male	-0.833	-0.270	-0.845	0.000		-0.570	
10	##########	107.00	male	0.955	0.721	1.859	0.000	0.818	1.519	-0.499
9	##########	98.00	male	-0.610	-1.261	-0.845	0.000	-0.205	2.215	

2. Z-score from all the tasks

ChildID	DOB	Age	Sex	Non-Digital DCCS with Points	Non-Digital DCCS with coding schema	Coris Block Points	HKTS	GNG points	DCCS points	Mr.Ant Points
8	##########	128.00	male	0.508	0.721	-0.845	0.000	-0.102	-0.221	-0.233
6	##########	111.00	Female	-0.163	-1.261	-0.169	0.000	-0.818	0.127	-0.765
7	##########	114.00	Male	-0.163	-0.270	0.338	0.000	0.511	-0.918	-0.499
5	##########	95.00	Male	-0.386	-0.270	-0.845	0.000	0.614	0.127	-0.499
4	##########	96.00	male	0.284	0.721	-0.169	0.000	0.409	-0.570	-0.499
15	##########	131.00	Male	0.508	0.721	1.183	0.000	-2.353	-0.918	2.162
14	##########	130.00	male	1.849	1.712	1.183	0.000	1.125	-0.221	0.831
12	##########	125.00	male	-1.951	-1.261	-0.845	0.000	0.000	-0.570	
11	##########	96.00	male	-0.833	-0.270	-0.845	0.000		-0.570	
10	##########	107.00	male	0.955	0.721	1.859	0.000	0.818	1.519	-0.499
9	##########	98.00	male	-0.610	-1.261	-0.845	0.000	-0.205	2.215	

Appendix D: Supplementary Figures or Tables

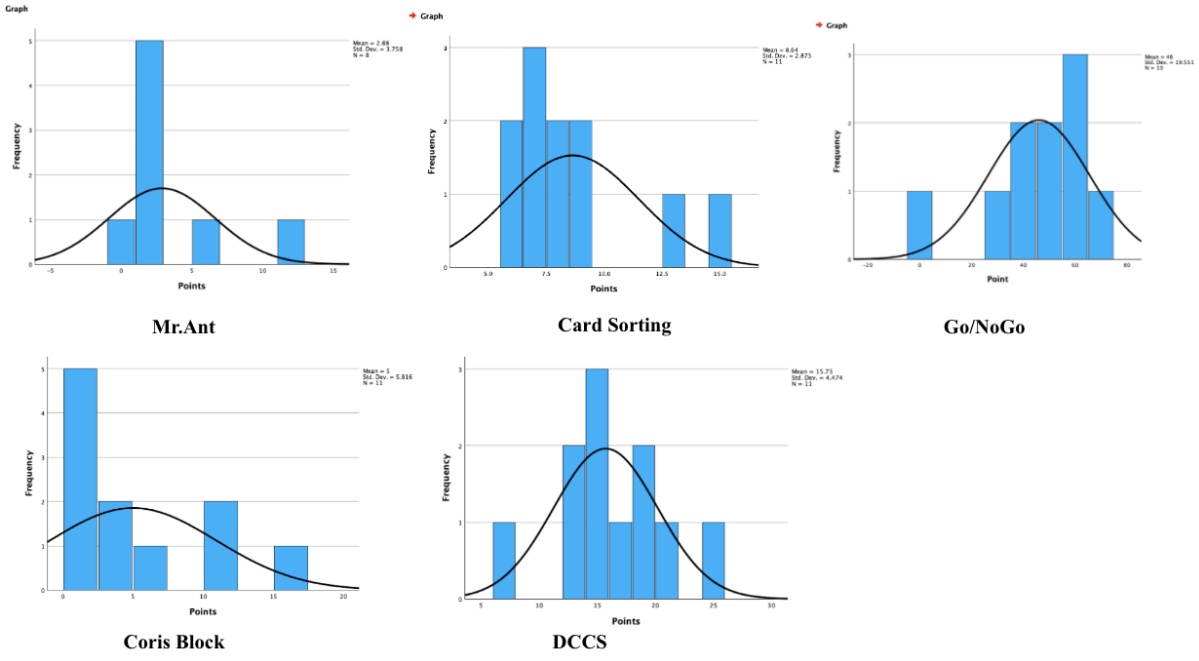
Detailed Statistical Outputs:

Descriptive Data

Descriptive Statistics

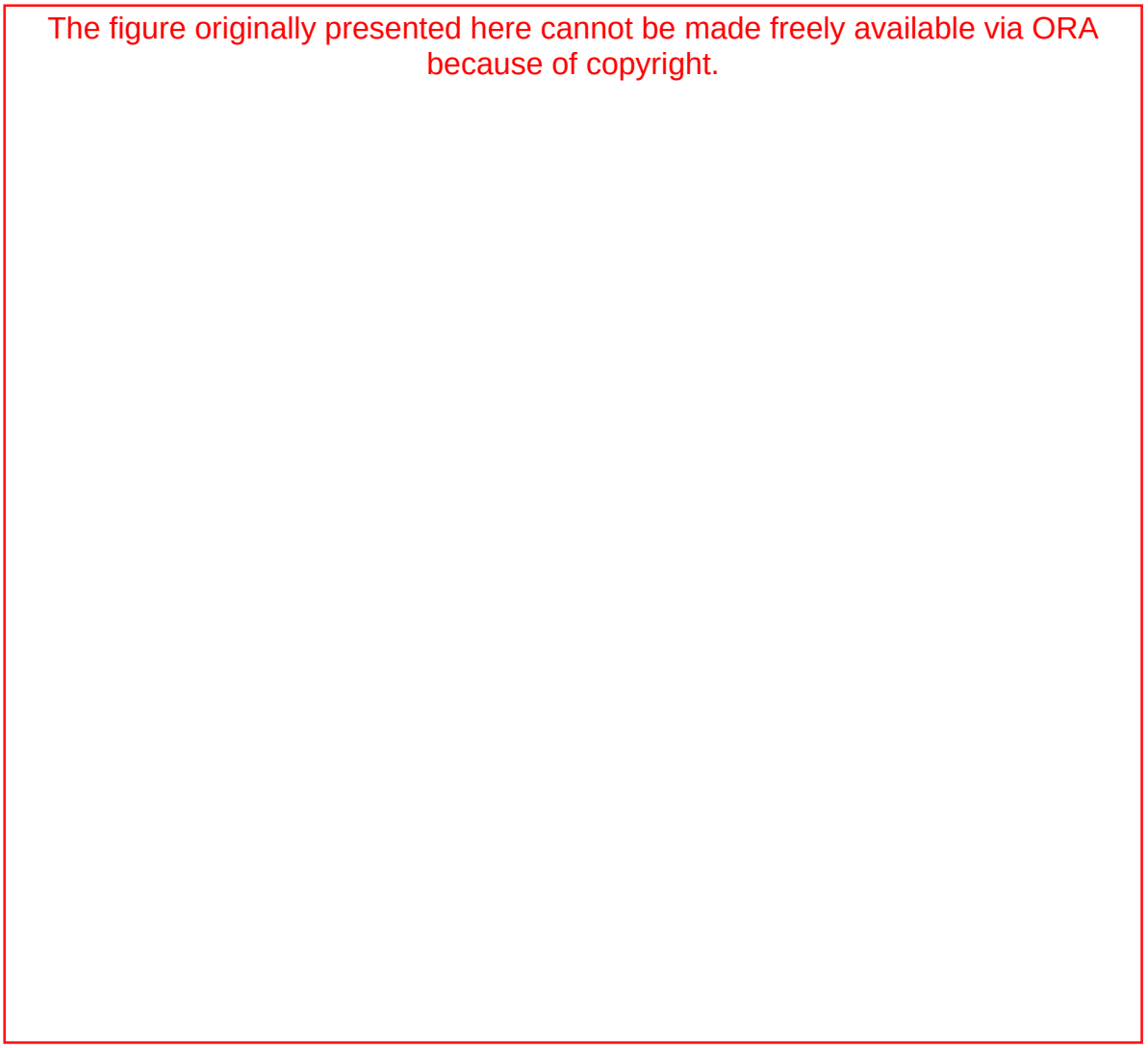
	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Non-Digital DCCS with coding schema	14	.000000000	3.00000000	1.23569481	.889989481	.198	.597	-.318	1.154
Coris Block Points	14	.000	35.000	7.20829	9.537649	2.112	.597	5.289	1.154
Mr.Ant Points	11	.000	14.125	3.97800	4.613399	1.521	.661	1.350	1.279
GNG points	13	.000	382.222	69.82869	95.657069	3.362	.616	11.813	1.191
DCCS points	14	2.87300000	15.0000000	8.19745455	2.95101386	.871	.597	1.856	1.154
Valid N (listwise)	11								

Histogram



ANCOVA SPSS Outputs

1. Non-digital DCCS with points & EYT Card Sorting



2. Coris Block Points & Go/NoGo

Univariate Analysis of Variance

Between-Subjects Factors

		N
Mr.Ant Points	-.764968621	1
	-.498892579	4
	-.232816537	1
	.831487631	1
	2.161867842	1

Descriptive Statistics

Dependent Variable: Coris Block Points

Mr.Ant Points	Mean	Std. Deviation	N
-.764968621	-.169030851	.	1
-.498892579	.295803989	1.14953407	4
-.232816537	-.845154255	.	1
.831487631	1.18321596	.	1
2.161867842	1.18321596	.	1
Total	.316932846	1.00381924	8

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Coris Block Points

F	df1	df2	Sig.
.892	4	3	.560

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Age + Mr. AntPoints

Tests of Between-Subjects Effects

Dependent Variable: Coris Block Points

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4.549[a]	5	.910	.726	.666	.645
Intercept	1.353	1	1.353	1.080	.408	.351
Age	1.459	1	1.459	1.165	.393	.368
Mr.AntPoints	3.778	4	.945	.754	.638	.601
Error	2.505	2	1.252			
Total	7.857	8				
Corrected Total	7.054	7				

a. R Squared = .645 (Adjusted R Squared = -.243)

Appendix D: Consent Forms and Ethical Approval

1. Head Teacher Consent Form

Comparing digital and non-digital executive function assessments with Chinese children with autism spectrum disorder

- Thank you for agreeing to discuss this study developed by Hetao Zhang, a master's student at the University of Oxford, United Kingdom, under the supervision of Dr. Ernesto Roque-Gutierrez. The objective of the study is to understand how some children with Autism Spectrum Disorder (ASD) perform in different cognitive tasks (e.g., memory games). We aim to compare their performance and experiences when they play these games on a digital tablet versus using other physical materials (cards, paper, etc.).
- Our focus is on the children's performance in different games, not comparing them with each other. If you agree to your school participating in the study, a researcher (Hetao Zhang) will come to school a) play games a maximum of three games with students per session, joined by their teacher; b) conduct a focus group activity with teachers and parents who consent to participate. No more than two sessions are expected per child. Each session of different modalities of games will last around 30 minutes, with three games and between each game, there will be a short break. Therefore, the duration of the whole experiment will be approximately 1 hour excluding breaks. There is also a possibility of organising these into three 20-minute sessions if the school agrees that this would be less disruptive to the daily schedule.
- To find out more about the study, please read the attached information sheet. You can e-mail us at hetao.zhang@education.ox.ac.uk or ernesto.roque-gutierrez@education.ox.ac.uk. You can also call the researcher Hetao Zhang on +8613655751526 if you have any questions.
- To confirm if you are happy for your class to take part, please indicate YES if you agree or NO if you disagree with the statements below. If you have answered YES to all statements, please add your name, date, and signature below. Once completed, please return this form to your class teacher.

Have you read the information leaflet describing the project? YES NO

Has someone explained the project to you? YES NO

Do you understand what this project is about? YES NO

Have you asked all the questions you want? YES NO

Have you had your questions answered in a way you understand? YES NO

Do you understand it's OK for your students and teachers to stop taking part at any time? YES NO

I understand that my school participation is entirely voluntary YES NO

I understand students and teachers can withdraw at any time without any negative consequences.

YES NO

I confirm I have the authority to give permission to my school to take part YES NO

Name of child:

Forename Surname

Name of school:

I give permission for the school to take part in the above study.

Name of head teacher:

Signature: Date: dd / mm / yyyy

Name of researcher:

Signature: Date: dd / mm / yyyy

If you would like to receive an annual newsletter summarising our research, please fill in your address:

2. Information Sheet For Children Aged 6 TO 12 Years

To be shown and read by parent/guardian if required

Ethics Approval Reference: R93428/RE001

My name is Hetao Zhang and I am studying at the University of Oxford in the United Kingdom. Do you know where that is? Although I'm studying there, I am from China. Part of my studies involve learning about how children like you learn through some games. If you are interested in joining me in the study, we can do some activities together. Some of them will be on a tablet, where you can touch and swipe the screen. Other activities will have you use your hands to move things around. There will be six games in total, three of them will be on iPad, and the other three will use paper and other materials. Before every game I will let you know about the rules, but if you don't want to play, or you dislike the game, you can let me know and we can stop it. You can talk to your family or ask me or your teachers questions if you want to before saying if you agree to join me.

Why have I been asked?

I am asking you if you would like to take part because you are students from Yuecheng School, Shaoxing, China, and I am interested in seeing how children here can learn using these games.
All children of the school are welcome to join the games if they and their parents agree to it. I'm asking you now because your parent/guardian has said it is OK for you to join in.

Do I have to join in?

No you don't have to if you don't want to! You can ask questions before choosing whether you want to join in. You can change your mind at any time by telling the researcher or your parent/guardian. You don't have to say why. If you decide to stop, no one will be upset with you.

What will happen?

Before we start our adventure with games, we'll have a little chat to get to know each other. You'll learn about the activities I have planned for you and when you're ready you can say: "Yes, let's do it!".

We'll meet twice on this journey – no need to pack a bag because we'll be doing all this at your school. That means you won't miss out on any school fun with your friends!
In our sessions, we will play with some super cool iPad games called "." Other games will take place without an iPad. However, they are all about you learning about some characters and helping them to solve puzzles. Each game lasts about as long as it takes to eat a snack, around 10 minutes. You'll have plenty of time to rest in between, just like during playtime. have plenty of time to rest in between, just like during playtime.

Will anything about the research upset me?

There won't be anything scary or terrifying– it's all about playing games on an iPad, like a puzzle-solving wizard!. If you ever feel a bit unsure or just need a break, you can tell us, and we'll be there with high-fives and time-outs whenever you need them. If you feel uncomfortable or don't to do this anytime, please let me know, we can stop this anytime.

Will joining in help me?

What I learn about how you solve these puzzles might help others to create games for children like you in the future.

Will anyone else know I'm doing this?

Only my supervisor and me will have the access to the results of the games. My supervisor is also at the University of Oxford in the United Kingdom but he won't come to school like me. No one will know that you have helped us with this research - unless, of course, you tell them yourself!

What happens to what the researchers find out?

When we are playing games, we will keep the results it in a safe place and only my supervisor and I will look at them. We will use this information to understand how you did in the game and we will share our results of this analysis with you at the end of the study.

Is this study OK to do?

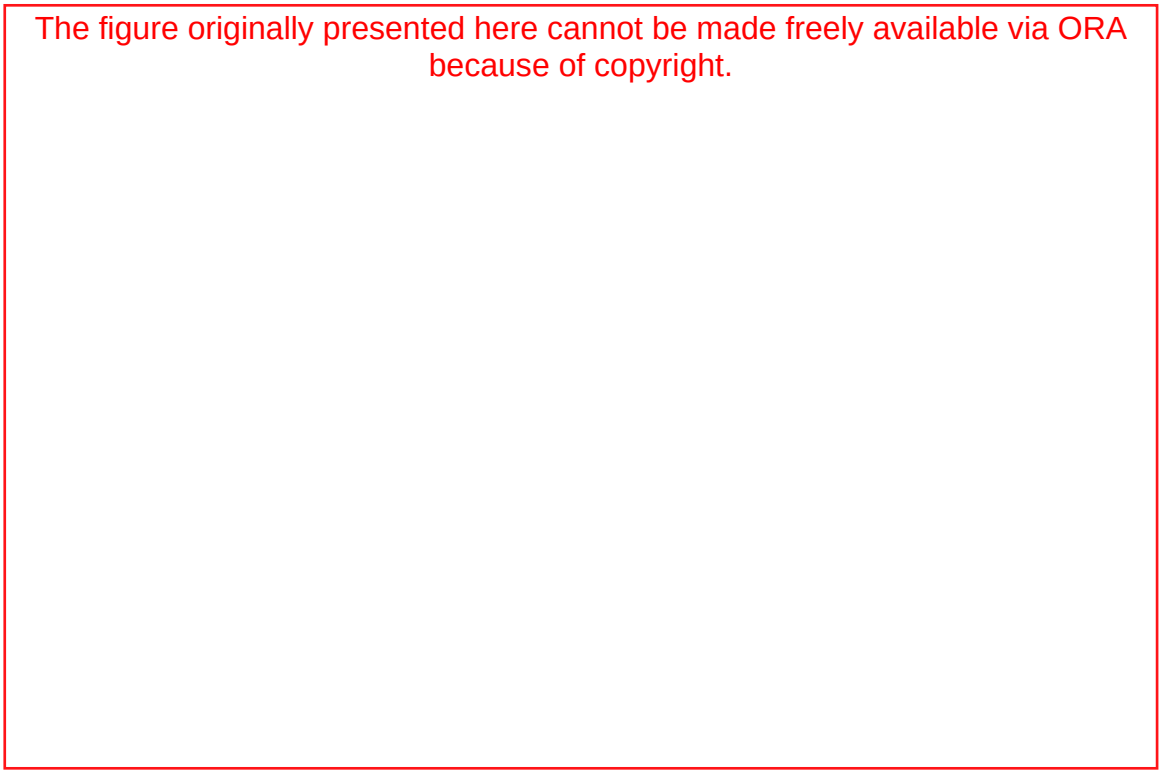
Before any research involving people happens it has to be checked by a group of people known as a Research Ethics Committee to make sure that it is fair. This study has been checked by the Ethics Committee at the University of Oxford.

What if there is a problem or something goes wrong?

If you are not happy because of something that happened in the study, please talk to your parent/guardian who will let the researcher know.

Thank you for reading – please ask us any questions.

Appendix – Sample images of the games



3. Assent From for Children

ASSENT FORM FOR CHILDREN

Attention and memory games for children.

Child (or if unable, parent/researcher/teacher on their behalf) to circle all they agree with:

- Has somebody else explained this project to you? Yes/No
- Has it been explained in the way that you understand? Yes/No
- Do you understand what this project is about? Yes/No
- Have you asked all the questions you want? Yes/No
- Have you had your questions answered in a way you understand? Yes/No
- Do you understand it's OK to stop taking part at any time? Yes/No
- Are you happy to take part? Yes/No

If any answers above are "no" or you don't want to take part, that's OK! No one will be upset.

If you do want to take part, please write your name below.

Your name

Date

Your parent or carer must write their name here too if they are happy for you to do the project.

Print name _____

Sign _____

Date _____

The researcher who explained this project to you needs to sign too:

Print Name

Sign

Date

Thank you!

4. **Information Sheet For Caregivers and Teachers**

Attention and memory games for children.

INFORMATION SHEET FOR PARENT AND CAREGIVER
To be shown and read by parent/guardian if required
Ethics Approval Reference: R93428/RE001

My name is Hetao Zhang and I am studying at the University of Oxford, United Kingdom. I am a Master's student in Education and my specialism is Child Development and Education. My supervisor, Dr. Ernesto Roque-Gutierrez, and I are planning a study and we would like to invite your children to participate. The objective of the study is to understand how children with Autism Spectrum Disorder (ASD) perform in different cognitive tasks. We are not planning to compare your children with other children. Our focus is on your children's performance in different games.

Some of these games will be on a tablet, where they can touch and swipe the screen. Other games will require they use their hands to move things around or sorting things by rules. There will be six games in total, three of them will be on iPad, and the other three will use paper, cards and other materials. We will explain the rules of each game to your children before we start, and they will be able to practice before the actual session begins. You can see some images of the games below. If children don't want to play or you have any concerns about their participation you can let me know at any time and we can stop the study. Ultimately it is your decision and theirs if they participate in the study.

Why have your children been asked?
We are asking you if you would like to take part because your children you are students from Yuecheng School, Shaoxing, China, and I am interested in seeing how children here can learn using these games.
All children of the school are welcome to join the games if they and their parents agree to it. If you agree to your child participating in the study, I will still ask them directly if they want to participate. If they are not willing to do it I will not ask them to participate.

Do your children have to join in?
No, you don't have to if you don't want your children to be a part of it! You can ask questions before choosing whether you want your children to join in. You can also change your mind at any time by telling me. You don't have to say why. If you decide to stop, that's all depends on you and your children. Not participating will not have any negative effect on your child and because the games are done individually and not in group they will not be left out if they decide not to join. A separate list linking participant names to their unique numbers will be maintained the latest in August 2024, and we will keep the research data for three years.

What will happen?

Before we start our adventure with games, I'll have a little chat with your children to get to know each other. Your children will learn about the activities I have planned for them and when they're ready to participate they will say "Yes, let's do it!" to my request.

I'll meet with your children twice on this journey – always at this school. That means your children won't miss out on any school fun with their friends. The games have been planned to be as least disruptive as possible. I have worked with the school teachers and leadership to make sure of this and they will be supporting the study.

In our sessions, we will use some iPad games that are part of the "Early Year Toolbox" suite, co-developed by a researcher at the University of Oxford, where I study. As I mentioned before, other games will take place without an iPad. However, they are all about your children helping some characters (e.g., an ant) and helping them to solve puzzles. Each game lasts approximately 10 minutes. They'll have a rest in between games and no more than 3 games will take place during one session. In total, this means your child will interact with these games for 60 minutes in two sessions, or 30 minutes per session.

Will anything about the research upset me?

There won't be anything scary or terrifying. These games have been used extensively with children from different parts of the world, including children with ASD in China. They are not unlike other puzzle-solving games that they have probably interacted with before. The school team and the child teachers have been briefed about the game and they will be supporting the study. If your child feels uncomfortable at any stage, even if they don't tell us, school staff have been asked to intervene to stop any of the exercises at any stage.

Will joining in help me?

Insights from this study can help researchers interested in ASD children's cognitive abilities. This, in turn, could inform the development of similar games in the future. However, I want to clarify that I'm not affiliated with the developers of the iPad games and have no interest in these games being used over others.

Will anyone else know I'm doing this?

Only my supervisor and I will have the access to the results of the games. All data about how your child performs in the games will be anonymised. Any reports or publications which refer to this data will never mention your child.

What happens to what the researchers find out?

The insights from the study will be reported in my Master's thesis, which I will submit in August 2024. Additionally, there may be opportunities to share the results more broadly through publication in academic journals or presentations at professional conferences, and again any details that might identify your children will be strictly protected, ensuring they remain unrecognizable in any data shared. If you're interested in the results of the study you can contact me, Hetao Zhang hetao.zhang@gtc.ox.ac.uk or my supervisor Ernesto Roque-Gutierrez at ernesto.roque-gutierrez@education.ox.ac.uk. The school might receive a report of the overall performance and trends, but this will not be for individuals and instead for the whole group.

Is this study OK to do?

This study has been approved by the Central University Research Ethics Committee at the University of Oxford (REF:R93428/RE001). It complies with all the parameters established by them for researchers to conduct studies that are ethical, meaning that they respect the dignity, rights and welfare of participants.

What if there is a problem or something goes wrong?

If you are not happy with something about the study or have any concerns you can contact me directly at hetao.zhang@gtc.ox.ac.uk or the school teacher or principal who will then contact me.

Thank you for reading – please ask us any questions.

Appendix – Sample images of the games

5. Parent/Guardian Consent Form

PARENT/GUARDIAN CONSENT FORM

CUREC Approval Reference: R93428/RE001

Comparing digital and non-digital executive function assessments with Chinese children with autism spectrum disorder

Your child's school has agreed to take part in a study developed by Hetao Zhang, a master's student at the University of Oxford, United Kingdom, under the supervision of Dr. Ernesto Roque-Gutierrez. The objective of the study is to understand how some children with Autism Spectrum Disorder (ASD) perform in different cognitive tasks (e.g., memory games). We're curious to compare their performance and experiences when they play these games on a digital tablet versus instances where they interact with other physical materials (cards, paper, etc.). We are not planning to compare your children with other children. Our focus is on your children's performance in different games.

- If your child takes part, a researcher will come and visit them at school, and play a maximum of three games with them per session. No more than two sessions are expected per child. Each session of different modalities of games will last around 30 minutes, with three games and between each game, there will be a short break. Therefore, the duration of the whole experiment will be approximately 1 hour excluding breaks. There is also a possibility of organising these into three 20-minute sessions if the school agrees that this would be less disruptive to the daily schedule.
- To find out more about the study, please read the attached information sheet. You can e-mail us at hetao.zhang@education.ox.ac.uk or ernesto.roque-gutierrez@education.ox.ac.uk. You can also call the researcher Hetao Zhang on +8613655751526 if you have any questions.
- To confirm if you are happy for your child to take part, please indicate YES if you agree or NO if you disagree with the statements below. If you have answered YES to all statements, please add your name, date and signature below. Once completed, please return it to your child's class teacher.

- -

Have you read the information leaflet describing the project?	YES	NO
Has someone explained the project to you?	YES	NO
Do you understand what this project is about?	YES	NO
Have you asked all the questions you want?	YES	NO
Have you had your questions answered in a way you understand?	YES	NO
Do you understand it's OK to stop taking part at any time?	YES	NO
Are you happy to let the child take part?	YES	NO

Name of child:

Forename Surname

Name of school:

I give permission for my child to take part in the above study.

Name of parent/guardian:

Signature: Date: dd / mm / yyyy

Name of researcher:

Signature: Date: dd / mm / yyyy

If you would like to receive an annual newsletter summarising our research, please fill in your address: _____

6. Information Sheet For Caregivers and Teachers for a Focus Group

Attention and memory games for children.

INFORMATION SHEET FOR CAREGIVERS AND TEACHERS

Interested in participating in a focus group.

Ethics Approval Reference: R93428/RE001

My name is Hetao Zhang and I am studying at the University of Oxford, United Kingdom. I am a Master's student in Education and my specialism is Child Development and Education. My supervisor, Dr. Ernesto Roque-Gutierrez, and I are planning a study and we would like to invite your children to participate. The objective of the study is to understand how children with Autism Spectrum Disorder (ASD) perform in different cognitive tasks. This study aims to gain insights into the educational impact of game-based learning on children. Your observations and opinions are invaluable to understanding the broader implications of gameplay on learning outcomes.

What You Will Do:

Following your child/student's gameplay, we will ask you to complete to participate in a focus group. This will involve responding to a series of questions/prompts about your impressions of how your child/student interacted with the tasks used. This will take no more than 60 minutes of your time and will be scheduled at your convenience.

Sample of Topics We Might Ask About:

- Your overall impression of the game's educational value
- Observations about your child's/student's engagement and learning
- Any changes you noticed in your child's/student's knowledge or skills
- Feedback on the game's content and usability

Confidentiality:

Your responses will be confidential. No personal or identifiable information will be published or presented. All data will be reported in aggregate form in my Master's thesis and may also be included in journal articles or conference presentations. At no point will any information be disclosed that could lead to the recognition of your children or students.

Do your children have to join in?

No, this is really about your opinions and views. We are really interested in what your thoughts are regarding the use of these games with your child/student.

What happens to what the researchers find out?

The insights from the study will be reported in my Master's thesis, which I will submit in August 2024. Additionally, there may be opportunities to share the results more broadly through publication in academic journals or presentations at professional conferences, and again any details that might identify your children will be strictly protected, ensuring they remain unrecognizable in any data shared. If you're interested in the results of the study you can contact me, Hetao Zhang hetao.zhang@gtc.ox.ac.uk or my supervisor Ernesto Roque-Gutierrez at ernesto.roque-gutierrez@education.ox.ac.uk. The school might receive a report of the overall performance and trends, but this will not be for individuals and instead for the whole group.

Is this study OK to do?

This study has been approved by the Central University Research Ethics Committee at the University of Oxford (REF:R93428/RE001). It complies with all the parameters established by them for researchers to conduct studies that are ethical, meaning that they respect the dignity, rights and welfare of participants.

What if there is a problem or something goes wrong?

If you are not happy with something about the study or have any concerns you can contact me directly at hetao.zhang@gtc.ox.ac.uk or the school teacher or principal who will then contact me.

Thank you for reading – please ask us any questions.

7. Focus Group Consent Form For Caregivers and Teachers

FOCUS GROUP CONSENT FORM FOR CAREGIVERS AND TEACHERS

Central University Research Ethics Committee (CUREC)

Approval Reference: R93428/RE001

Please initial each box

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, and without any adverse consequences or penalty.
3. I understand that research data collected during the study will be looked at by authorised people within the research team. I give permission for these individuals to access my data.

4. I understand that this project has been reviewed by, and received ethics clearance through, the University of Oxford Central University Research Ethics Committee.
5. I understand who will have access to personal data provided, how the data will be stored and what will happen to the data at the end of the project.
6. I understand how this research may be written up and published.
7. I understand how to raise a concern or make a complaint.
8. I give permission to be quoted directly in research outputs against a pseudonym.
9. I agree to take part in the study

	dd / mm / yyyy	
Name of Participant	**Date**	**Signature**

	dd / mm / yyyy	
Name of person taking consent	**Date**	**Signature**

8. Research Ethic Approval

Research ethics approval

Research title: Comparing digital and non-digital executive function assessments with Chinese children with Autism Spectrum Disorder

Research ethics reference: R93428/RE001

The above application has been considered by the Social Sciences and Humanities Interdivisional Research Ethics Committee (SSH IDREC) in accordance with the University's procedures for ethical approval of all research involving human participants.

I am pleased to confirm that, on the basis of the information provided to the IDREC, ethics approval has now been granted for this study for the period 28th June 2024 to 28th December 2025.

Please note the following:

Personal data: It is the responsibility of the Principal Investigator to ensure that all personal data collected during the project is managed in accordance with the University's guidance and legal requirements.

Fieldwork: The University's Safety in Fieldwork Policy must be followed.

Amendments: Please notify the committee if you intend to make any amendments to the information in your ethics application as submitted at date of this approval, as all changes must receive ethical approval prior to implementation. The amendment form is available on the SSH IDREC webpage.

Adverse events: The SSH IDRECs must be notified within seven days of any unexpected adverse consequences to the research participants, researchers or other people involved in this research project.

Audit: The SSH IDREC audits a sample of projects each year to enable the Committee to monitor the ethical aspects of research in progress.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ethics@socsci.ox.ac.uk.

Yours sincerely

Mr Charles Brassley, for

Jennifer Blaikie, Research Ethics Manager (SSH IDREC) cc: Dr Ernesto Roque-Gutierrez, Irina Lepadatu