Future-Oriented Cognition during Preschool Years:

Cognitive Correlates and Cultural Contrast

Ning Ding

Hughes Hall

University of Cambridge

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Declaration

The work in this thesis was carried out under the supervision of Professor Nicola S. Clayton FRS at the Department of Psychology. All parts of this dissertation are the result of my own work and includes nothing which is the outcome of work done in collaboration except for those aspects which are detailed below.

In Chapter 3, Rachael Miller and Anna Frohnwieser collected data of British site. The data of Chinese site was collected by myself.

In Chapter 5, the experiment was designed with collaborators specified in the publication and the data was collected by Rachael Miller, Anna Frohnwieser and myself.

The thesis is not substantially the same as any that I have submitted or is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other university or similar institution. It does not exceed the prescribed word limit for the relevant Degree Committee.

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The capacity to understand, construct, imagine and plan for the future goes hand in hand to scaffold and support future-oriented cognition. The development of future-oriented cognition undergoes critical changes during the preschool period and an emerging theme in developmental psychology is to elucidate its cognitive correlates. A significant oversight, however, is that the existing body of literature is reliant almost exclusively on data drawn from children from Western societies, with little evidence on children growing up in Eastern countries. The overarching aim of my thesis is to further our understanding of cognitive correlates and potential cultural contrast of future-oriented cognition. To this end I report four empirical studies testing and comparing pre- schoolers from Britain and mainland China on an array of future-oriented cognition tasks.

In Chapter 2, I test Chinese pre-schoolers with a comprehensive and standardised task battery and they show age-related performance and developmental trajectory across different components of future-oriented cognition, which resembles that found for Western children. Performance on some tasks is significantly linked to children's executive function ability but not with theory of mind competency. In Chapter 3, I utilise a delay choice paradigm modified from comparative research and Chinese pre-schoolers demonstrate greater capacity of delay of gratification compared to British counterparts when reward visibility is manipulated (though it has no significant effect on performance). Across both countries, pre-schoolers perform better when rewards vary in quality than in quantity and Chinese pre-schoolers' delay of gratification is related to their inhibition ability.

In Chapter 4, I focus on children's understanding of changes in future preferences, finding that the developmental trajectories are universal between British and Chinese pre-schoolers. Children's prediction of future preferences is more accurate for a peer than for themselves and performance is improved when children have first identified their current preferences before anticipating the future. Furthermore, inhibition and cognitive flexibility are associated with the prediction of children's own, though not peers' future preferences. In Chapter 5, I adopt a flexible future planning task in tool use context while addressing existing methodological critiques. British children show standard age-related developmental patterns with the novel task and their performance is unrelated to executive function and language competency. I conclude

by discussing the implications of my findings and future directions for the research of future-oriented cognition in young children.

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Publications

The empirical chapters in this thesis were written to stand alone with the purpose of facilitating conversation into journal articles.

Chapter 2 includes content from:

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Chapter 4 includes content from:

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Chapter 1. General Introduction

"Living backwards!" Alice repeated in great astonishment. "I never heard of such a thing!"
"But there's one great advantage in it, that one's memory works both ways."
"I'm sure mine only works one way," Alice remarked. "I can't remember things before they happen."
"It's a poor sort of memory that only works backwards," the Queen remarked.
"What sort of things do you remember best?" Alice ventured to ask.
"Oh, things that happened the week after next," the Queen replied in a careless tone.

— *Lewis Carroll 《Alice in Wonderland》*

The White Queen's foresight is in stark contrast with Alice's "youthful short-sightedness" (temporal myopia), a well-established phenomenon among developmental psychologists that children are less future-oriented than adults and more prone to poor decision making (Steinberg et al., 2009). Ranging from trivial mundane events such as tomorrow's grocery list to significant long-term choices of career and relationship, thoughts about the future arise consciously and involuntarily and constitute an important part of human's mental life (Berntsen & Jacobsen, 2008; D'Argembeau, Renaud, & Van der Linden, 2011). Future-oriented cognition is an umbrella term, which broadly encompasses an array of cognitive processes involved in understanding, constructing, imagining, and planning for the future. The past two decades witnessed the field of future-oriented cognition becoming a research topic in its own right (Atance, 2015). The exponential growth has been fuelled by evidence highlighting the intrigue link between remembering the past and anticipating the future (Addis, Wong, & Schacter, 2007; Okuda et al., 2003; Szpunar, 2010; Szpunar, Watson, & McDermott, 2007; Tulving, 2002). It also coincided with the unsettled debates about its evolutionary roots with emerging animal research challenging the idea that future thinking capacity is uniquely human (Boeckle & Clayton, 2017; Clayton, Bussey, & Dickinson, 2003; Raby & Clayton, 2009; Tulving, 1985; 2005).

The importance of future-oriented cognition has long been recognised in developmental literature and it was considered to scaffold planning ability and prudence behaviours (Haith, 1997; Thompson, Barresi, Moore, 1997). With various new experimental paradigms, there is general agreement that children undergo important development of future-oriented cognition in preschool years (Atance, 2015; Hudson, Mayhew, & Prabhakar, 2011). Nevertheless, there are still significant empirical questions in relation to its cognitive correlates. Furthermore, the existing body of knowledge has been reliant on data from Western samples, largely overlooking the populations from non-Western cultures. Addressing these literature gaps, this thesis has two primary aims (i) to examine and cross-culturally compare Eastern children's future-oriented cognition with their Western peers, (ii) to elucidate its cognitive correlates. This chapter provides an overview of the relevant literature and sets the stage for four empirical chapters each with its independent rationale and findings.

1.1 Conceptualisation and theories

Future-orientation is a concept which has been studied across different disciplines in psychology, including social psychology, cognitive psychology and developmental psychology (Keough, Zimbardo & Boyd, 1999: Seginer, 2019; Shipp & Aeon, 2019). It is a conglomerate of diverse thinking and behaviours, including imagining and constructing mental representations of the future, anticipating, prioritising, and planning for future needs, as well as understanding changes in emotions and attitudes at different temporal points (McCormack & Hoerl, 2020). From an evolutionary perspective, future-oriented cognition provides powerful survival strategy in allowing human to predict and avoid threats before they manifest and shaping current behaviours for future needs (Suddendorf, 2006). Clinically, impaired future-oriented cognition has been associated with anxiety, depression, addiction and obesity problems (Daniel, Said, Santon, & Epstein, 2015; Henry, Addis, Suddendorf, & Rendell, 2016; Terrett et al., 2017). Furthermore, its educational implications extend to the development of self-concept and academic achievement, especially children's ability to intentionally engage in deliberate practice to perform repeated actions for future improvements (Davis, Cullen, & Suddendorf, 2016; Prabhakar, Coughlin, & Ghetti, 2016; Suddendorf, Brinums, & Imuta, 2016).

In recent developmental literature, future-oriented cognition has been synonymous with the ability to mentally project oneself in time to pre-experience future events. The parallel conceptualisation was the result of Tulving's profound work on the distinction between episodic and semantic memory (1985). Indeed, many terms have been coined to reflect their theoretical roots, such as mental time travel (Suddendorf, & Corballis, 1997; Tulving, 2002), episodic foresight (Suddendorf & Moore, 2011), and episodic future thinking (Atance & O'Neill, 2001, 2005). Notably, episodic memory is the recollections of personally significant events and has the adaptive significance of allowing people to mentally travel back to the past and forward to the future (Tulving, 1985). Semantic memory, in contrast, does not involve subjectively re-experiencing personal events and it comprises of general and script-based knowledge.

Different lines of research, including neuroimaging studies and reports from clinical patients, have consistently documented the link between remembering the past and thinking of the future (Addis et al., 2007; D'Argembeau & Van der Linden, 2006; Hassabis, Kumaran, Vann & Maguire, 2007; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002; Okuda et al., 2003; Schacter & Addis, 2007; Szpunar, 2010; Williams et al., 1996). Recent theoretical account proposed that simulation of mental representations of the future is a constructive and flexible process where memory of the past serve as the building blocks and in turn the anticipated future can guide current behaviours to address future problems (constructive episodic simulation hypothesis, Schacter, Addis, & Buckner, 2007).

This is not to say that future-oriented cognition only requires episodic information. Researchers have argued that planning for the future requires both semantic knowledge and episodic recollections, with semantic future thinking may even be the precursor of episodic future planning and behavious (D'Argembeau & Mathy, 2011; Martin-Ordas, Atance, & Caza, 2014; Prabhakar, & Hudson, 2014; Quon & Atance, 2010; Schacter & Addis, 2007; Schacter, Benoit, & Szpunar, 2017). Additionally, several cognitive abilities have been researched independently but they also fit into the holistic conceptual framework of future-oriented cognition because of the involvement of a prospective component (Atance & Jackson, 2009; Mazachowsky & Mahy, 2020). Specifically, delay of gratification reflects future-oriented decision making in which children need to forgo the immediate available reward to obtain a more valuable reward in future (Mischel, Shoda, & Rodriguez, 1989). Characterized as "memory for future intentions" (Hitch & Ferguson, 1991), prospective memory entails the ability to remember an intention and executive it at a specific future moment (Ellis & Kvavilashvili, 2000). In this thesis, for clarity and consistency consideration, I use the term future-oriented cognition to refer to an array of reasoning and behaviours involved in conceiving the future, imagining and preparing for future events and making decisions that will affect how the future unfolds. Terms such as prospective memory and delay of gratification are used to refer to specific components of future-oriented cognition.

1.2 Methodological approaches of future-oriented cognition

This section reviews the development and findings of existing paradigms which measure pre-schoolers' (children aged between 3 and 5 years old) future-oriented cognition, focusing on the recently developed behavioural paradigms. Four different components of future-oriented cognition are covered, specifically episodic future thinking, delay of gratification, planning ability and prospective memory. Prior to that, studies using verbal methods are briefly presented.

1.2.1 Verbal paradigms

Children's early talk of the future stemmed in child-parent dyadic conversations about upcoming events and future plans (Hudson, 2004, 2006; Nelson, 1998; Sachs & Nelson, 1983). From age 3, children started to use different verb forms and modalities to differentiate events happening in the past, present and future with greater uncertainty expressed when discussing about the future (Atance & O'Neill, 2000; Harner, 1975, 1981; Herriot, 1969). Although largely to be script-based and lack the episodic details in their future-oriented talk, children's use of broader temporal, such as "later" and "soon", was correct and frequent (Busby, Grant, & Suddendorf, 2011). A series of studies have asked pre-schoolers to report personal experience of yesterday and tomorrow and the accuracy of their answerers were checked by parents. Despite no age differences in their ability to provide verbal reports, 3-year-olds' reports were largely rated as inaccurate compared to the 4- and 5-year-olds (Busby & Suddendorf, 2005; Suddendorf, 2010).

Furthermore, understanding specific lexical terms, for instance 'yesterday" and "tomorrow", appeared to be more difficult than general temporal, "did" and "will" for children under age 4. Also, children's verbal accounts were more accurate when asked about specific events and events that they had more control of (Grant & Suddendorf, 2011; Harner, 1975; Quan & Atance, 2010). Questions of more distant future (e.g., when you grow up) have been used to examine children's judgments of changes in general knowledge (Atance & Caza, 2018). Researchers have documented age-related improvements in per-schoolers' understanding that they would have knowledge in the future which they currently don't possess. However, only 5-yer-olds were able to acknowledge that certain things were even unknowable for adults.

A different line of enquiry has combined verbal and behavioural measures in assessing pre-schoolers' future-oriented cognition. Atance & O'Neill (2005) designed a trip task in which they asked 3-year-olds to selected items for a future trip and to explicitly explain their choices. Although children succeeded in choosing the correct item for specific trip locations (e.g., a beach), they were less successful in providing descriptions to reflect future orientation and future uncertainty. A more recent paradigm has examined children's spontaneous and involuntary talk and researchers found that children who chose the right item uttered more about the task set up and referred both to their past experience and the expected future problem (Caza & Atance, 2019).

1.2.2 Behavioural paradigms

Relying on verbal responses to measure future-oriented cognition maybe particularly misleading during the preschool years, a period when language itself undergoes substantial development. Behavioural tasks with age-appropriate instructions are therefore considered more informative and reliable because they lessen the potential confound of language in children's performance (Suddendorf & Busby, 2005). As Suddendorf and Corballis (2007) noted, any behaviour deems to be mental time travel must plan for a future need or stress a future state that the individual is not currently experiencing, a criterion based on Bischof-Köhler's work. Specifically, the Bischof-Köhler hypothesis suggests that non-human animals cannot anticipate future needs, especially physiological ones, and they only act based on their current needs (Bischof-Köhler, 1985). This has become the cornerstone of comparative research and converging evidence show that animals were able to plan for satisfying future needs which were not currently experienced (Correia, Dickinson, & Clayton, 2007; Raby, Alexis, Dickinson, & Clayton, 2007).

Tulving (2005) proposed a nonverbal measure of mental time travel, the "spoon paradigm". It was based on an Estonian tale of a little girl who took a spoon to bed in order to avoid the disappointment of not being able to eat pudding which she experienced in her dream the previous night. The first study of "spoon paradigm" tested children's ability to select puzzle pieces to avoid anticipated boredom (empty puzzle board with no puzzle pieces to play with). Only 4-and 5-year-olds were able to act in the present to satisfy future psychological needs (Suddendorf & Busby, 2005). However, children could have succeeded in the task by semantically associating puzzle pieces with puzzle board and the continued desire to play may have influenced their selection (thus not fulfilling the Bischof-Köhler hypothesis). Designed to involve less semantic association, Suddendorf, Nielsen and von Gehlen (2011) presented 3- and 4-year-olds with a novel problem in one room and after 15 minutes later in a different room children were given the opportunity to secure a solution (select a specific item) and take it back to the first room. Researchers have shown that temporal displacement between the problem and its solution, rather than spatial displacement, influenced children's performance and only children aged 4 were able to select the correct item above chance level. Subsequent research of the spoon paradigm consistently found that children below the age of 4 are unable to use past information to solve future problems (Payne, Taylor, Hayne, & Scarf, 2015; Redshaw & Suddendorf, 2013; Scarf, Smith, & Stuart, 2014).

Similarly, a study with the two rooms design built on Raby and colleagues' work on western scrub-jays' future planning ability. Researchers shown that 4- and 5-year-olds were able to recall personal experience and put toys in the room where the resources were lacking

(Atance, Louw, & Clayton, 2015, Raby et al., 2007). Saving behaviours reflect “future-self continuity” and anticipation of the future (Ersner-Hershfield, Garton, Ballard, Samanez-Larkin, & Knutson, 2009). Notably, studies with pre-schoolers have shown that the ability to allocate and save resources improved with age and was sensitive to the desirability of future reward and temporal manipulation as well as the use of verbal prompt and planning strategy (Atance, Meltcalf, & Thiessen, 2017; Kamawar, Cannolly, Astle-Rahim, Smygwaty, & Vendetti, 2019; Martin-Ordas, 2018; Meltcalf & Atance, 2011).

That said, the delay between the problem and item selection and children’s memory of the past episode has found to significantly contribute to task success (Atance & Sommerville, 2014; Scarf, Boden, Labuschagnen, Gross, & Hayne, 2017; Scarf, Gross, Colomno, & Hayne, 2013). Furthermore, the role of memory retrieval in future-oriented cognition was further highlighted in a new paradigm, the “music game”, in which children’s memory of how they played the musical instruments was compared against their anticipation of how they would play in the future (Prabhakar & Hudson, 2019). Notably, even when the 3-year-olds could remember the past, they were still outperformed by the 4- and 5-year-olds, suggesting that children’s ability to select items for future solution and to link past and future events, not memory *per se*, underlined the age-related performance (Caza & Atance, 2019; Prabhakar & Ghetti, 2020).

Until very recently, there have been investigations of pre-schoolers’ ability to generate the means to address future need, which is different to the traditional spoon paradigm where children were asked to select the means with a forced choice design (Moffett, Moll, & FitzGibbon, 2018). The fact that 4- and 5-year-olds not only identified the means to future ends but only determined and created means to achieve future ends provides compelling evidence for future-oriented cognition. Furthermore, researchers have found that verbally generating the correct item to address future needs was more difficult than selecting the item among a set of distractors (Atance, Celebi, Mitchinson, & Mahy, 2019). It was only until the age of 6 that children managed to spontaneously seek information to prepare for future events, an ability not shown by pre-schoolers (Brinums, Redshaw, Nielsen, Suddendorf, & Imuta, 2021).

According to the mental scene construction, spatial context is important to episodic cognition and mentally projecting oneself to a specific location in the future would provide strong evidence for episodic future thinking (Clayton & Russell, 2009; Hassabis & Maguire, 2007). In the “Blow Football task”, pre-schoolers played a game on one-side of a table and were asked to select the items they would need to play in the future when at the opposite side of the table which they had never experienced (Russell, Alexis, & Clayon, 2010). Only 5-year-olds chose the correct items above chance level while 3-year-olds were notoriously poor. Worth noting is that 4-year-olds were more successful when selecting for another child than for themselves, a finding attributed to the growth error of visual perspective taking skills. In a different study, Burns and Russell (2016) investigated children's predictions of future perceptual experience and found that understanding a future temporal perspective and integrating spatial and temporal information was even challenging for children aged 5 and 6 years old.

A different line of studies has focused on pre-schoolers' understanding of anticipated physiological states. Specifically, Atance and Meltzoff (2005) developed the "Picture Book task" in which children were asked to select items in anticipation of hypothetical states, such as cold and hunger, and their item selection was accompanied by verbal explanations. Performance of the 4- and 5-year-olds approached ceiling level and they also made more reference to the future and specific physiological states than the 3-year-olds. Moreover, researchers have experimentally manipulated children's physiological states and found that children's prediction of future preferences was heavily influenced by their current physiological states (Atance & Meltzoff, 2006). In the "pretzel task", after consuming salty pretzel and feeling thirsty, children were asked whether they would like pretzel or water for tomorrow. Despite strong preferences for pretzel in the baseline conditions, children predominantly chose water over pretzel and their predictions of future preferences was heavily influenced by their current physiological state. Furthermore, there was no age improvement between 3 and 5 years of age with subsequent studies consistently reporting poor performance in the task even with older children and young adults (Cheke & Clayton 2019; Kramer, Goldfarb, Tashjian, & Lagattuta, 2017; Mahy, 2016; Mahy, Grass, Wagner, & Kliegel, 2014; Mahy, Masson, Krause, & Mazachowsky, 2020). Taken together, these findings indicated that young children are tethered to the present when salient and powerful physiological states are involved, challenging the Bischof-Köhler hypothesis which proposed that only non-human animals were stuck in the present for decision making (Bischof-Köhler, 1985).

When asked to predict for another person, e.g., the experimenter, children's performance on the Pretzel task improved (Mazachowsky, Koktavy, & Mahy, 2019) and this echoed the findings from Russel et al. (2010) who reported that the 4-year-olds were more successful in selecting the correct items for another child than for themselves. Similar trends were also found in children's understanding of changes in preferences for short and distant future (Bélanger, Atance, Varghese, Nguyen, & Vendetti, 2014; Martin-Ordas, 2018). Pre-schoolers were more accurate in predicting their peers' future preferences than predicting for themselves (Bélanger et al., 2014, for a fuller review, see Chapter 4). Notably, predicting for a similar peer was less accurate than for a dissimilar peer, highlighting the role of psychological distance in children's future-oriented cognition (Lee & Atance, 2016). In addition to changes in preferences, future also entail emotional uncertainties. Research on affective forecast (predicting future emotional reactions) has shown that pre-schoolers were prone to emotional intensity bias, but only with negative events in which they overpredicted how negative they would feel when facing undesirable outcomes (Gautam, Bulley, von Hippel, & Suddendorf, 2017; Kopp, Atance, & Pearce, 2017).

Weighing immediate gains against long term rewards is critical for decision making. Abstain from small and immediate gratification in order for the future self to reap the greater benefits is undoubtedly an adaptive function (Stevens, 2014). The study of delay of gratification has been one of the most prolifically researched topics in psychology. Half central of research has enriched our understanding of its development trajectory and contextual factors that influence children's capacity to postpone gratification (Mischel, et al., 1989; Moore, Barresi, & Thompson, 1998) (see Chapter 3 for a fuller review). Thompson and colleagues (1997) described the ability as "behaviour aimed at benefiting one's future self" and it is reliant on the understanding that present actions are connected to future outcomes (Lemmon & Moore, 2007). As Bulley and colleagues proposed, delay of gratification and intemporal choices in adults are supported by vivid envision of future scenarios and mentally projecting into the future would allow people to evaluate the likelihood and affective consequences associated with immediate and delayed options (Bulley, Henry, & Suddendorf, 2016). A very recent study has revealed convergence between children's ability to inhibit immediate temptations and to select item to address anticipated need (Burns, McCormack, O'Connor, Fitzpatrick, & Atance, 2021).

Planning with a prospective component is inherently future-oriented cognition (Atance & Metcalf, 2013; McCormack & Atance, 2011). Classic paradigm such as the Tower of Hanoi has been intensively used in developmental literature. Notably, 4-year-olds were able to solve one-step ahead and 5-year-olds managed to form multiple strategies and select the most efficient one (Carlson, Moses, & Claxton, 2004; Kaller, Rahm, Spreer, Mader, & Unterrainer, 2008; Welsh, 1991). More recent methodological development of future planning came from McColgan and McCormac (2008). The "Zoo task" taps into children's ability to use past memory and semantic knowledge to construct temporally ordered future scenarios with embedded future goals. In the Zoo task, children were presented with a model zoo and tested on their ability to conceptualize temporal event sequences. Specifically, the 3-year-olds were notoriously poor in planning future intended actions with multiple steps and only 5-year-olds made inferences using temporal order information and constructed future event sequences. When the numbers of events reduced, 4-year-olds remembered information of past events but were still unable to plan for future events.

A similar but simplified route planning task was developed by Prabhakar and Hudson (2014) in which children needed to maintain future goals and construct two sequential steps of a future event (getting a present and attending a birthday party). 4-year-olds accomplished the complex version of the task with high working memory demand, and performance were equal when they were planning for themselves and for another child. In contrast, 3-year-olds only succeed in the low demand version when the two embedded goals were explicit and not contingent, and they performed better when planning for themselves than for others. Researchers have argued that young children' success on the task suggest that the ability to use sematic and general knowledge may well be the foundation of prospective memory and for the more complex future-oriented cognition that developed later in life (Prabhakar and Hudson, 2014).

One final future-oriented component of note is prospective memory. It is defined as the ability to remember an intended action and execute it at a specific future time. There are two subtypes, namely event-based prospective memory and time-based prospective memory (Ellis & Kvavilashvili, 2000; Kerns, 2000). Cumulative studies have shown that prospective memory is not only critical for daily functioning but also has important long term social and education implications (Causey, Bjorklund, 2014; Kliegel & Martin, 2003; Kretschmer et al., 2014). The typical format of prospective memory test involves inserting a prospective memory target in an ongoing task and measures that are suitable for different age groups have been developed (Kliegel, Mackinlay, & Jäger, 2008; Kvavilashvili, Messer, & Ebdon, 2001; Rendell, Vella, Kliegel, & Terrett, 2009). Notably, research with pre-schoolers has largely focused on event-based prospective memory given time-based prospective memory is considered more difficult and emerges later in development (Kliegal, Ropeter, & Mackinlay, 2006). Specifically, children start to develop prospective memory in the third year of life and continue into childhood, a developmental trajectory that is parallel to the other components of future-oriented cognition (Atance & Metcalf, 2013).

1.2.3 Insights from comparative studies

Whether future-oriented cognition, especially the capacity to mentally project oneself into the future to pre-experience events, is a uniquely human ability has been a heated debate of comparative research (Clayton et al., 2003). According to Bar (2007), foresight exist on a continuum and animals possess abilities that are sufficient for surviving in their environment. Empirically, Clayton and colleagues have investigated the natural food-storing and caching behaviours in scrub-jays and Eurasian jays and tools use in ravens. The evidence suggest that these birds were capable of planning for future states that were different from their current ones (Boeckle, et al., 2020; Boeckle, & Clayton, 2017; Cheke & Clayton, 2012; Clayton, Dally, Gilbert, Dickinson, 2005; Correia et al., 2007; Raby et al., 2007). Tulving (2005) proposed that to be considered as mental time travel animals should demonstrate behaviours that were not only satisfying current needs in the very near future. This has encouraged subsequent research with children and animals to adopt design with longer delays between the tool selection and future tool use (Atance et al., 2015; Kabadayi & Osvath, 2017; Martin-Ordas, 2018; Mulcahy & Call, 2006; Osvath & Osvath, 2008; Russell et al., 2010; Scarf et al., 2013).

Some future-oriented cognition paradigms that were initially developed for human have been shown to be suitable for testing other species (Beran, 2018; Miller et al., 2019, 2020; Mulcahy & Call, 2006). Notably, researchers have tested chimpanzees, corvids and children's delay of gratification with the exchange paradigm in which subjects were required to swap small reward or tokens for the better reward (Dufour et al., 2012; Steelandt, Thierry, Broihanne, & Defour, 2012). Comparing different species on the same paradigm was also possible. Recently, Miller and colleagues (2019) adopted a paradigm originally designed for primates and found that pre-schoolers' and New Caledonian Crow's delay of gratification were similarly influenced by reward quality. As Atance & Meltcalf (2013) noted, nonverbal paradigms tease apart the linguistic component in future-oriented context and provide useful framework and offer unique insights to developmental research, especially with preverbal and young children with limited language ability. Nevertheless, interpretation of animal data is open to question, mainly because the paradigms and designs are facing methodological critiques relating to possible learning explanations (Redshaw, Taylor, & Suddendorf, 2017, for a fuller review, see Chapter 5).

1.3 Cognitive correlates of future-oriented cognition

Future-oriented cognition is a multi-faceted cognition which is supported by abilities from different cognitive domains (Suddendorf & Corballis, 1997, 2007). Understanding the cognitive correlates would provide insights into its development, unravel the underlying mechanism and potentially shed light on designing new paradigms. In this section I present recent work on the different cognitive abilities that may contribute to young children's ability to understand and plan for the future.

Theory of mind and executive function came out as the strongest candidates for supporting future-oriented cognition, not only because of their parallel developmental trajectories during the preschool years but more importantly the proposed link was suggested by theoretical accounts and neuroimaging evidence (Atance & Jackson, 2009; Atance & Metcalf, 2013; Gautam, Suddendorf, Henry, & Redshaw, 2019). Notably, theory of mind refers to the ability to understand and attribute mental states to different people (Wellman, Cross, & Watson, 2001). As Buckner & Carroll (2007) argued, the ability to envision the future, remember the past, conceive other's viewpoints and spatial navigation share the same core brain network, e.g., frontal lobe and temporal-parietal lobe. Specifically, a common "self-projection" mechanism is suggested to be involved when projecting the current perspective to future perspective (future-oriented cognition) and when attributing mental states to another person (theory of mind) (Okuda et al., 2003). Indeed, meta-analysis of neuroimaging studies has highlighted the common network underlying perspective taking and prospection in adults (Spreng, Mar, & Kim, 2009). Furthermore, an early study on children's sharing behaviour has linked theory of mind competency to children's decision to share future rewards with peers (Moore et al., 1998).

Historically known as the frontal lobe function, executive function compasses a set of higher-order cognition which is employed in goal-directed actions and adaptive responses (Diamond, 2013; Hughes, 2011). There is general agreement that executive function is a unitary construct with three key components: (1) inhibition, also referred as inhibitory control, is the ability to deliberately withhold prepotent responses and control attention and behaviours in complex situations; (2) working memory is to mentally maintain and manipulate information; (3) cognitive flexibility entails the ability to shift flexibly between tasks and adapt to different demands (Best & Miller, 2010; Garon, Bryson, & Smith, 2008; Miyake et al., 2000). The link between executive function and future-oriented cognition has been highlighted with neurological evidence revealing overlapping brain regions, such as the frontal and prefrontal areas (Addis et al., 2007; Spreng, Stevens, Chamberlain, Gilmore, & Schacter, 2010; Stuss & Alexander, 2000). Although both cognitive abilities involve goal-directed behaviours and planning, temporal differences exist in that most executive function tests measure more immediate responses while future-oriented cognition usually includes decisions for more distant future (McCormack & Atance, 2011).

It is also possible that each executive function sub-component is employed differently in various future-oriented contexts (Buckner & Carroll, 2007; Suddendorf & Corballis, 2007). Broadly speaking, multiple mental representations may coexist at the same time and inhibition is particularly useful in reducing broad associative activations and ensuring the most relevant representations are activated (Bar, 2011). Thus, inhibition may be highly relevant in future-oriented scenarios when both the current and future perspectives are involved, especially when they are in conflict, as people need to put aside their current feelings and desires to make adaptive decisions (Hanson, Atance & Paluck, 2014). Additionally, working memory and cognitive flexibility are important for keeping track of multiple perspectives while being able to flexibly shift and coordinate the different demands.

Indirect evidence on the relationship between executive function, theory of mind and future-oriented cognition come from studies on episodic memory. Specifically, executive function and theory of mind were related to episodic memory in children and adults. The retrieval of episodic and factual details plays an important role in certain future-oriented context such as the spoon test (Blankenship & Bell, 2015; Blankenship, O'Neill, Deater-Deckard, Diana, & Bell, 2017; Naito, 2003; Perner, Kloo, & Gornik, 2007; Rajan, Cuevas, & Bell, 2014). Although prospective memory and delay of gratification have been consistently linked to executive function and theory of mind (Causey, Bjorklund, 2014; Ford, Dirscoll, Shum, & Macaulay, 2012; Hongwanishkul, Donaya, Happaney, Lee, & Zelazo, 2005; Kretschmer et al., 2014; Moore et al., 1998; Zuber, Mahy, & Kliegel, 2019), only a handful of studies have tested other components of future-oriented cognition, especially those newly developed paradigms, and yielded mixed results.

Ünal and Hohenberger (2017) reported that children's performance in a modified "Blow Football task" was predicted by spatial working memory. Executive function was also related to pre-schoolers' semantic future thinking (Blankenship, Broomell, & Bell, 2018). So far, the most comprehensive research was conducted by Hanson et al. (2014) who administered a battery of tasks of theory of mind, executive function and different measures of future-oriented cognition to children aged between 3 and 5. After controlling for age and language, children's performance in various future-oriented cognition tasks did not associate with theory of mind or executive function ability. According to the researchers, "conflicting alternate perspectives" may be the key element for establishing the relationship between the different cognitive domains, which was not captured by their task battery. As for theory of mind, it was questionable whether the nature and demand of perspective shift was comparable between mental states attribution and future-oriented cognition.

Another cognitive ability that has been considered to scaffold future-oriented cognition is language, which is the "broadcaster and communicator" as well as the evidence and manifestation of mental time travel (Atance & Metcalf, 2013; Suddendorf & Corballis, 2007). Specifically, language contributes to the development of future-oriented cognition through two distinctive pathways. First, a host of linguistic markers and temporal terms are available to differentiate events that happening at different time points and in this case the development of language itself acts as the backbone for understanding temporality (Grant & Suddendorf, 2010; Hudson, 2006; Suddendorf, Addis, & Corballis, 2009; Tillman, Marghetis, Barner, & Srinivasan, 2017). Second, in additional to its communicative function, memories of the past are constructed thorough narratives which provide the building blocks for mental representation of future events (Nelson & Fivush, 2004; Simcock & Hayne, 2002). Notably, children's ability to report memories of past events was positively associated with their predictions and narratives of the future after controlling for age and temporal language ability (Quon & Atance, 2010; Suddendorf, 2010). Engaging in future-oriented conversation also prompted pre-schoolers' prospective abilities (Chernyak, Leech, & Rowe, 2017). Ünal and Hohenberger (2017) directly tested the role of language in children's spoon task performance and found that the ability to envision future from a different spatial perspective and to select items for future use was significantly predicted by children's temporal language ability.

1.4 Cultural perspective on development of future-oriented cognition

It has long been recognised that human cognition is not only the product of biological and neurological maturation but also a malleable process that is susceptible to social-cultural influences (Hong, Morris, Chiu, & Benet-Martinez, 2000; Tomasello, 1999). How culture is defined and operationalised in research are vastly divided and psychologists consider culture as a holistic system and process of symbolic mediation where shared values, norms and beliefs are manifested and practiced through rituals, customs, and practices (Bruner, 1990, Rogoff, 2003; Wang, 2018). Culture is a multi-faceted construct which operates at different levels, from broad distal contexts, (e.g., the country) to specific social units (e.g., the family). It is through the interpersonal interactions that languages, actions, thoughts, history and moral values are shared and passed (Donald, 1991; Holland & Quinn, 1987; Valsiner, 2001). Consequentially, culture can cohere and unite groups as well as regulate intrapersonal and interpersonal psychological functions (Super & Harkness, 2002; Wang & Brockmeier, 2002). Broadly speaking, Western societies are characterised as individualistic given their emphasis on independence, self-expression and autonomy, whereas collectivistic East Asian cultures encourage interdependence, obedience and social connections (Oyserman, Coon, & Kemmelmeier, 2002; Trommsdorff, 2009). Besides consistent findings of cultural variations in memory, attention, perception and decision making (Cohen & Kitayama, 2007; Nisbett, Peng, Choi, & Norenzayan, 2001), growing neuroscience studies have highlighted the role of culture and social experiences in shaping brain structures and neural functions (Chiao, 2009; Han & Ma, 2015; Kobayashi, Glover, & Temple, 2006; Ma et al., 2014; Park & Huang, 2010).

The consensus cumulated from two decades of research suggests that culture and development go hand in hand (Bruner, 1990; Jablonka & Lamb, 2006; Tomasello, 2016; Vygotsky, 1978; Wang, 2013). The emerging cultural developmental science is devoted to investigating the early origins of cultural differences in reasoning and behaviours as well as understanding culturally specific developmental trajectories and pathways (Wang, 2018). According to Bronfenbrenner's (1979) model, broad socio-cultural context provides the "macrosystem" and the "microsystem" of schools and families incorporate socialization and traits, altogether influencing children's cognitive development. Indeed, observational studies have revealed clear contrasts in curriculum, structure and teaching methods among Western and East Asian educational settings. Specifically, collectivistic countries focus on self-discipline, order and adopt proactive behavioural instructions with whole-class activities, compared to the Western reactive approach of individualised training which facilitates exploration and self-expression (Kwon, 2004; Lan et al., 2009; Wang & Mao, 2006). Different rearing attitudes and parenting practice are also evident from the early years with East Asians emphasising self-discipline and fitting into the social circle whereas parents in Western societies encouraging self-autonomy and independent behaviours (Chen et al., 1998; Eisenberg, Chang, Ma, & Huang, 2009; Jaramillo, Rendón, Muñoz, Weis, & Trommsdorff, 2017; Liu et al., 2005; Olweus, Rubin, & Asendorpf, 1993).

How might culture potentially influence the development of future-oriented cognition? One possible pathway is through parent-child dyadic interactions (Wang, 2018). The importance of parent-child future-oriented conversation have already been recognised (Hudson, 2002, 2004, 2006). As noted previously in this chapter, memories of the past are vital to anticipation of future and there is burgeoning evidence on cross-cultural differences of autobiographical memory (Busby & Suddendorf, 2005; Suddendorf, 2010; Wang, 2021). Children's narratives and reports of autobiographical memory were predicted concurrently and longitudinally by culturally specific maternal reminiscence style (for a review, see Wang, 2013, 2021). Notably, parents from European American countries were characterised with their high elaborative style (focusing on individuals' experience, feelings and thoughts) when reminiscing and sharing memories of past events with their children. Whereas East Asian parents revealed low elaborative style and focused more on the factual details and highlighted the social connections between people (Wang, 2006, 2007, 2021; Wang & Fivush, 2005).

More importantly, a recent intervention study suggests that young children's imagination and narratives of future events were sensitive to parental behaviours. Wang et al. (2019) assigned Chinese and American mothers of 6-year-olds to either the control group, or the training group in which they received instruction to share memories with children and encouraged to talk about thoughts, desires and feelings. One year later, children with mothers in the training group reported past and future events with greater episodic details. Wang (2018, 2021) suggested that the conversation content and style are likely to be one of the early origins that contribute to the observed cultural differences in episodic future thinking (Chen et al., 2015; Shao, Yao, Ceci, & Wang, 2010; Wang, Hou, Tang, & Wiprovnick, 2011; Wang, Yue, & Huang, 2016). Another pathway that culture could influence future-oriented cognition is thorough language and understanding of temporality. Research has revealed that East Asian people, especially Chinese populations, have a stronger past-orientation than European Americans and the Mandarin language fosters temporal continuity with space-time metaphors, which is different to the system of temporal tenses in English (Boroditsky, 2001; Gao, 2016; Gu, Zheng, & Swerts, 2019; Hong, He, Tillman, Zhao, & Deng, 2017). Such cultural differences in language and temporal conceptualisation have been linked with variations in adults' future-oriented decision in terms of discounting future rewards (Croote et al., 2020).

Importantly, the knowledge of other key cognitive abilities has been broadened through the cultural lens. For example, stable cultural variations have been found in children's development of executive function and theory of mind across the period from preschool to adolescences and a host of socio-cultural factors have been identified to explain these differences (Hughes, Devine, & Wang, 2018; Lan, Legard, Ponitz, Li, & Morrison., 2011; Liu, Wellman, Tardif, & Sabbagh, 2008; Sabbagh, Xu, Carlson, Moses, & Lee, 2006; Wang & Kushnir, 2019; Wellman; Fang, Liu, Zhu, & Liu, 2006). In comparison, little is known about the development of future-oriented cognition outside the so-called WEIRD (Western, Educated, Industrialised, Rich, and Democratic) societies (Henrich, Heine, & Norenzayan, 2010). To date, only a handful of research have examined non-Western children's future-oriented cognition with one study directly compared children from different cultures (Naito & Suzuki, 2001; Redshaw et al., 2019; Wang, Capous, Koh, & Hou, 2014).

Also noteworthy is that these studies either narrowed research focus to one specific component of future-oriented cognition, e.g., delay of gratification, or have focused on children in middle childhood. What remain scarce, are investigations of non-Western children's development of different aspects of future-oriented cognition and their related cognitive correlates in the preschool stage. Relying on knowledge built from children growing up in

European American cultures would be problematic with culturally skewed and biased findings, resulting in an incomplete and non-representative picture of children's cognitive development (Nielsen and Huang, 2016; Nielsen, Haun, Kärtner, & Legare, 2017).

1.5 Thesis overview

Recent years have witnessed an explosion of interest in future-oriented cognition and newly designed paradigms have provided a clearer picture of its development in preschool years. However, existing body of literature has been predominantly reliant on European American children, rendering developmental trajectories of East Asian pre-schoolers *terra incognita*. Furthermore, only a small number of studies have examined the cognitive correlates of future-oriented cognition and the universality of these correlates is open to question. Addressing the twin gaps, this thesis recruited pre-schoolers from the United Kingdom and mainland China and measured different aspects of future-oriented cognition[1]. The Confucian culture and ideology from Ancient China is prevalent across Eastern societies and Chinese children has been one of the most widely studied groups in cultural developmental science (Liu et al., 2008; Nisbett & Masuda, 2003; Sabbagh et al., 2006; Xu, Ellefson, Ng, Wang, & Hughes, 2020).

With a comprehensive task battery measuring different cognitive domains, Chapter 2 presents a systematic investigation of Chinese pre-schoolers' future-oriented cognition and examines its developmental trajectories and cognitive correlates. Chapter 3 narrows the focus to one specific future-oriented behaviour, delay of gratification, and compared Chinese and British children's performance on a paradigm modified from comparative research (Bramlett, Perdue, Evans, & Beran, 2012). This study also examines whether children from different cultures are similarly or differently influenced by contextual factors, namely reward type and reward visibility. The experiment in Chapter 4 uses the future preference task (Bélanger et al., 2014) and investigates Chinese and British children's prediction of themselves and of peers. It also tests the proposal that executive function should be related to future-oriented cognition when current and future states are in conflict (Hanson et al., 2014). In Chapter 5, British children's ability to select item for future need is assessed in a tool-use context with a modified comparative paradigm (Kabadayi & Osvath, 2017). Furthermore, measures of language and executive function are included to test the cognitive correlates of children's flexible future planning.

[1] The starting age for school is different between Britain (Reception class from age 5) and mainland China (Year 1 class from age 6) (School Curriculum and Assessment Authority, 1997; Wang & Mao, 2006). However, the term "pre-schoolers" is consistently used in developmental research to refer to children aged between 3 and 5 years old.

Chapter 2: Developmental Patterns and Cognitive Correlates of Chinese Pre-schoolers' Future-Oriented Cognition[2]

2.1 Abstract

Existing literature on pre-schoolers' future-oriented cognition predominantly tested children from European American countries, whereas little is known about its developmental trajectory and cognitive correlates in Eastern populations. Addressing the literature gap, this chapter presents the first systematic investigation of Chinese children's future-oriented cognition. 87 Chinese pre-schoolers, aged between 3 to 5 years, were administered with comprehensive batteries of tasks measuring executive function, theory of mind and an array of paradigms tapping into different aspects of future-oriented cognition. Overall, Chinese pre-schoolers' performance across the different cognitive domains were significantly age-related. Importantly, there were consistencies between previous literature with Western samples and Chinese children's developmental trajectories of future-oriented cognition. Specifically, the 3-year-olds were outperformed by the 4- and 5-year-olds, with 4-years-old being the critical age indicated by their consistent above chance level performance. Additionally, there were significant associations between some future-oriented cognition tasks and children's performance on executive function, though not with theory of mind. With a culturally diverse sample, the current study contributes to the emerging evidence on the relationship between executive function and future-oriented cognition in the preschool years.

Keywords: future-oriented cognition, executive function, theory of mind, cognitive development,

[2] Chapter 2 has been prepared to submit to *Cognitive Development*. Ding N, Miller R, & Clayton NS. (in preparation). Developmental Patterns and Cognitive Correlates of Chinese Pre-schoolers' Future-Oriented Cognition

2.2 Introduction

The previous two decades have witnessed a burst of research into future-oriented cognition with advances in the development of age-appropriate measures. It is a multi-faceted cognitive ability which encompasses an array of distinctive components of future-oriented reasoning and behaviours. As noted in the general introduction, it has been well established that the development of future-oriented cognition undergoes significant changes during the preschool period (Atance, 2015; Hudson et al., 2011). Specifically, by the age of 5, children have demonstrated the ability to anticipate future physiological states (Atance & Meltzoff, 2005, 2006), understand changes of preferences and emotions (Belenger et al., 2014; Martin-Ordsas, 2017), select tool for future use (Atance et al., 2015; Redshaw & Suddendorf, 2013; Russell et al., 2010; Suddendorf et al., 2011) and construct temporally ordered future event (McClogan & McCormack, 2008; Prabhakar & Hudson, 2014). However, the existing body of knowledge is predominantly drawn from studies conducted with children in Western cultures, which inherited morals and traditions from Ancient Greece (Nisbett & Masuda, 2003). There is a substantial gap in the literature on how children in Eastern societies, characterised by their common ideology from Ancient China, develop future-oriented cognition and whether it is similarly supported by the cognitive correlates that researchers have identified with Western children.

Studying children from different cultures contributes to the field of developmental psychology both conceptually and practically (Wang, 2016, 2018). At the broadest level, it provides evidence on whether certain cognitive abilities and related mechanisms exist universally, or are only observable in a specific cultural environment. This enables researchers to gain a more comprehensive understanding of psychological processes with a non-biased perspective (Nielsen et al., 2017; Nielsen & Haun, 2016). Besides, in addition to detecting any group or cultural differences, it can inspire future work to understand and respond to such differences, leading to potential positive outcomes in child development. For instance, the false belief test (e.g., “Sally-Ann” task) was originally developed in the West and has been shown to be a reliable and universal measure of theory of mind ability. However, it was then essential to use cross-cultural comparisons to reveal the cultural-specific sequence of theory of mind maturation, with the findings that children from different cultures were similarly benefited from parental mental state talk and mind-mindedness (Hughes et al., 2018; Shahaeian, Peterson, Slaughter, & Wellman, 2011; Taumoepeau, Sadeghi, & Nobilo, 2019).

Although research with Eastern pre-schoolers is scant, several studies have measured future-oriented cognition in young adults and children in middle childhood and adulthood from Eastern societies (Chen et al., 2015; Shao et al., 2010; Wang et al., 2011; Wang et al., 2014; Wang et al., 2016). Overall, research has revealed universal trends as well as culturally specific patterns. For example, in a similar approach to testing autobiographical memory, one approach involved asking participants to imagine and describe personally significant future events happening at a specific time and place. Content analysis demonstrated that universally both semantic and episodic memory were used to construct future events and that female young adults provided more episodic details than male young adults (Wang et al., 2011; Wang et al., 2016). Cultural contrasts were found in the emotion and content dimension, though not specificity, of episodic future thinking report among Chinese and Australians university students (Chen et al., 2015). Also, European Americans included more positive experience and self-descriptions than Chinese college students (Shao et al., 2010). Investigation with middle childhood children (7-10 years old) suggested that regardless of culture, children relied more on their general knowledge in the construction of future events than adults (Wang et al., 2014). Moreover, European American children provided more specific details than their Chinese peers.

A few studies have tested young children from Eastern societies on cognitive tests that are conceptualised and categorized as future-oriented cognition, primarily on prospective memory (Han et al., 2017; Zhang et al., 2019) and delay of gratification (Ma, Chen, Xu, Lee, & Heyman, 2018). However, these studies were conducted separately with different rationale and hypotheses. The Eastern child literature appears to be even scarcer for paradigms that were specifically developed to measure children's ability to understand and plan for the future, such as the "Spoon task" (Suddendorf et al., 2005; Tulving, 2005) and the "Picture Book task" (Atance & Meltzoff, 2005). To the best of my knowledge, there have been no systematic investigation of Chinese pre-schoolers' future-oriented cognition. I therefore intended to address this literature gap in the current study.

Cognitive development does not happen in a vacuum, and consequently knowledge of the cognitive correlates of future-oriented cognition is essential for understanding its developmental mechanism and pathways (Atance & Meltcaf, 2013). As mentioned in the general introduction, theory of mind and executive function have been theoretically linked with future-oriented cognition (Atance & Jackson, 2009; Buckner & Carroll, 2007; Moore et al., 1998; Suddendorf & Corballis, 1997, 2007). Specifically, theory of mind refers to the ability to understand and attribute mental states to different people and a common "self-projection" mechanism is suggested to underlie the process of projection into the future and projection into different people’s mental states (Buckner & Carroll, 2007; Wellman et al., 2006). Executive function encompasses a set of higher order cognition and is regularly employed for goal-directed behaviours with three core components, namely inhibition, working memory and cognitive flexibility (Diamond, 2013; Hughes, 2011). Executive control may be required to manage conflicts between current and future mental representations and to implement future-oriented actions (Bar, 2011; Suddendorf & Corballis, 2007), A substantial body of research has highlighted the common brain networks and neural structures underlying executive function, theory of mind and future-oriented cognition (Addis et al., 2007; Blankenship et al., 2017; Spreng, et al., 2009; Stuss & Alexander, 2000).

Empirically, there have been mixed findings on the relationship between executive function, theory of mind and future-oriented cognition in the developmental literature. Notably, Hanson and colleagues (2004) administered a battery of tasks to Canadian pre-schoolers and found no inter task correlations across the different cognitive domains. In contrast, spatial working memory was related to children’s selection of items for future use, and prospective memory was related to theory of mind ability (Ford et al., 2012; Ünal & Hohenberger, 2017). These studies exclusively recruited Western children, thus it remains unclear whether or not Eastern children show similar patterns. As noted by Nielsen & Haun (2016) and Wang (2016), research with diverse groups avoids culturally skewed and biased conclusions, and deepens our understanding of cognitive development in different cultural environment.

Chapter 2 in this thesis therefore focused on testing future-orientated cognition in Chinese pre-schoolers. There were two main aims: first to investigate the developmental trajectory of future-oriented cognition, and second to examine its cognitive correlates by testing its relationship with children’s executive function and theory of mind. As this was the first systematic investigation of Chinese pre-schoolers’ future oriented cognition, I believed that at this stage, it was most informative to provide an overview of the different aspects of this cognitive faculty, rather than providing a detailed investigation of one specific component of future-oriented cognition. Moreover, findings from the current study were expected to provide a foundation for the subsequent chapters in this thesis where I directly compare Chinese and British children. Four tests, namely the Picture Book task (Atance & Meltzoff, 2005), Card in Basket task (Kvavilashvili et al., 2001), Future Event Sequence task (Prahabakar & Atance, 2014) and Spoon task (Redshaw & Suddendorf, 2013), were selected on the basis as they reflect the multi-faceted nature of future-oriented cognition.

A further sub-aim of the current study was to investigate the coherence among different measures of future-oriented cognition. Previous literature suggests that there were no significant inter-task correlations between delay of gratification, prospective memory, verbal descriptions of future events and anticipation of physiological states (Atance & Jackson, 2009). The current study adopted a different task battery to include more recently developed paradigms and sought to provide evidence of the convergent validity between different measures of future-oriented cognition. For measures of theory of mind, I chose widely used standardised tasks that represent the sequential step of theory of mind development. The executive function task battery corresponds to the three-core-components structure of executive function ability. For validity and comparison reasons, the current study focused on tasks that have been previously tested in Chinese pre-schoolers and included for future-oriented cognition research (Duh et al., 2011; Hanson et al. 2014; Lan et al., 2011; Liu et al., 2008; Sabbagh et al., 2006; Wellman et al., 2006).

Based on previous research on future-oriented cognition, it was predicted that, across tasks, Chinese children would show significant age-related performance, with older children being more successful in making future-adaptive decisions. As prior research findings on the cognitive correlates of future-oriented cognition are mixed, I did not hold specific directional predictions for the inter-task correlations of Chinese children's performance across the different cognitive domains. Specifically, between the theory of mind, executive function and future-orientated tasks, as well as within the four future-oriented cognition tasks.

2.3 Methods

2.3.1 Ethics

There was no national regulation applying to foreign researchers and no relevant approval required to conduct data collection in mainland China. However, all procedures performed in the current study were in accordance with the ethical standards and approved by the University of Cambridge Psychology Research Ethics Committee (PRE. 2017. 108, for letter of ethical approval and complete application form see Appendix A & Appendix B). Headmasters at the participating nurseries were contacted first and I explained the purpose and procedure of the study (for contacting letter see Appendix C). Information sheets and consent forms (Appendix D & Appendix E) were provided to parents and written parental consent was obtained prior to participation of the children. Parents were told that they could withdraw before, during, and after the study without giving a reason. All children were told that they could stop at any time and they could choose not to complete any activities. Furthermore, their verbal consent to participate was obtained before each testing session. Due to the kindergarten's policy, filming was not allowed, therefore, children's performance of all tasks was live scored. Participants received stickers and souvenirs at the end of study. Several steps were in place to ensure and protect participant confidentiality, which included using random and anonymised ID numbers and storing data in password-protected files and locked cabinets within the Department of Psychology. The length of testing session (each session no longer than 40 minutes) was age-appropriate and breaks were included to avoid over-tiring the participants.

2.3.2 Participants

A statistical power analysis was performed using G* Power software for sample size estimation and the effects sizes were obtained from previous literature (Atance & Jackson, 2009; Atance & Meltzoff, 2006; Hanson et al., 2014; Prabhakar & Hudson, 2011; Redshaw & Suddendorf, 2013). Specifically for detecting age-related effects, using parametric or non-parametric tests, a minimum sample of 72 was needed to reach a power of 0.8 with an alpha level at .05 and an effect size of 0.5 (Faul, Erdfelder, Lang, & Buchner, 2007). For correlational analysis, a minimum sample of 67 was required to reach a power of 0.8 with an alpha level at .05 and an effect size of 0.3 (Bonett & Wright, 2000; Faul, Erdfelder, Buchner, & Lang, 2009). Thus the final sample size of 87 would be adequate for the main objectives of this study.

In total, 87 Chinese pre-schoolers took part in the study: 30 3-year-olds (Mean = 3.42 years, Range = 3.02 - 3.96 years, 15 boys and 15 girls), 30 4-year-olds (M = 4.66 years, R= 4.18 - 4.95 years, 14 boys and 16 girls), and 27 5-year-olds (M = 5.43 years, R = 5.01- 5.98 years, 14 boys and 13 girls). 30 children were recruited for each age group, however, 3 children in the 5-year-old group did not attend the testing sessions due to sick leave and intermission reasons. A pilot study involving 15 different children (5 in each age group) took place before the testing period. The pilot data was used to finalise and modify the study protocol though was not included in the final dataset.

Children were recruited in Kunming, Yunnan Province, which is a typical regional and new first tier city based on its population, economy and urbanisation (Wu, Cheng, Liu, Han, & Yang, 2015). The total population of Kunming is 8.46 million with 86.16% as the Han Chinese, the most dominant ethnic group in China (2020 Chinese Census). Specifically, 74.53% of the total population are aged between 15-64 years old and 26.97% of people have university or higher degrees. Participants were all normally developing children and they were recruited from a university-affiliated public nursery. Children who admitted to the nursery must have at least one of the parents working as university academia or staff (with at least university degrees).

2.3.3 Procedure

Each child was individually tested in two face-to-face sessions. The first session lasted approximately 40 minutes and children were administered with four executive function tasks (block 1), five theory of mind tasks (block 2) and two future-oriented cognition tasks (block 3: Picture Book task and Card in Basket task). Total randomization across all tasks would require an enormous and unfeasible sample size, therefore block randomization was adopted (Kim & Shin, 2014). This procedure ensured there were no links between types of tasks and specific positions in the testing session (Table S2.1). There were roughly equal numbers of participants assigned to each block. The second session lasted approximately 20-25 minutes and included two future-oriented cognition tasks, the Spoon task and the Future Event Sequence task. The Spoon task was designed to incorporate a 15-minute interval that children could engage in unrelated activities, where they were tested with the Future Event Sequence task and otherwise were given drawing and colouring games.

The minimum interval between the two testing sessions was 3 days, and 82 (of 87) children completed both sessions within 7 days. The 5 remaining children received the sessions within 10 days due to schedule arrangement and participant availability. During the testing session, the child sat face to face with the experimenter beside a table that was suitable for the children's height where task materials were presented. All materials and task instructions were initially prepared in English for review purpose. The standard translation and back translation procedures were followed to generate the Mandarin version. Any discrepancies were resolved among three native Chinese speakers who were fluent in English and had Psychology degrees (Erkut, 2010).

Picture book task (Atance & Meltzoff, 2005)

This task was designed to measure young children's ability to anticipate future physiological states and select items to address these needs in future. It consisted of 4 test trials[3]. One at a time, children were presented with four different colour photographs depicting various locations: a sandy dessert with strong sunlight, mountain areas covered in grass and trees, a

[3] [3] In the pilot study another two types of trials were used, the warm-up trials and control trials. The format of the warm-up trials was identical to test trials with the purpose of ensuring that task structure and language was age appropriate. Across age groups, children found the task was easy to understand without the need for any familiarisation procedure. Given the similarities and overlaps between the warm-up and test trials, as well as concerns of limited testing time and potential practice effect, only test trials were administered to the final sample of 87 pre-schoolers. Additionally, in the pilot study, I used four control trials to check that the correct item choices in the test scenarios did not correspond to children's favourite items. The results suggested that in less than 10% of trials, children's choice in the control trials corresponded to the correct choice in the test trials. This was a smaller proportion than the percentage that Atance & Meltzoff (2005) considered acceptable (no more than 33%) in their original experimental design. Therefore, I only included test trials and this procedure was consistent with recent studies using the same task and test stimuli (Atance et al., 2021; Atance & Jackson, 2009; Hanson et al., 2014).

snowy forest covered in white, and a waterfall between the rocks. Children were asked to describe what they saw and imagine and pretend going to the locations. Next, the experimenter showed 3 small photographs of different objects and asked children to select the item that they would need to take with them to the scenarios in question. Among the three choices, only one item could be used to address a need or state in the future. For example, the sunglasses in the dessert would prevent strong sunlight getting in one's eyes (Table S2.2). Presentation position of the correct item (left, centre and right) was counterbalanced across trials. Children received 1 score if the correct item was selected. On each trial, the experimenter also asked children to explain their item selection. A further score of 1 was given if children's explanations contained both future referent (e.g., "going to do so", "might do so") and state referent (e.g., "hungry", "eyes hurt") terminology. Across the item selection and verbal explanation, the overall score range across the 4 trials was from 0 to 8.

Spoon task (Redshaw & Suddendorf, 2013)

The Spoon task was initially modified by Suddendorf et al., (2011) to build on Tulving's (2005) classic Spoon task of children's episodic future thinking. This task investigated children's capacity to use information from the past and to select a tool or item to solve a problem in the future. In a warm-up area, before introduction to the experimental set-up, children were shown a sand-timer. The experimenter explained its nature and mechanism with child-appropriate language. The sand-timer was selected as it visualised the lapse of time and children were given time to observe the motion of sand falling from the top to the bottom compartment. Next, children and the experimenter visited the "green room" owing to its green wallpaper, where an animal puppet "Tiaotiao the Monkey" was introduced. Children were told that Tiaotiao likes apples. They were encouraged to play with the puppet and to feed it using the plastic apples on the table. Next, the experimenter introduced a different animal puppet "Honghong the Fox" and told children that he likes grapes. No grapes were placed on the table and children were told that they couldn't feed the fox. In the instant condition, the experimenter led children to a corner of the room where a pre-hidden tray was left. Upon revealing the tray, there were 6 different fruits (grapes, oranges, apples, pineapples, strawberries and bananas) and children was asked to select only one fruit without being able to look back at the test table.

In the delayed condition, after showing children that there were no grapes available to feed the fox, the experimenter told them that they were going to a different room and left the fox on the table. Children then spent 15 minutes in the blue room where they completed unrelated activities and the sand-timer was reintroduced at the end of the interval. The experimenter told children that when all the sand fell from the top compartment (a 3-minute cycle) they would be going back to the green room. Children's understanding was checked by whether they were able to independently generate and explain these plans. Next, the experimenter revealed a pre-hidden tray containing 6 different fruits (grapes, oranges, apples, pineapples, strawberries and bananas). Children were given a basket and asked to pick only one fruit and verbally explain their choice. The experimenter then started a new cycle of the sand-timer and upon its completion, children returned to the green room with their selected fruit in the basket. The experimenter provided the correct fruit if not selected and children were encouraged to play and feed the puppet animal. Children's performance in both the instant and delayed condition were recorded and a score of 1 was given if they correctly selected the target fruit. To be credited as a correct verbal response, children needed to provide explanations containing both reference to the problem (e.g., lack of target fruit in the green room, no fruit to feed the animal) and reference to the future (e.g, when we go back to green room later/in the future/after the sand-timer finishes). Therefore, the total score range in the delayed condition was between 0 and 2.

Children completed both the instant and delayed condition. The order of the condition was counterbalanced; half of the children received the instant condition first followed by the delayed condition (order 1: instant-delayed) and vice versa for the other half of children (order 2: delayed-instant). In order 1, children were first asked to select fruit for "Honghong the Fox" in the instant condition. Then in the same room (the green room), a different animal puppet "Tuantuan the Bear (likes strawberries)" was introduced to the child for the delayed condition. In order 2, the experimenter introduced the animal puppet for the instant condition only after children had made their selection for the delayed condition in the blue room. Therefore, in the delayed condition, regardless of test order, children were presented with the problem of not being able to feed the animal in the green room and after a period of 15-minute delay, they were asked to select the fruit in the blue room. The type of animals (Honghong the Fox who likes grapes and Tuantuan the Bear who likes strawberries) was counterbalanced across the conditions.

Future event sequence task (Prabhakar & Hudson, 2014)

This two-step future planning task measured pre-schoolers' ability to maintain future goals and construct temporally ordered future scenarios with semantic information. A 3-D model of neighbourhood of 4 different houses (two target locations and two distractor locations) was built on a hard paperboard measured as 60cm x 80 cm [4]. Each house differed in colour and

[4] Prabhakar & Hudson (2014) designed two neighbourhood models: one low demand version with four locations (two distractors and two target locations) and one high demand version with 6 locations (four distractors and two target locations) to manipulate the demands on working memory. The pilot study tested both versions and found

location, and they were identified and referred to by the colour and name (e.g, the yellow house is a toy store, the red house is Liang Liang's house). The experimenter introduced all the locations on the neighbourhood model in random order without highlighting any specific one as the place of interest. There was one sub-goal location (the toy store) and one final-goal location (Liang Liang's house) located on the opposite side and their positions were counterbalanced. Children was given a doll corresponding to their own sex to move around the neighbourhood.

The experimenter checked the children's memory of the neighbourhood by asking them to verbally and physically identify each location using the doll. To proceed with the experiment, children needed to correctly identify each location and the experimenter would correct them if they failed on the memory test. Next, the experimenter told children "today is Liang Liang's birthday and she is going to have a birthday party at her home. You want to give Liang Liang a birthday present. Where will you go first?". The script was designed to accommodate pre-schoolers' linguistic understanding as well as provide temporal sequence of a two-step future event. All children started and were given the sub-goal prompt on the same location. To receive a score of 1, children needed to both physically point to the target location (toy store) and verbally identify it. If they failed, the experimenter would correct the child and guide them to walk the doll to the correct sub-goal location. Before the final goal prompt was given, all children were at the same location and have had a toy. The experimenter then asked the final-goal question: "you now have a present for the birthday party, where will you go next?". Children were given a score of 1 if they correctly pointed to and identified the final-goal location (i.e. Liang Liang's house). The overall score range was between 0 and 2.

Card in basket task (Kvavilashvili et al., 2001)

This task measured event based prospective memory, specifically the ability to remember to perform an action in the future. Children were invited to play a game in which they were asked to loudly speak the name of objects on cards. There were 2 practice trials. Next, an animal puppet called "Goofy" was introduced and the children were told Goofy was afraid of all other animals. Children were asked to *not* speak the name of any animal and put the card immediately

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that with the high demand version, some younger children had difficulty in remembering the locations and failed the memory test after multiple attempts. The aim in the current study was to examine age-related developmental trajectory in children's ability to construct future events, not to elucidate the effects of working memory demand. It is important to highlight that previous research reported significant age effects with the low demand version. Given these considerations and due to restricted testing time, I decided to adopt the low demand version of the Future Event Sequence task.

in the basket. The basket was placed out of the children's sight under the table, therefore, it was not a visible memory cue. In the test phase, children were presented with two stacks of cards depicting common objects. There was one animal card in each stack arranged in a counterbalance position (the 7th and 10th card). A score of 1 was given if the child did not speak the animal's name and hid the card in the basket. If the child only remembered one action, then a half point was given. Therefore, the total range of scores across the two trials was between 0 and 2.

Test battery of executive function and theory of mind

The following executive function tasks were administered: Knock-Tap task for motor inhibition control (Luria, 1966), Day-Night task for cognitive inhibition control (Gerdadt, Hong, & Diamond, 1994), Spin the Pots for working memory (Ensor & Hughes, 2005) and Dimensional Change Card Sort task (DCCS) for cognitive flexibility (Zelazo, 2006). For theory of mind task battery, five individual tasks were adopted: Diverse Desire (Wellman & Liu, 2004), Diverse Belief (Wellman & Liu, 2004), Knowledge Access (Pratt & Byrant, 1990), False Belief Content (Flavell, Green, & Flavell, 1989), and False Belief Location (Baron-Cohen, Lesile, & Frith, 1985). The detailed protocol of these tasks was included in Appendix F and brief task descriptions were outlined in Table 2.1.

Table 2.1. Brief task descriptions for executive function and theory of mind tasks.

Task	Description
Executive function task	
Day-Night (Gerstadt et al., 1994)	Child was instructed to say "Day" when presented with a picture of Moon and to say "Night" when presented with a picture of Sun.
Knock-Tap (Luria, 1966)	Child was asked to perform the opposite hand movement from the experimenter, for example to tap the table with flat palm when the experimenter knocked on the table.
Spin the Pots (Hughes & Ensor, 2005)	Child was instructed to find stickers hidden underneath cups of different colours on a lazy Susan tray.
DCCS (Zelazo, 2006)	Child was instructed to sort cards by one rule (colour) and then was asked to sort cards by a different rule (shape).
Theory of mind task	
Diverse Desire (Wellman & Liu, 2004)	Child was asked to choose a drink for a puppet whose preference was stated to be the opposite of their own desire.

Diverse Belief (Wellman & Liu 2004)	Child indicated where a puppet would look for a bunny after being told that the puppet held the opposite belief to themselves.
Knowledge Access (Pratt & Bryant, 1990)	Child saw inside a box that contained a toy dinosaur. They were then asked whether a puppet that had not seen inside the box knew what was inside.
False Belief Contents (Flavell et al., 1989)	Child saw inside an eggbox that contained an unexpected item (bouncing balls). They were asked whether a friend who had not seen inside the box knew what the content would be.
False Belief Location (Baron-Cohen et al., 1985)	The classic "Sally-Ann" task which assessed child's understanding of mental states in different people with false belief questions.

2.3.4 Analytical plan for the different test batteries

Children's performance in the future-oriented cognition tasks, executive function tasks and theory of mind tasks were analysed for two purposes; first to examine age-related performance and developmental trajectories, and second to investigate the relationship across the different cognitive domains. Specifically, for tasks where ordinal or binary nominal outcomes were recorded, non-parametric tests, namely Pearson's Chi square test, Kruskal-Wallis or Wilcoxon singed-rank test and Mann Whitney U test, as appropriate, were carried out. Bonferroni corrections were adopted for multiple pairwise comparisons (Lee & Lee, 2018; Sheskin, 2003; Rodger & Roberts, 2013). Tasks that fell in this category included the Spoon test, Future Event Sequence task, and each individual theory of mind tasks. For tasks measured in interval scale, the normality of raw scores was checked by comparing the Kurtosis and SE Kurtosis value against with the critical value of 1.98. Greater than the critical value would be considered indicative of violating the assumptions of normality, in which case, the alternative non-parametric analysis was used (Sheskin, 2003; Wright & Herrington, 2011). Tasks that were suitable for parametric analysis included each individual executive function task, Picture Book and Card in Basket task.

Next, non-significant results of Leven's test were interpreted as homogeneity of variances, which validated the use of one-way analyses of variance (ANOVA) with Tukey test for host-hoc comparisons. With non-equal variances, Welch ANOVA with Games-Howell post-hoc comparisons was adopted. Notably, children's raw scores in the Knock-Tap task were non-normally distributed and still violated the assumption of normality after log transformation. Therefore, non-parametric alternative Kruskal-Wallis test were adopted. Additionally, the composite score of future-oriented cognition was created by standardizing the raw sum scores across the Picture Book task, Card in Basket task, Spoon test and the Future Event Sequences task. The composite score of inhibition (Day-Night task and Knock-Tap task) and the composite score of theory of mind (across the five individual tasks) were also created with the same method.

Correlational analyses were carried out to investigate the underlying relationships between children's performance on various tasks measuring future-oriented cognition, executive function and theory of mind ability. Notably, both composite score and score of individual tasks of executive function were adopted because they reflected the different components of this ability. The composite score of theory of mind was used because the task battery represented a serial of skills that developing in a sequential order. Specifically, Pearson's r correlation was adopted when tasks were measured on interval data with age in years as a control variable. With ordinal data, Spearman's rho was carried out with the data collapsed across three different age groups as well as for separate analysis of each age group (Sheskin, 2003). Fisher Z test was conducted to compare correlations using the R package 'cocor' (Diedenhofen & Musch, 2015).

2.4 Results

Preliminary analysis suggested that children's performance across all tasks did not vary as a function of gender, therefore data were collapsed across this variable for all subsequent analyses (all p>.05). The descriptive statistics and main age effects across tasks were summarised in Table 2.2.

Table 2.2. Mean scores on all tasks as a function of age.

Tasks	3-year-olds	4-year-olds	5-year-olds	Age effects
Future-oriented cognition				
Picture Book (range 0-8)	3.2 (1.85)	6.33 (1.56)	7.07 (1.52)	F(2,84) = 45.130***
Spoon (range 0-2)	0.23 (.43)	.67 (48)	0.89 (.32)	$\chi^2(2)$ = 26.399***
Future Event Sequence (range 0-2)	0.76 (.68)	1.46 (.73)	1.85 (.36)	$\chi^2(2)$ = 30.285***
Card in Basket (range 0-2)	0.6 (.70)	1.42 (.67)	1.63 (.45)	F(2, 84) = 23.645***
Executive function				
Day-Night (range 5-16)	10.10 (2.92)	12.33 (2.33)	14.04 (1.40)	F(2,53.049) =23.28***

Knock-Tap (range 1-15)	10.73 (3.07)	13.03 (1.75)	13.22 (2.72)	$\chi^2(2) = 17.771$***
Spin the Pots (range 5-12)	7.53 (2.05)	8.83 (2.00)	9.78 (2.24)	$F(2, 84) = 8.289$***
DCCS (range 1-6)	2.93 (1.01)	5.13 (1.46)	5.56 (0.97)	$F(2, 84) = 40.511$***
Theory of mind				
Diverse Desire (range 0-1)	.90 (.31)	1 (0)	1 (0)	$\chi^2(2) = 5.904$
Diverse Belief (range 0-1)	.70 (.45)	.77(.43)	1 (0)	$\chi^2(2) = 9.267$**
Diverse Knowledge (range 0-1)	.40 (.36)	.70 (.47)	1 (0)	$\chi^2(2) = 23.925$***
False Belief Content (range 0-1)	0 (0)	.17 (.38)	.78 (.42)	$\chi^2(2) = 44.844$***
False Belief Location (range 0-1)	0 (0)	.43 (.50)	.89 (.32)	$\chi^2(2) = 45.950$***

Note. Standard deviations are in parentheses. *** indicates p <.001, **indicates p <.01, * indicates p <.05.

2.4.1 Future-oriented cognition tasks

Picture book task (Atance & Meltzoff, 2005)

Age had a significant effect (F (2, 84) = 45.130, p <.001, η^2 = .518, Table 2.2) on children's overall performance. Specifically, 5-year-olds (Tukey comparisons: M = 7.07, $S.D.$ = 1.52) and 4-year-olds (M = 6.33, $S.D.$ = 1.56) significantly outperformed 3-year-olds (M = 3.20, $S.D.$ = 1.85, p <.001) with no significant differences between the two older groups (p =.215). Next, children's behavioural choices and their verbal explanations were separately analysed. In children's item selection, 3-, 4-, and 5-year-olds chose the correct item on 50%, 85%, and 90.7% of the scenarios respectively across the 4 trials (frequency analysis; Table 2.3 for results per age group per trial). There was a significant difference in the number of correct items as a function of age group (One-way ANOVA: F (2, 84) = 33.231, p <.001, η^2 = *.442,* Fig 2.1). 4-year-olds (Tukey comparisons: M = 3.40, $S.D.$ = .77) and 5-year-olds (M = 3.63, $S.D.$ = .69) outperformed 3-year-olds (M = 2.00, $S.D.$ = .98, p <.001), with no significant difference between 4 and 5-year-olds' performance (p =.550).

In comparing children's item selection against chance level (Binomial tests; at 33.3%, 1 target item and 2 distractors) indicated that 3-year-olds failed to choose the correct item significantly above chance level in Trial 1, 2 and 4 with above chance level performance in Trial 3 (Table 2.3). In contrast, 4- and 5-year-olds' performed above chance level in all trials (all p <.05, Table 2.3). With regards to children's verbal explanations (e.g.,"I *might* get *thirsty*, you could get *cold*"), there was also an age effect on the number of future state explanations provided (F (2, 84) = 43.673, p <.001, η^2 = .510, Fig 2.1). Similar to children's behavioural choices, 5-year-olds (Tukey comparisons: M = 3.44, $S.D.$ = .89) and 4-year-olds (M = 2.93, $S.D.$ = .91) outperformed 3-year-olds (M = 1.20, $S.D.$ = 1.06, p <.001) with no difference between 4 and 5-year-olds' verbal explanations (p =.117).

Table 2.3. Percentage of correct trials and binomial test results (in parentheses) for each age group in the Picture Book task.

	3-year-olds	4-year-olds	5-year-olds
Trial 1	23.3 (.019)	83.3 (<.001)	81.5 (<.001)
Trial 2	36.7 (.043)	63.3 (<.001)	81.5 (.028)
Trial 3	50 (<.001)	100 (<.001)	100 (<.001)
Trial 4	10 (<.001)	46.7 (<.001)	81.5 (.028)

Spoon task (Redshaw & Suddendorf, 2013)

There was no difference in children's performance between test order 1 (instant-delayed) and test order 2 (delayed-instant) (z = -.343, p =.731), therefore, data across the two orders were collapsed for subsequent analysis. In the instant condition, across age groups, 97.7% children correctly selected the target fruit and performance did not vary as a function of age group ($\chi^2(2)$ = 3.889, p =.143). In the delayed condition, the success rate was 23.3% for 3-year-olds, 66.7% for 4-year-olds and 88.9 % for 5-year-olds. Performance differed among the three age groups ($\chi^2(2)$ = 26.399, p <.001, Table 2.2, Fig 2.2). 5- and 4-year-olds significantly outperformed 3-year-olds respectively, with no differences between 4- and 5-year-olds (Mann-Whitney U tests against a Bonferroni-adjusted alpha level of 0.008 (0.05/6): 3 vs. 4: z = -3.345, p <.001; 3 vs.5: z = -4.918, p <.001; 4 vs 5: z = -1.978, p =.288).

Across the instant and delayed condition, there were 6 different fruits (5 distractors and 1 target item) presented to children. Thus, the chance level of successfully selecting the correct fruit was at 16.7% (1/6). In the instant condition, children in each age group performed above chance level (Binomial test: p <.001). Contrarily, in the delayed condition, 3-year-olds failed to select the correct item significantly above chance level (p <.001), while 4- and 5-year-olds passed the test above chance level (p <.001).

In assessing the verbal responses, 20% of 3-year-olds, 66.7% of 4-year-olds and 88.9% of 5-year-olds successfully provided future-oriented explanations of their selection of the target fruit. Children's verbal explanations varied as a function of their age groups ($\chi^2(2) = 29.176$, $p < .001$). Echoing the behavioural findings, 4- and 5-year-olds were significantly better in providing future-oriented verbal explanations than 3-year-olds, with no significant differences between the two older age groups (Mann-Whitney U tests against a Bonferroni-adjusted alpha level of 0.008 (0.05/6): 3 vs. 4: $z = -3.617$, $p < .001$; 3 vs.5: $z = -5.155$, $p < .001$; 4 vs 5: $z = -1.979$, $p = .288$).

Future event sequence task (Prahabakar & Hudson, 2014)

In the sub-goal step, 36.7% of 3-year-olds, 80% of 4-year-olds and 96.3% of 5-year-olds correctly selected the location of the toy store. Children's performance varied as a function of age group in the sub-goal step ($\chi^2(2) = 26.479$, $p < .001$, Fig 2.3). Likewise, age had a significant effect on children's performance in the final-goal step ($\chi^2(2) = 14.914$, $p = .001$, Fig 2.3), with 40% of 3-year-olds, 66.7% of 4-year-olds and 88.9% of 5-year-olds successfully selecting the location of Liang Liang's house. Moreover, using composite scores across the two steps, there was a significant effect of age groups (Kruskal-Wallis test: $\chi^2(2) = 30.285$, $p < .001$, Table 2.3). Specifically, 3- and 4-year-olds differed, and 3- and 5-year-olds differed, but with no difference between the 4- and 5-year-olds (Mann-Whitney U tests against a Bonferroni-adjusted alpha level of 0.008 (0.05/6): 3 vs. 4: $z = -3.532$, $p < .001$; 3 vs.5: $z = -5.427$, $p < .001$; 4 vs 5: $z = -2.236$, $p = .150$). Additionally, across age groups performance did not differ between the sub-goal and final-goal steps (Wilcoxon Signed rank: $z = -.962$, $N = 87$, $p = .336$). Within age groups, in the sub-goal step, both the 4- and 5-year-olds significantly selected the correct location above chance level (Binomial test; chance level at 25%, $p < .001$) while 3-year-olds' performance did not differ from chance ($p = .106$). In the final-goal step, all age groups performed above chance level (all $p < .001$).

Card in basket task (Kvavilashvili et al., 2001)

Age had a significant effect on children's performance on the perspective memory task ($F(2, 84) = 23.645$, $p < .001$, $\eta^2 = .360$, Table 2.2, Fig 2.4). Specifically, 3-year-olds (Tukey comparisons: $M = 0.6$, $S.D = 0.68$) were significantly outperformed by the 4-year-olds ($M = 1.46$, $S.D = 0.73$) and 5-year-olds ($M = 1.85$, $S.D = 0.36$, $p < .001$), with no difference between the latter two groups ($p = .382$).

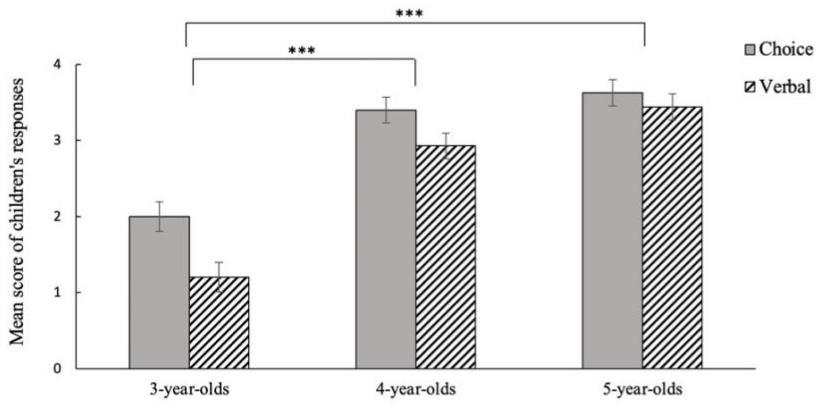

Fig 2.1: Mean scores of children's behavioural choices and verbal explanations separated by age groups in the Picture Book task (collapsed across the 4 trials).

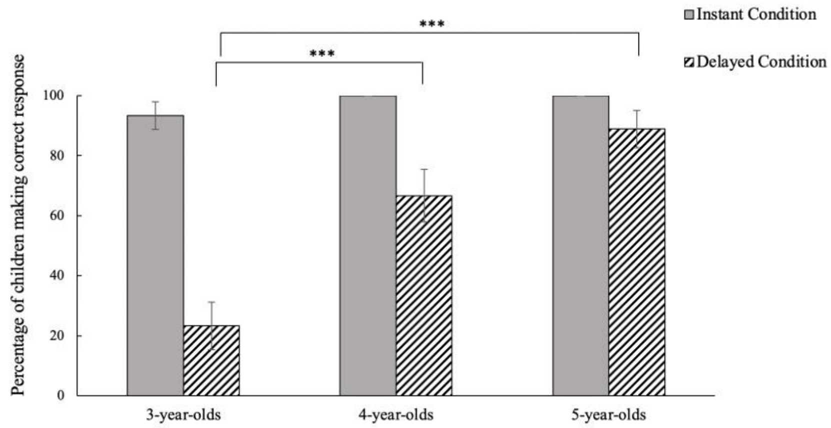

Fig 2.2: Percentage of children who made the correct item choice in the instant and delayedconditions separated by age groups in the Spoon task.

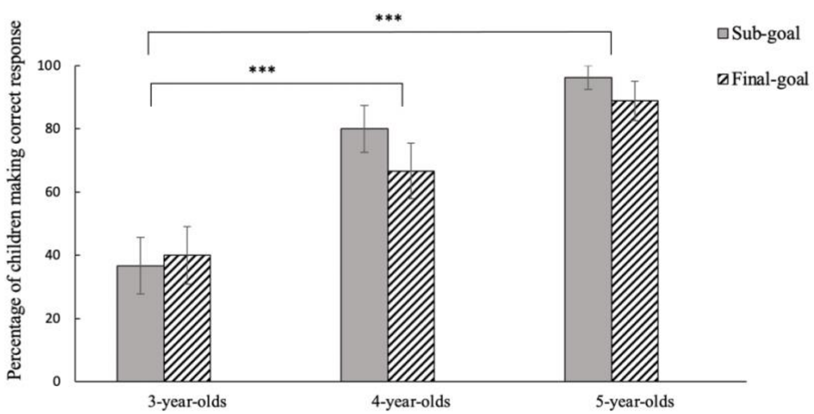

Fig 2.3: Percentage of children who selected the correct location in the sub-goal and final-goal step separated by age groups in the Future Event Sequence task.

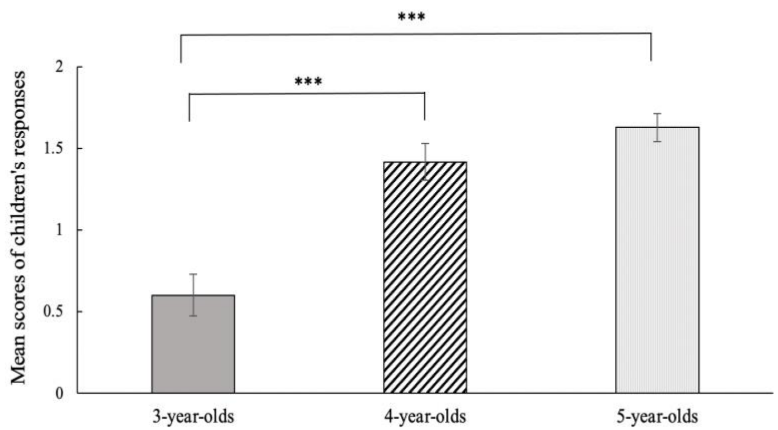

Fig 2.4: Mean scores of children's responses in Card in Basket task (collapsed across the 2 trials).

2.4.2 Executive function and theory of mind tasks

Age had a significant effect on children's performance in all tasks on the executive function test battery (Day-Night: Welch's $F(2, 53.049) = 23.280$, $p <.001$, $\eta^2 = .335$; Knock-Tap: $\chi^2(2) = 17.771$, $p <.001$, $\eta^2 = .169$; Inhibition composite score: $F(2,84) = 18.641$, $p <.001$, $\eta^2 = .307$; Spin the pots: $F(2, 84) = 8.289$, $p =.001$, $\eta^2 = .165$; DCCS: $F(2, 84) = 40.511$, $p <.001$, $\eta^2 = .491$, Table 2.2). Adjusted alpha value has been applied using Bonferroni correction method (0.05/6) and Tukey comparison method when appropriate. Specifically, 5- and 4-year-olds outperformed 3-year-olds on Knock-Tap, Spin the pots, DCCS test and the inhibition composition scores (all $p <.005$). There were no significant differences between 4- and 5-year-olds' performance on all EF tasks (all $p >.05$), except for the Day-Night task ($p =.005$).

Other than the Diverse Desire task ($\chi^2(2) =5.904$, $p =. 052$), children's performance on each individual task of the theory of mind test battery significantly varied as a function of age group (Diverse Belief: $\chi^2(2) = 9.267$, $p =.010$; Knowledge Access: $\chi^2(2) = 23.925$, $p <.001$; False Belief Content: $\chi^2(2) = 44.844$, $p <.001$; False Belief Content: $\chi^2(2) = 45.950$, $p <.001$, Table 2.2). Further, age significantly affected children's composite theory of mind score (Welch's F: $F(2, 53.518) = 102.017$, $p <.001$, $\eta^2 = .615$). Specifically, 5-year-olds (Games-Howell comparisons: $M = 4.67$, $S.D = .56$) outperformed 4- ($M = 3.077$, $S.D = 1.08$) and 3-year-olds ($M = 2.00$, $S.D = .87$) ($p <.001$) with significant differences between the 4- and 3-year-old performance ($p <.001$).

2.4.3 Relationship within the task batteries

First, inter-task correlations within the three batteries were tested (Table 2.4). As for the future-orientated cognition tasks, after controlling for age, children's performance in the Card in Basket task was significantly related to performance in the Picture Book task (Pearson's correlation: $r = .342$, $p = .001$). Across age groups, performance in the Picture Book Task was significantly associated with Future Event Sequence task (Spearman's correlation: $r = .633$, $p <.001$) and Spoon task ($r = .558$, $p <.001$). However, these relationships did not hold when tested within age group (all $p >.05$). Similarly, Card in Basket task performance was significantly associated with Spoon Task performance ($r = .397$, $p <.001$) before taking account of age. Across age groups, performance correlated across the Card in Basket test and Future Basket task showed significant relationships with Day-Night task ($r = .262$, $p = .015$), Event Sequence test ($r = .632$, $p <.001$), as well as within the 3-year-olds ($r = .397$, $p = .030$) and 4-year-olds age groups ($r = .469$, $p = .009$), though not for the 5-year-olds ($r = .134$, $p = .065$). Performance correlated across the Spoon and Future Event Sequence Task across age groups ($r = .529$, $p <.001$) and for 4-year-olds ($r = .510$, $p = .004$), but not 3- or 5-year-olds (p >.05).

The composite score of future-oriented cognition significantly correlated with performance on Picture Book task (r = .878, p <.001) and Card in Basket (r = .571, p <.001), after controlling for age. Across age groups, the future-oriented cognition composite score was significantly related to the Future Event Sequence Task (Spearman's correlation: r = .761, p <.001) and Spoon task (r = .727, p <.001), However, these relationships did not hold when tested within age group (all p >.05). The only exception were the 5-year-olds (Future Event Sequence Task: r = .376, p = .035; Spoon Task: r = .278, p = .016).

Within the executive function task battery, there were significant inter-task correlations between the two inhibition tasks (Day-Night and Knock-Tap tasks, r = .400, p <.001, Table 2.4). In addition, performance on working memory (Spin the Post) and cognitive flexibility (DCCS) was significantly correlated (r = .255, p = .018, Table 2.4), though neither task was significantly related to children's motor or cognitive inhibition performance. Within the theory of mind task battery, across age groups Diverse Desire was significantly related to Knowledge Access (Chi-square test: $\chi^2(1)$ = 6.905, p =.028), and Diverse Belief was significantly associated with Knowledge Access ($\chi^2(1)$ = 5.824, p =.021), False Belief Content ($\chi^2(1)$ = 8.356, p =.002) and False Belief Location $\chi^2(1)$ = 14.508, p <.001). Furthermore, there were significant correlations between Knowledge Access and False Belief Content ($\chi^2(1)$ = 12.807, p <.001), and with False Belief Location ($\chi^2(1)$ = 12.303, p <.001). Performance within the two tasks of False Belief (Content and Location) was also significantly related ($\chi^2(1)$ = 26,873, p <.001).

2.4.4 Relationship between task batteries

Next, correlations between the three task batteries were conducted (Table 2.4). Specifically, as for executive function, the future-oriented composite score was significantly correlated with the Knock-Tap task (r = .264, p = .014), Inhibition composite score (r = .235, p = .031), Spin the Pots (r = .277, p =.01) and DCCS (r = .443, p < .001). In examining future-oriented individual tasks with individual executive function tasks, performance in the Picture Book task was significantly associated with that of the Knock-Tap task (r = .286, p = .008), Spin the Pots (r = .258, p =.016) and DCCS test (r = .415, p < .001), though not the Day-Night task (r = -.019, p = .861) and inhibition composite score (r = .171, p = .115). After controlling for age, Card in Inhibition composite score (r = .230, p = .033), Spin the Pots (r = .284, p =.008) and DCCS test (r = .296, p = .006), but not with Knock-Tap (r = .132, p =.226).

Across age groups, there were significant relationships between the Future Event Sequence task and Day-Night (r = .514, p <.001), Knock-Tap (r = .415, p <.001), Inhibition composite score (r = .525, p <.001), Spin the Pots (r = .405, p <.001) and DCCS test (r = .560, p <.001).

Table 2.4. Correlations between future-oriented cognition tasks, executive function and theory of mind tasks.

	1	2	3	4	5	6	7	8	9	10	11
1. Future-oriented cognition composite	-	.878***	.571***	.761***	.727***	.120	.264*	.235*	.277**	.443***	.152
2. Picture Book		-	.342***	.633***	.558***	-.019	.286**	.171	.258*	.415***	.137
3. Card in Basket			-	.632***	.397***	.262*	.132	.230*	.284**	.296**	.040
4. Future Event Sequence				-	.529***	.514***	.415***	.525***	.405***	.560***	.526***
5. Spoon Test					-	.372***	.295**	.369***	.510***	.226*	.485***
6. Day-Night						-	.400***	.812**	-.016	.070	-.043
7. Knock-Tap							-	.859***	.131	.087	-.140
8. Inhibition Composite								-	.074	.095	-.113
9. Spin the Pots									-	.255*	.110
10. DCCS										-	.123
11. Theory of mind composite											-

Note. *** indicate p <.001, ** indicate p <.01, * indicate p <.05.

Within age groups, there were no significant inter-task relations in the 4- and 5-year-olds (all p >.0.5). While in 3-year-olds, the Future Event Sequence task significantly correlated with performance on the Knock-Tap (r = .468, p =.009), Spin the Pots (r = .431, p =.017), Inhibition composite (r = .404, p =.027), though not the Day-Night task (r = .342, p =.064). Across age groups, the Spoon task was significantly related to Day-Night (r = .372, p <.001), Knock-Tap (r = .295, p =.006), Inhibition composite score (r = .369, p <.001), Spin the Pots (r = .510, p <.001) and DCCS (r = .226, p =.035). However, within age groups, only the 3-year-olds' performance between the Spoon task and DCCS was significant (r = .389, p =.034). Importantly, controlling for age, there were no significant correlations between the composite future-oriented cognition score and composite theory of mind score (r = .152, p =.162, Table 2.4). Across age groups, composite theory of mind score was related to performance on the Future Event Sequence task (r = .526, p <.001) and Spoon task (r = .485, p <.001). However, within age groups, there were no significant inter-task correlations (all p >.05).

Fisher's Z test of the significance of difference was conducted for the various correlations (for results of individual tasks see Table S2.3, S2.4, S2.5, S2.6). Notably, children's overall performance on the task battery of future-oriented cognition was significantly related to performance on the task battery of executive function (r = .473, p <.001), whereas not significantly associated with theory of mind ability (r = .152, p = .076). Importantly, there was a significant difference between these two sets of corrections (Z = 2.417, p = .015).

2.5 Discussion

This chapter presents the first step to investigate Chinese children's development of future-oriented cognition. The main goal was two-fold: first to examine Chinese children's developmental trajectory of various future-oriented cognitive abilities; and second to explore its cognitive correlates by elucidating the relationship between future-oriented cognition, executive function and theory of mind ability. A comprehensive battery of tasks was administered to 87 Chinese children aged between 3 to 5 years old and significant age-related performance were found across the tasks. These findings corroborated the predictions and supported the presence of universality on children's development of future-oriented cognition. Furthermore, with this culturally diverse sample, the study provided new evidence on the cognitive correlates of future-oriented cognition in highlighting significant inter-task correlations with tests of executive function (inhibitory control, working memory and cognitive flexibility), though not with theory of mind.

Before discussing the cognitive correlates of future-oriented cognition, it is important to highlight that the developmental patterns in Chinese children were consistent with literature based on Western children. Evidence of replicated and typical developmental trajectory would help to rule out the possibility that any inter-task correlations found were due to specific testing condition or participants responding in a particular way. Regarding the Chinese per-schoolers' executive function and theory of mind performance, the current study found significant age effects where the 5- and 4-year-olds outperformed the 3-year-olds across the domains of inhibitory control, working memory, cognitive flexibility, and overall theory of mind competency. These findings were consistent with a substantial body of literature on Chinese children's development of executive function and theory of mind ability (Lan et al., 2011; Liu et al., 2008; Sabbagh et al., 2006). There were no age effects on the Diverse Desire task though this was expected given the ability to understand that different people have diverse desires has been shown to be present from 2 years old (Wellman & Liu, 2004).

Importantly, Chinese children showed significant age-related performance across the four different future-oriented cognition tasks. Specifically, in the Picture Book task when children were asked to anticipate future states and select items to address future need (Atance & Meltzoff, 2005), 3-year-olds were outperformed by 4- and 5-year-olds (with no difference between 4- and 5-year-olds). The same pattern was found in relation to children's ability to use future state referent to verbally explain their item selection. These results were in line with previous research in Western children, which adopted the same procedure with similar or identical test stimuli (Atance & Jackson, 2009; Atance & Meltzoff, 2005; Hanson et al., 2014). Similarly, there was a significant age effect in Chinese children's prospective memory measured by the Card in Basket test (Kvavilashvili et al., 2001). 4- and 5-year-olds were more successful in remembering to perform future actions than the 3-year-olds, though performance did not differ between 4- and 5-year-olds.

For the Spoon task, previous studies (Redshaw & Suddendorf, 2013; Suddendorf et al., 2011) included only 3- and 4-year-old children, while the current study adopted a wider age range by including 5-year-olds. There were significant differences of children's behavioural choices as well as verbal explanations between 3- and 5-year-olds as well as between 3- and 4-year-olds in the delayed condition. In contrast, across age groups in the instant condition, children's performance approached ceiling level. Importantly, converging evidence suggested a critical age of 4 years old when children consistently passed the test significantly above chance level (Redshaw & Suddendorf, 2013; Suddendorf et al., 2011). Younger children either consistently failed the task as in the current study or performed at chance level as in previous studies (Suddendorf et al., 2011).

Developmental differences were also evident in children's performance on the Future Event Sequence task (Prabhakar & Hudson, 2014). Specifically, there was no difference between the 4- and 5-year-olds, however, both age groups significantly outperformed the 3-year-olds. The 3-year-olds' underperformance suggested that this task required future-oriented planning and was more cognitively demanding than semantically linking events with locations, as 3- and 4-year-olds did not differ in their use of script-based and general event knowledge in generating future plans (Hudson, Shapiro, & Sosa, 1995). The age effect was further highlighted in the comparison to chance level (binomial tests). Notably,3-year-olds passed the final-goal step above chance level while their performance was at chance level in the sub-goal step. As for the 4- and 5-year-old children, they passed both steps above chance level. The findings are in line with Prabhakar & Hudson (2014) which also reported that 3-year-old Americans performed better in the final-goal trial than in the sub-goal trial. The researchers suggested two possibilities to explain the 3-year-olds' asymmetrical performance in the two sequential steps. First, younger children's limited inhibition ability may have made it more difficulty to suppress the final goal. Second, there was a contingent relationship between the sub-goal and final-goal and it is possible that younger children had difficulty understanding and constructing future events with temporally embedded subgoals. Indeed, when the two future goals were explicit and not contingent, 3-year-olds' performance did not differ between the two steps (Prabhakar & Hudson, 2014).

To our knowledge, this was the first study to systematically examine the developmental trajectory of future-oriented cognition with Eastern pre-schoolers. At the broadest level, the replicated and significant age effects suggested that the tests were developmentally sensitive measure that tapped effectively into Chinese children's future-oriented cognition. These findings are of theoretical and practical importance to cross-cultural research by validating the use of the same task batteries to different cultural groups. Although cross-cultural groups were not directly compared within this study, it appeared that Chinese children's performance on the future-oriented cognition tasks were parallel to or at similar levels as their Western counterparts (Atance, 2015; Hudson et al., 2011; McCormack & Hoerl, 2020). These results indicate that there is a universal developmental trajectory of future-oriented cognition in the preschool period. An important next step for future research will be to directly compare children from different cultures using the same task batteries to further our knowledge of the social and cultural influences on children's cognitive development (Nielsen & Haun, 2016).

4 years old seems to be the cut-off point in children's performance on several future-oriented cognition tasks in Chinese children as well as Western samples (Atance et al., 2015; Redshaw & Suddendorf, 2013; Russel et al., 2010; Suddendorf et al., 2011). This age may indicate a significant developmental milestone point, similar to the passing of the false belief test in theory of mind research (Wellman et al., 2005). Alternatively, it may reflect limitations of the existing developmental paradigms in future-oriented cognition. The majority of tests predominately record children's performance with exclusive dichotomous measure (i.e. pass or fail). Such discrete methods risk missing subtle and gradual developmental changes (Kopp et al., 2021), which may explain the lack of performance difference between the 4- and 5-year-olds in the current study. The future-oriented behaviour and thinking that children demonstrated on the various tasks was, at its best, a rudimentary and developing stage of a far more complex cognitive ability. In order to enrich our understanding of future-oriented cognition beyond the preschool period, future work that designs complex tests with continuous measures are warranted.

As noted in general introduction, future-oriented cognition has been conceptualized as an umbrella term that encompasses different aspects of thinking and behaviour (Atance, 2015; Hudson et al., 2011; McCormack & Hoerl, 2020). Indeed, previous research has indicated that different measures of this cognitive ability were not tightly or coherently related to each other (Atance & Jackson, 2009). To this end, a sub-aim of the current study was to investigate the coherence among different aspects of future-oriented reasoning and behaviour. The results revealed more complex and mixed relationships among the four future-oriented cognition tasks. Overall, the significant inter-task correlations across the future-oriented cognition tasks could be interpreted as evidence of a common cognitive faculty with distinctive components. Specifically, children's ability to anticipate future physiological states (Picture Book task) was significantly related to their prospective memory performance (Card in Basket test), even after controlling for age. At the same time, the Picture Book task, Future Event Sequence task (ability to construct sequentially future episodes) and spoon task (ability to use past information for solving anticipated problems) were significantly related to each other across age groups, though not within age groups. The same pattern was obtained for the relationship between performance on Card in Basket and Spoon tasks. One possible reasoning is that although all tasks included in the current study were theorized to tap into various future-oriented thinking and behaviour, these different components may develop relatively independently and are dissociable during the early stages of development (Manukata, 2001). It may only be in later years when different aspects of future-oriented cognition better merge into a more coherent cognitive faculty (Fair et al., 2008; Spreng et al., 2009).

Notably, some significant inter-task correlations were only found for children within age groups. For example, in the 3- and 4-year-olds, but not 5-year-olds, children's performance in the Future Event Sequence task and Card in Basket was significantly associated. This supports the theoretical account which suggested that the ability to maintain future goals and construct temporally different events were precursors of prospective memory, particularly in younger children (Prabhakar & Hudson, 2014). Additionally, in 4-year-olds, Future Event Sequence task correlated with Spoon Task. Notably, both tasks tapped into children's ability to maintain and act on future goals (to perform actions and to visit a location). It is possible that the inter-task correlation was particularly salient at the age when children start to consistently pass these tasks higher than chance level.

Despite the speculative theoretical relationship between future-oriented cognition and children's executive function and theory of mind ability (Buckner & Carroll, 2007, Suddendorf & Corballis, 2007), the empirical evidence remains scant with mixed findings (Blankenship et al., 2017; Ford et al., 2012; Ünal & Hohenberger, 2017). Notably, Hanson et al. (2014) adopted a battery of future-oriented cognition tasks different to the current study and failed to detect significant inter-task correlations after controlling for children's age. It was proposed that the link between future-oriented cognition, executive function and theory of mind would require tasks that directly involved conflicting perspectives, for example, current desire that differed from future desire (Hanson et al., 2014). Challenging this claim, the present study revealed significant correlations between children's executive function task performance and some future-oriented cognition tasks that did not necessarily involve conflicting perspectives. After controlling for age, the composite score of future-oriented cognition were significantly associated with children's overall inhibition competence, motor inhibition, working memory and cognitive flexibility. These correlations reflect at least some degree of behavioural and cognitive overlap between children's abilities across the different domains.

Understanding the relationship between various future-oriented cognition tasks and different components of executive function ability is essential. First it would help to tease apart the exact cognitive abilities involved in different future-oriented contexts and second potentially aids the design of future experimental paradigms. To be noted, in the current study, the role of cognitive flexibility was highlighted across the different measures. The common aspect across the different future-oriented cognition tasks was the existence of multiple perspectives. In the Picture Book task, children were explicitly asked to take the imagined hypothetical perspectives that were different to their current environment. In the prospective memory test, the Future Event Sequence task and the Spoon task, children's performance were linked with their capacity to switch between temporally different perspectives and to make decisions based on a future perspective. Without the ability to flexibly coordinate through multiple perspectives, it is unlikely that children would be able to pass these tests.

Mentally holding and updating information taps into children's working memory. In the current study, the involvement of working memory was evident across the whole task battery. For example, in the Picture Book task, children needed to update their anticipated perspective from trial to trial based on the specific scenarios in the questions. Other tasks were more reliant on their ability to maintain certain information over time, such as to remember the instruction not to name the specific card in the prospective memory test, and to remember the event of going to a friend's birthday party in the future event sequences task. Finally, the spoon task was specifically designed to assess children's ability to use past information to solve future problem. The significant correlations found in the current study fit with the growing evidence on the role of memory in children' performance in similar spoon type paradigms (Atance & Sommerville, 2014; Scarf et al., 2014). Nevertheless, the non-significant relationships when age was controlled for were possibly due to aspects of task design; before children were asked to select the item, they were explicitly told that they would be going back to the other room. Therefore, this information may have provided a reminder of the problem that they would encounter in the other room. It would be beneficial to investigate how manipulation of memory demand may affect children of different ages in the spoon task context in future.

In order to be future-oriented, it is necessary to prioritise the needs of the future perspective and to put aside any interference from the current perspective. This is a process where control of attention and behaviours as well as suppression of prepotent responses is greatly demanded. The findings from current study indicated that there were significant associations between children's performance on future-oriented cognition tasks and measures of inhibition - some of which remained significant after controlling for age while others did not. That said, echoing previous literature, one of the clearest links found was between prospective memory and inhibition, particularly cognitive inhibition measured by Day-Night task (Causey, Bjorklund, 2014; Kretschmer et al., 2014; Zuber et al., 2019). In the Card in Basket task, children's ability to suppress the prepotent action of naming card was undoubtably the determining factor for task performance. This finding was in line with Mahy et al (2014) study, which reported that the relationship between age and prospective memory was fully mediated by pre-schooler's inhibition ability. With respect to the Picture Book task, a recent study has supported its link with inhibition, though only when semantically associated items were used as distractors (Atance et al., 2021).

Across age groups, children's performance on the Spoon task was associated with motor inhibition and cognitive inhibition, as well as the inhibition composite score, though only before age was controlled. Considering that the Spoon task was specifically designed to represent the classic spoon paradigm (Tulving, 2005), it is possible that the task taps into a cognitive domain that is independent and dissociable to general goal-directed cognition measured by executive function tests. However, Atance et al. (2021) reported the opposite findings which highlighted the relationship between Spoon task performance and inhibition ability. The disparity of results was likely to be the consequences of different categorisation of executive function measures as well as selection of analysis method with ordinal scores, an issue not only related to the current study, but a more general limitation across developmental research on future-oriented cognition. To advance the field further, future research effort should be directed to specify and standardise the methodological and analytical approaches that would better justify and simplify cross-study comparisons.

Overall, there was no evidence supporting the proposed link between future-oriented cognition and theory of mind ability (Atance & Jackson, 2009; Atance & Metcalf, 2013; Buckner & Carroll, 2007). Ford et al. (2012) adopted a similar though more challenging version of the Card in Basket task and found that pre-schoolers' ability to attribute mental states significantly contributed to their prospective memory performance. It is possible that the different level of task difficulty may explain the inconsistent findings, as it has been found that more cognitively demanding tasks draw additional resources from other domains (Leigh & Marcovitch, 2014; Voigt et al., 2014). The current study was, however, consistent with Hanson et al. (2014) and taken together it adds to the converging evidence on the absence of relationship between future-oriented cognition and theory of mind during the preschool years.

There were several possibilities underlying the null findings. Firstly, the extent that the perspective shift in future-oriented cognition task is similar or different to the one in theory of mind tasks should be considered. To date, no empirical evidence suggests that the contrast between current and future perspective equates to the distinction between different person's mental states. Second, it is possible that the link between future-oriented cognition and theory of mind is weak in pre-schoolers, though may be present in older children and adults, which is supported by behavioural and neuroimaging studies. For example, the "default mode network" is the common process underlying perspective taking, prospection and autobiographical memory (Spreng et al., 2009). However, it was only around the age of 7 that the related brain regions start to sparsely functionally connected (Fair et al., 2008). Furthermore, researchers have found that episodic memory - a cognitive ability closely related to future-oriented cognition - was only associated with theory of mind in school-aged children though not pre-schoolers (Naito, 2003; Nigro, Brandimonte, Cicogna, & Cosenza, 2014). Third, in the current study, there was no manipulation of perspective to the future-oriented cognition tasks. There may be greater overlaps between future-oriented tasks that involve another person's perspectives and classic theory of mind paradigms that measure children's understanding of a third person's mental states. Future work would benefit from incorporating a wider range of future-oriented cognition tasks that vary in task structure and perspective comparison.

In conclusion, the current study makes an inroad into researching future-oriented cognition within the overlooked sample of Eastern children and sets the stage for future cross-cultural comparison. Specifically, Chinese pre-schoolers demonstrated typical developmental trajectories and age-related performance on various future-oriented cognition tasks. The next step would be to directly compare children from different countries on the same test battery. Consistent with existing literature on Western children, the findings highlighted the involvement of executive function, though not theory of mind, in Chinese children's ability to understand and plan for the future. However, the study was limited in its power to investigate other key factors which have been shown to influence future-oriented cognition, such as the different perspective between oneself and other person (Bélanger et al., 2014; Russel et al., 2010). This would be a promising path for future enquires and I intend to address it within the scope of this thesis. To further examine the universality of future-oriented cognition, the obvious next step would be to directly compare children from different countries on the same test battery. In the next chapter, I present the cross-cultural comparison of Chinese and British's delay of gratification ability while additionally testing the influence of contextual factors on children's capacity to resist temptations.

Table S2.1. Task block orders in the first testing session.

	Task blocks		
Order	First	Second	Third
1	EF	ToM	FOC
2	EF	FOC	ToM
3	ToM	EF	FOC
4	ToM	FOC	EF
5	FOC	EF	ToM
6	FOC	ToM	EF

Note. EF (executive function) test battery included Knock-Tap task, Day-Night task, Spin the Pots task and DCCS task. ToM (theory of mind) test battery included tests on Diverse Desire, Diverse Belief, Knowledge Access, False Belief Content and False Belief Location. FOC (Future-oriented cognition) test battery included Picture Book task and Card in Basket task.

Table S2.2. Scenarios and item choices in the test trials in the Picture Book task.

Scenario	Correct item	Distractor 1	Distractor 2
Sandy dessert	Sunglasses	Mirror	Soap
Mountain areas	Lunch	comb	Bowl
Snowy forest	Winter coats	Armbands	shampoo
Waterfall	Raincoat	Money	Blanket

Table S2.3. Correlations between children's performance on the task battery of future-oriented cognition, Day-Night and theory of mind and Fisher Z scores (*p* value in bracket)) comparing the correlations.

	Day-Night	Theory of Mind	Fisher Z
Future-Oriented Cognition Composite	.120	.152	-0.209 (.834)
Picture Book	-.019	.137	-1.018 (.309)
Card in Basket	.262*	.040	1.481 (.139)
Future Event Sequence	.514***	.526***	-0.101 (.919)
Spoon Task	.372***	.485***	-0.862 (.389)

Note. $**p < .01$. $*p < .05$. Pearson and Spearman's rank order correlations across age groups are presented.

Table S2.4. Correlations between children's performance on the task battery of future-oriented cognition, Knock-Tap and theory of mind and Fisher Z scores (*p* value in bracket)) comparing the correlations.

	Knock-Tap	Theory of Mind	Fisher Z
Future-Oriented Cognition Composite	.264*	.152	0.719 (.472)
Picture Book	.286**	.137	0.960 (.336)
Card in Basket	.132	.040	0.573 (.567)
Future Event Sequence	.415***	.526***	-0.851 (.394)
Spoon Task	.295**	.485***	-1.358 (.174)

Note. ***p* < .01. **p* < .05. Pearson Spearman's rank order correlations across age groups are presented.

Table S2.5. Correlations between children's performance on the task battery of future-oriented cognition, Spin Pots and theory of mind and Fisher Z scores (*p* value in bracket)) comparing the correlations.

	Spin Pots	Theory of Mind	Fisher Z
Future-Oriented Cognition Composite	.277**	.152	0.909 (.367)
Picture Book	.258*	.137	0.875 (.382)
Card in Basket	.284**	.040	1.772* (.038)
Future Event Sequence	.405***	.526***	-1.023 (.306)
Spoon Task	.510***	.485***	0.244 (.807)

Note. ***p* < .01. **p* < .05. Pearson and Spearman's rank order correlations across age groups are presented.

Table S2.6. Correlations between children's performance on the task battery of future-oriented cognition, DCCS and theory of mind and Fisher Z scores (*p* value in bracket)) comparing the correlations.

	DCCS	Theory of Mind	Fisher Z
Future-Oriented Cognition Composite	.433***	.152	2.161* (.031)
Picture Book	.415***	.137	2.121* (.034)
Card in Basket	.296**	.040	1.963* (.049)
Future Event Sequence	.560***	.526***	0.316 (.752)
Spoon Task	.226*	.485***	-1.905 (.057)

Note. ***p* < .01. **p* < .05. Pearson and Spearman's rank order correlations across age groups are presented.

Chapter 3. Waiting For the Better Reward: Comparison of Delay of Gratification in Young Children across Two Cultures[5]

3.1 Abstract

Chapter 2 tested Chinese pre-schoolers with a range of future-oriented cognition tasks and the findings suggest that their overall age-related performance resembles Western children' developmental trajectory. Yet, directly comparing children from different cultures on the same paradigm is a critical step to examine the universality of future-oriented cognition. In this chapter, I focused on one specific component of future-oriented cognition, delay of gratification, which entails the ability to forsake immediately available rewards in order to obtain larger-valued outcomes in the future. Utilising on a recently published dataset of British children (*N*=61), delay of gratification in 3 to 5-year-old Chinese children (*N*=75) was further tested using a delay choice paradigm (Bramlett, Perdue, Evans, & Beran, 2012). The paradigm was previously used in non-human primates and it featured a mechanized rotating tray that sequentially moves rewards within reach. Additionally, 3 inhibitory control tasks and 1 standardised delay choice task were administered to Chinese pre-schoolers (British children were not tested). The overarching aims were to investigate the influence of culture, reward type and reward visibility on pre-schoolers' ability to make future-oriented decisions. There were significant age-related improvements in delay of gratification ability in both countries and children performed better when presented with rewards varying in quality than quantity. Consistent with previous cross-cultural literature, Chinese children showed better overall performance than their British peers when reward visibility was manipulated (though reward visibility itself had no significant effect on performance). There were significant correlations in Chinese children's performance in the delay choice paradigm and performance in some (though not all tested) inhibitory control tasks. These results are discussed in relation to task demands and the broader social orientation of self-control.

Keywords: delay of gratification, self-control, inhibition, cross cultural research, cognitive development

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3.2 Introduction

The overarching aim of this thesis is to investigate the cognitive correlates and cultural contrasts of future-oriented cognition in the preschool years. Given its multi-faceted nature, it is important to examine the different aspects of future-oriented cognition while difficult to cover all components in a single experiment. The purpose of Chapter 2 was to provide the first systematic investigation of Chinese pre-schoolers' developmental and cognitive profile of future-oriented cognition. The study methodologically prioritised more recently designed tasks, such as the Spoon task (Suddendorf et al., 2011) and Picture Book task (Atance & Meltzoff, 2006). Nevertheless, with sample from a single country, findings from Chapter 2 are insufficient to shed light on the potential cultural contrasts of future-oriented cognition. Experiments in this chapter were, however, specifically conducted with the rationale to directly compare British and Chinese pre-schoolers' future-oriented cognition. Specifically, I narrowed the focus to one component of future-oriented cognition, namely delay of gratification.

Delay of gratification has been considered as an important aspect of future-oriented cognition (Atance, 2015; Atance & Jackson, 2009). It is a specific form of self-control that involves future-oriented decision-making and refers to the ability to abstain from taking immediate smaller rewards in order to achieve larger-valued goals in the long-term (Mischel et al., 1989). From financial decisions to foraging behaviours, humans and other animals frequently face inter-temporal choices in which they weigh the costs and benefits associated with immediacy or delayed actions (Beran, 2015; Stevens, 2014). As a developmental index of self-control (Kochanska, Coy, & Murray, 2001), young children's propensity to postpone gratifying responses has been associated both with day-to-day functions, such as eating behaviours (Caleza, Yañez-Vico, Mendoza, & Iglesias-Linares, 2016), as well as long-term consequences in academic achievement, social and cognitive competence and wellbeing (Ayduk et al., 2000; Michaelson & Munakata, 2020; Mischel, Shoda, & Peake, 1988; Moffitt et al., 2011).

Mentally projecting oneself to the future would facilitate future-oriented decision by allowing individuals to subjectively feel and evaluate the different outcomes (Boyer, 2008; Bulley et al., 2016). Converging evidence has found that after episodically constructing and simulating future events, performance on intertemporal choices was increased and discounting of delayed future rewards was reduced in adults and adolescence (Burns, Atance, O'connor, McCormack, 2021; Daniel et al., 2015, 2016; Sasse, Peters, Buchel, & Brassen, 2015). In pre-schoolers, although cueing about future did not improve prospective abilities, delay of gratification and the ability to select items for future use was related to each other over and above age-related improvement (Burns et al., 2021). Nevertheless, conversation about the future self has been shown to be particularly beneficial to children's performance on delay of gratification, prospective memory and ability to anticipate future physiological states (Leech, Leimgruber, Warneken, & Rowe, 2019).

Children's capacity to delay gratification undergoes dramatic changes in pre-school years and continues to mature into early adolescence (de Water, Cillessen, & Scheres, 2014). Predominantly, researchers have used two paradigms to measure delayed gratification ability in humans and other animals, specifically delay maintenance and delay choice tasks. In the classic delay maintenance paradigm, the marshmallow test, children were given a single trial to decide whether to have one marshmallow now or wait for more marshmallows later (Mischel & Ebbesen, 1970; Mischel, Ebbesen, & Raskoff Zeiss, 1972). The measure of interest is the length of time lapsed as children need to maintain their action in the face of a tempting treat. On a standardised delay choice paradigm, delay of gratification ability is assessed over multiple trials in which dichotomous choices are made between a smaller immediate reward and a larger delayed reward (Imuta, Hayne, & Scarf, 2014; Lemmon & Moore, 2007; Prencipe & Zelazo, 2005; Thompson, Barresi, & Moore, 1997).

The typical and consistent findings of delay choice tasks have indicated that 3-year-olds have difficulty in choosing future rewards whereas 4-year-olds and older children demonstrate higher level of success in future-oriented decisions (Imuta et al., 2014; Lemmon & Moore, 2007; Prencipe & Zelazo, 2005; Thompson et al., 1997). With delay maintenance paradigms, researchers have repeatedly found that pre-schoolers' waiting time increases with age. Previous studies found that a delay above 5 minutes is difficult for 3-year-olds (Mischel & Ebbesen; Mischel & Metzner, 1962), whereas older children can sustain a delay of more than 20 minutes (Evans & English, 2002; Sargent, 2014). Recently, emerging evidence has revealed a cohort effect; over the past 50 years, there has been an increase of children's performance in the delay maintenance task, with children born in 2000s waiting on average 2 minutes longer than children in the 1960s (Carlson et al., 2018; Protzko, 2020).

The maturation of delay of gratification ability is a slow process because of its complex cognitive profile. Recent work has identified several potential candidates which scaffold its development in young children. Notably, executive function, a set of higher order cognition, is regularly employed for goal-directed behaviours (Hughes, 2004). Among children, it has been considered as a unitary construct comprising three key components, namely working memory, cognitive flexibility and inhibition (Hughes, 2011; Miyake et al., 2000). Working memory involves holding and updating information mentally even when it's no longer perceptually present. Cognitive flexibility entails the capacity to switch perspectives and adjust behaviours to changed demands. Inhibition, also referred as inhibitory control, is the ability to control one's attention and behaviour to suppress pre-potent impulsive responses and select the more appropriate responses for different circumstances (Diamond, 2013). Although delay of gratification can be considered a form of inhibition, there are fundamental distinctions between self-control and inhibitory control (Beran, 2015). Specifically, the former requires decisions and actions to sustain a waiting period or to employ greater effort to obtain the delayed but more valuable outcomes, whereas the latter requires suppressing pre-potent responses. A battery of tasks, including the Stroop tasks and go/no-go tasks (Johnstone, Pleffer, Barry, Clarke, & Smith, 2005; Macleod, 1991), has been developed to measure cognitive and motor inhibition yet not all tasks rely on self-control ability (Beran, 2015).

Theoretically, each executive function component has been hypothesized to contribute differently to children's propensity to resist short-term temptations (Mischel et al., 2011). The most intuitive link lies between inhibition and delayed gratification, as the former prevents irrelevant thoughts and actions to interfere with future-oriented decisions and to resist the temptation of an immediately available reward (Duckworth & Steinberg, 2005; Simpson & Riggs, 2007). Indeed, better inhibitory control ability has been linked with higher rate of success on delay maintenance paradigms as well as delay choice tasks (Hongwanishkul et al., 2005; Yu, Kam, & Lee). Specifically, children who performed better on cognitive inhibition tasks (e.g., Day-Night task) and motor inhibition tasks (e.g., self-ordered pointing test) also showed greater capacity of delayed gratification. Moreover, working memory could facilitate children's ability to postpone gratification by holding the task demand and the goal to obtain a better reward in mind (Carlson, White, & Davis-Unger, 2014; Hinson, Jameson, & Whitney, 2003). Neuroscience findings have indicated overlapping prefrontal regions of executive function and inter-temporal decisions (Figner et al., 2010). Furthermore, an intervention study, which targeted working memory and inhibitory control, found that through weekly 1.5 hour small group play activities in a school setting for 6-8 weeks, there were significant improvements on children's capacity to delay gratification (Traverso, Viterbori, & Usai, 2015).

The individual differences of delayed gratification ability have been attributed both to children's underlying cognitive competency as well as contextual factors, such as reward type and reward visibility. Raclin (1971) suggested that reward value varies as a function of quality and quantity, and humans take reward representation into consideration while making inter-temporal choices. Notably, researchers have consistently found that children were more likely to delay when the *quantity* of later options increased (Garon, Longard, Bryson, & Moore, 2012; Imuta et al., 2014; Lemmon & Moore, 2007). When faced with a significantly larger delayed option, even 2-year-olds could sustain a delay period as long as 16 minutes (Steelandt et al., 2012). Comparably, less is known about the effect of reward *quality* in human developmental literature. Recently, Miller et al. (2020a) utilised an intuitive task on delay of gratification, which was originally designed by Bramlett et al. (2012) to test self-control in non-human primates, referred to as the "rotating tray" task. New Caledonian crows and pre-school children showed increased delayed gratification behaviours with qualitatively different rewards than with quantitively different rewards.

More replicated findings come from investigations on reward visibility. Children waited longer for non-visible rewards (Mischel & Ayduk, 2002; Mischel & Mischel, 1987). The strategy of directing attention away from the reward and decreasing its consummatory nature facilitated delayed gratification performance (Metcalfe & Mischel, 1999; Mischel & Ebbesen, 1970). Similar findings have been obtained with primates (Beran & Evans, 2006). Specifically, capuchin monkeys exhibited delay of gratification in Bramlett et al. (2012) rotating tray paradigm even with invisible delayed rewards (Perdue, Bramlett, Evans, & Beran, 2015). Nevertheless, there is a methodological imbalance associated with the findings of contextual factors in the human developmental literature. The majority of studies have adopted the delay maintenance paradigm and the evidence on the role of reward visibility tested with delay choice paradigm is scant (Miller et al., 2020a).

Thus, it would be indecisive and potentially inaccurate to suggest that the contextual factors which influence children's capacity to maintain a delay would work similarly with tasks in which children are required to make dichotomous choices. To date, only two studies have systematically manipulated reward representation in choice tasks and found mixed findings. First, Garon et al. (2012) revealed that children's performance changed as a function of reward quantity but covering the reward had no effect. Second, Addessi et al. (2014) found that pre-schoolers displayed greater inclination towards the delayed option with actual food rewards and low-symbolic tokens, but not with more abstract high-symbolic tokens. Given this background of inconclusive findings, further investigation is required to clarify the role of reward representation on the delay choice task in children.

A noteworthy characteristic of the research on children's delay of gratification is that the data has primarily come from European-American countries, so that our knowledge of its developmental trajectory, cognitive correlates and consequences could be culturally skewed and biased (Nielsen & Haun, 2016). In recent years, there has been increased effort devoted to examining cognitive development outside the Western societies (Henrich et al., 2010). The development of self-control is acknowledged as a malleable and context-specific process, which is sensitive to social and cultural influences (McClelland & Wanless, 2015). Each country has its unique set of culturally specific ideologies and social norms; in traditional Chinese Confucian philosophy, self-restraint and inhibition are considered as highly desirable traits and the sign of accomplishment and maturity (King & Bond, 1985). Thus, self-control and self-regulation are valued and encouraged more in Chinese society than in Western cultures, which advocate self-expression and assertiveness (Chen et al., 1998; Chen, Rubin, & Sun, 1992; Jaramillo et al., 2017; Olweus et al., 1993). Consequentially, Chinese parents intentionally adopt specific child-rearing strategies to facilitate self-control behaviours in children and such effort extends to teaching activities and school environment (Chen, Rubin, & Li, 1995; Eisenberg et al., 2009; Liu et al., 2005).

Taking the cultural emphasis and societal effort into consideration, one may expect that Chinese children show advantageous performance on self-control tasks than their European-American peers. Indeed, there are consistent findings suggesting that Chinese children outperform their Western counterparts on a battery of executive function tasks and specifically measures of inhibitory control (Lan et al., 2011; Sabbagh et al., 2006; Xu et al., 2020). Such cultural differences emerge as early as pre-school age and continue into adolescence (Ellefson et a., 2017; for a review, see Schirmbeck, Rao, & Maehler, 2020). However, these studies have predominantly employed cognitive and motor inhibition tasks. There has been little attempt to directly compare children's delay of gratification ability cross-culturally despite its theoretical and developmental significance. To the best of my knowledge, only one study had done so. Lamm and colleagues (2018) tested pre-schoolers from a German city and a rural Cameroonian Nso community with a standardised delay maintenance marshmallow test. The findings indicated that Nso children displayed greater level of delayed gratification ability than their German peers. Socialization goals and parental interactions were correlated with children's delay of gratification performance, a finding consistent with previous literature (Mauro & Harris, 2000). Nevertheless, to date there has been no investigation on the Eastern and Western contrast of delayed gratification ability with a delay choice paradigm. Furthermore, the role of reward representation has not been examined in East Asian cultures, posing important questions regarding the universality of contextual factors in children's inter-temporal decisions.

The current study aimed to address these literature gaps by testing Chinese and British pre-schoolers on delay of gratification. Cultural and social environments differ greatly between the United Kingdom and mainland China. Previous researchers have conducted Eastern versus

Western comparisons in children's cognitive development with these two populations (Ellefson et al., 2017; Xu et al., 2020). In the present study, children's delayed gratification performance was assessed with Bramlett et al. (2012) delay choice paradigm, with additional manipulations of reward type using rewards differed in quality and quantity. Specifically, the rotating tray task has recently been adopted to test capuchin monkeys (Beran et al., 2016; Purdue et al., 2015) as well as comparatively in New Caledonian crows and British children (Miller et al., 2020a).

Furthermore, meta-analysis has revealed a very moderate convergence between the different tests measuring delay of gratification ability (Duckworth & Kern, 2011). Therefore, in order to compare performance between the rotating tray delay choice paradigm with several standardised developmental paradigms, a battery of standardised developmental measures was administered to the same sample of Chinese children (though not British children). Specifically, these were: a standardised delay choice task (Prencipe & Zelazo, 2005) and three inhibitory control tasks (Day-Night, Gerstadt et al., 1994; Grass-Snow, Carlson & Moses, 2001; Knock-Tap, Luria, 1966). Few studies have investigated whether delay of gratification performance is consistent within individuals when tested with different paradigms (Beran et al., 2016; Miller et al., 2020a). Furthermore, to date there has been no investigation dedicated to examining the underlying relationship between the comparative task of delay of gratification (Bramlett et al., 2012) and inhibitory control tests among pre-schoolers. In addition to inhibiting the pre-potency of reaching-and-taking responses for the sooner reward, the rotating tray task taps into the ability to make and act upon future-oriented decisions (Beran, 2015; Bramlett et al., 2012). Therefore, knowledge of how Bramlett et al. (2012) delay choice paradigm correlate with standardised inhibitory control tasks would shed light on our understanding of the similarities and differences among various measures of self-control.

Focusing specifically on delay of gratification, Chapter 3 further adds to the emerging profile of Chinese pre-schoolers' future-oriented cognition, which was the main theme in Chapter 2. More importantly, in this thesis, Chapter 3 is the first cross-cultural investigation of per-schoolers' future-oriented cognition between Western and Eastern children. Specifically, the aims of the present study were twofold: 1) to compare delay of gratification in Chinese and British pre-schoolers, including whether reward representation (Experiment 1) and reward visibility (Experiment 2) influence children's capacity to postpone gratification, and 2) to examine the convergent validity of the rotating tray task by testing whether performance in Bramlett et al. (2012) paradigm correlates with performance in standardised developmental paradigms in the Chinese sample.

Data on the British children came from a recently published study (Miller et al., 2020a) using the same rotating tray task while the Chinese data was collected and utilised only in the current study. Based on existing literature of the Western-Eastern contrast of socialization goals and Chinese children's advantage on various self-control measures, I predicted that Chinese children would outperform their British counterparts in the rotating tray delay choice task. In particular, it was hypothesized that Chinese children would make more future-oriented decisions and exhibit greater delayed gratification ability by waiting for the delayed and more preferred rewards. With the rotating tray task, I expected to find universal age-related performance in children that follows a similar developmental trajectory as other delay of gratification paradigms (Imuta et al., 2014; Lemmon & Moore, 2007; Prencipe & Zelazo, 2005; Thompson et al. 1997). Additionally, Chinese children's performance on Bramlett et al. (2012) rotating tray task was predicted to correlate with the standardised measures of inhibition and delay choice task. In terms of the contextual factors, I expected to see similar patterns to those in Miller et al. (2020a), Garon et al. (2012) and Purdue et al. (2015) where children and non-human primates performed better when the rewards varied in quality than in quantity, and reward visibility had no influence on performance.

3.3 Methods

3.3.1 Ethics

All procedures performed in the present study were in accordance with the ethical standards of and were approved by the University of Cambridge Psychology Research Ethics Committee (PRE. 2018. 080, for an example of ethics application, see Appendix A & Appendix B). There was no national regulation applying to foreign researchers and no relevant approval required to conduct data collection in China. However, I did follow the same protocols for the rotating tray task as outlined in our UK ethics approval. Headmasters at the participating nurseries were contacted first and I explained the purpose and procedure of the study (for an example see Appendix C). Information sheets and consent forms were provided to parents and written parental consent was obtained prior to participation of the children (for examples see Appendix D & Appendix E). Parents were told that they could withdraw before, during, and after the study without giving a reason. All children were told that they could stop at any time and they could choose not to complete any activities. Additionally, written consent from parents was also obtained to video record the experimental sessions (for an example see Appendix E). To protect participant confidentiality, I used random and anonymised ID numbers and securely stored data and videos in password-protected files and locked cabinets within the Department of Psychology. The length of testing session, which lasted less than 35 minutes, was children-friendly and breaks were included to avoid over-tiring the participants.

3.3.2 Participants

A statistical power analysis was performed for sample size estimation in G* Power and the effects sizes were obtained from previous studies (Duckworth & Kern, 2011; Lemmon & Moore, 2007; Miller et al., 2020a; Prencipe & Zelazo, 2005). Specifically for detecting age-related effects in children's delayed gratification ability, using parametric or non-parametric tests, a minimum sample of 72 was needed to reach a power of 0.8 with an alpha level at .05 and an effect size of 0.5 (Faul et al., 2007). G* Power suggests that for multiple regression with 6 predictors with an alpha level at .05, a power of 0.8 and an effect size of 0.3, a total sample size of 53 was required. Specifically, for Generalised Linear Mixed Models, the regression-based technique uses every single response from all the participants and each participant completed 20 control and testing trials, ensuring sufficient power for statistical analysis including interaction effects (Kumle, Võ, & Draschkow, 2021; Verma & Verma, 2020). For correlational analysis, a minimum sample of 67 was required to reach a power of 0.8 with an alpha level at .05 and an effect size of 0.3 (Bonett & Wright, 2000; Faul et al., 2009). Therefore, the final sample size of 136 would be adequate for the main objectives of this study.

One hundred and thirty-six normally developing children aged between three and five-years-old participated in the study. In Britain, 61 children took part in the study: 20 3-year-olds (Mean = 3.65 years, Range = 3.01-3.98 years), 21 4-year-olds (M = 4.68 years, R = 4.05-4.99 years) and 20 5-year-olds (M = 5.34 years, R = 5.05-5.87 years), of which 31 were male and 30 were female. The British participants were recruited and tested at nurseries and schools in Cambridgeshire and Buckinghamshire, which served predominantly white, middle-class backgrounds. Specifically, 60.6% of the population in these areas are aged between 16-64 years old and 39.5 % of its population's educational attainment are NVQ4 or above (Office for National Statistics, 2018). In terms of ethnicity, Cambridge is mostly Caucasian with 66.1% of residents identifying as the white ethic group. All children participated in the study on the British site were non-Asian and normally developing children.

In China, we recruited and tested 75 children: 25 3-year-olds (M = 3.65 years, R = 3.02-3.96 years), 25 4-year-olds (M = 4.43 years, R = 4.08-4.95 years), 25 5-year-olds (M = 5.32 years, R = 5.00-5.90 years), of which 40 were male and 35 were female. The Chinese participants were recruited in Kunming, Yunnan Province, which is a typical regional and new first tier city based on its population, economy and urbanisation (Wu et al., 2015). The total population of Kunming is 8.46 million with 86.16% as the Han Chinese, the most dominant ethnic group in China (2020 Chinese Census). Specifically, 74.53% of the total population are aged between 15-64 years old and 26.97% of people have university or higher degrees. Participants were all normally developing children and they were recruited from a university-affiliated public nursery. Children who admitted to the nursery must have at least of the parents working as university academia or staff (with at least university degrees).

The British data was collected using the rotating tray delay choice paradigm in March-June 2018, with the data set being utilised already in Miller et al. (2020a) comparative study on delay of gratification in children and New Caledonian crows. The Chinese data (all tasks described in the present study) was collected from November-December 2018 specifically for the present study. Due to the difficulty of tracking previous participants, obtaining consent and the children getting older (which could influence developmental patterns), it was unfeasible to recruit the same group of British children as in Miller et al. (2020a) again for further testing for the present study. Therefore, data on the inhibition control tests and standardised delay choice task was collected from Chinese participants only.

3.3.3 Apparatus

Rotating tray paradigm (adapted from Bramlett et al. (2012)

In the rotating tray paradigm, a 38cm diameter elevated revolving disk was used (Fig 3.1). The task was adapted from previous non-human primate studies (Beran et al., 2016; Bramlett et al., 2012; Purdue et al., 2015). The disk was mounted on top of a rotation device moving at a speed of 68 seconds per rotation and was operated with a remote control by the experimenter. The apparatus was positioned on a table between the experimenter and the participant, allowing them to sit face-to-face. To prevent children from taking rewards before they were positioned directly in front of them, the revolving disk was contained within a transparent Perspex box (41cm x 34cm x 14cm) with a 29cm x 7cm rectangular opening at the front. Two small plastic containers were used to hold rewards (stickers – see details below) and they were positioned at pre-set locations on the disk, referred to as location 1 and location 2. Specifically, the first container at location 1 would come within the participant's reach after 5 seconds, and the second container at location 2 after 15 seconds. These delays were chosen for two reasons; first to be comparable to the previous non-human studies using a similar paradigm (Bramlett et al., 2012; Purdue et al., 2015) and second to be identical to the length of delays adopted in the Miller et al. (2020) study with British children.

In the current study, different types of rewards were prepared for the quality and quantity conditions. In the quality condition, the most preferred reward was a large glittery picture

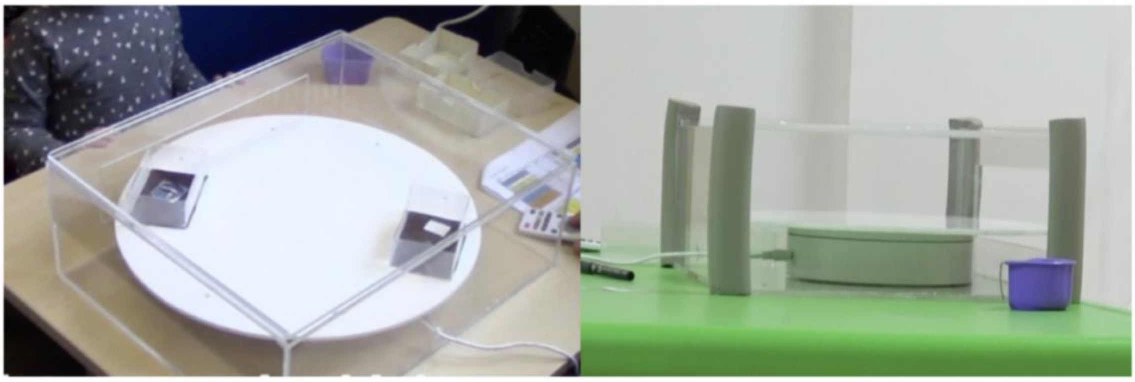

Fig 3.1: Rotating tray with two containers.

sticker (higher quality) and the least preferred reward was a plain sticker of similar size (lower quality). For the quantity condition, mini sparkly, picture stickers were used- the most preferred reward was 4 mini stickers (larger quantity) and the least preferred reward was 1 mini sticker (smaller quantity). Additionally, an “OK” reward which was a yellow smiley sticker was used during the training in order to maintain participants’ motivation during testing as all trials were conducted in one session.

3.3.4 Procedure

Preference test

To check that the participants were able to accurately select the reward determined to be “most preferred”, i.e. higher quality or larger quantity over the reward determined to be “least preferred”, i.e. lower quality or smaller quantity a preference test was conducted between the higher quality sticker and lower quality sticker (quality condition), and for the large and small amount of stickers (quantity condition). Both reward options were presented on the table simultaneously and the experimenter asked participants to pick their favourite option. One trial per condition was run because the pilot testing revealed that most children showed a clear preference for the most preferred over least preferred options on their first choice. Considerations were also given to limit the number of stickers being offered in order to maintain motivation in obtaining the rewards across the trials.

Participants were tested on a one-to-one basis with a female experimenter in temporary visual isolation from other children in nurseries, preschools and schools (UK) and nurseries (China). In the UK, for some of the younger children, a member of staff was present but did not interact with the participant. To minimise any potential influence of the experimenter and reduce unconscious cueing, a protocol of procedural and specific instructions was developed and followed to guide behaviours during the interactions with participants.

Experiment 1: influence of reward type – reward quality vs. quantity

Training

There was one demonstration trial, where the experimenter started the rotating tray and asked the child to select the container once it arrived in front of them. The experimenter then used two forced-choice training trials i.e. only one transparent container present at either location 1 or 2, with one trial per condition, and no container at the other location, to introduce the rotating apparatus and to ask the participant to select the container with the "OK" reward when it arrived in front of them, within their reach. Participants were then told that there would be 2 containers on the rotating disk, but they could select only 1 container and the disk would stop moving once they made their choice. The purpose of these training trials was to ensure that children were able to pay attention when rewards become accessible and to retrieve the reward in its container from the rotating disk.

Testing

In test trials, the container holding the most preferred reward (higher quality/larger quantity) was placed at location 2 and the least preferred reward (lower quality/smaller quantity) at location 1, and vice versa in control trials. Therefore, in test trials, participants need to wait longer (15 seconds) for the most preferred rewards. The purpose of control trials was to make sure that participants were selecting the most preferred reward on the basis of its location, as opposed to learning to wait for the delayed reward irrespective of the reward type. The rewards were placed inside the transparent containers in sight of participants and they remained visible throughout the trials. Trials for the quality and quantity condition were run separately. Overall, there were 8 trials: 2 test trials and 2 control trials for each condition and they were administered in a counterbalanced order. Participants were only allowed to make one choice, i.e. to select one container by pointing to it. The experimenter stopped the tray from rotating as soon as a choice was made and children were immediately given their selected reward to keep.

Experiment 2: influence of reward visibility

Training

The training comprised of 4 forced-choice trials, which was considered to represent a memory test. The purpose of the memory test was to ensure that children were able to remember the location of a hidden reward, so that failure in the testing was unlikely to be attributed to any memory constraints. The experimenter simultaneously picked up the two transparent containers and placed them on the rotating disk. An "OK" reward was placed in one of the containers (location 1 or 2) in sight of participants, with no reward in the second location, and an opaque lid was then placed on both containers. As such, the reward hidden within one of the containers was not visible once baiting had finished and the disk started rotating. In total, there were 4 memory test trials, with 2 trials with the container at location 1 baited with the reward, and 2 trials with the container at location 2 baited. Children who failed any of the first 4 trials would be given 2 additional trials, with one trial per location. All participants passed the memory test; 84% of participants passed in the first 4 trials and 16% of participants scored 3 out 4 in the first 4 trials and passed the subsequent additional trials.

Testing

Similar to Experiment 1, test trials were conducted with the most preferred reward (higher quality/larger quantity) in location 2 and least preferred reward lower quality/smaller quantity) in location 1, and vice versa for control trials. The rewards were baited in containers at both locations simultaneously in view of the participants. To investigate the influence of reward visibility, three different test types were adopted (Fig 3.2). In test type 1 (immediate reward visible), the container in location 1 had a transparent lid whereas the container in location 2 had an opaque lid. Therefore, in this case, only the immediately available reward at location 1 was visible once the disk rotation started. In test type 2 (delayed reward visible), only the delayed reward was visible as the container in location 2 had a transparent lid while the container in location 1 had an opaque lid. In test type 3 (neither reward visible), neither reward were visible once baiting completed as opaque lids were used for both containers.

Fig 3.2: The quality and quantity condition test trials in Experiment 2. The least preferred in location 1 would come within participants' reach after 5 seconds, and location 2 with the most preferred reward after 15 seconds.

In Experiment 2, there were 12 trials with 6 trials for quality condition and 6 trials for quantity condition. Of the 12 trials, there were 4 trials for each test type and within each test type there were 2 test and 2 control trials. The trials were administered in a counterbalanced order. Children were not allowed to revoke their decision once they selected the container. All participants completed both experiments with a fixed order (Experiment 1 first followed by Experiment 2) within the same session. Overall, the study lasted approximately 20 minutes with a total of 28-30 trials (number of trials dependent on training performance). Participants were randomly assigned to 2 subgroups for order of test conditions; half of children received the quantity condition then the quality condition, and the other half received the quality condition first followed by the quantity condition.

Standardised developmental paradigms

In addition to Bramlett et al. (2012) rotating tray paradigm, the same sample of Chinese pre-schoolers were tested with three standardised inhibition tasks and one delay choice task (Prencipe & Zelazo, 2005) to These tasks were selected on the basis that they were sensitive to detect age-related changes and were widely used in developmental literature (Carlson, 2005; Petersen et al., 2016). Participants completed these tasks in a fixed order after the rotating tray task and the total length of these tasks was around 8 minutes. Brief task descriptions of the inhibition tasks are outlined in Table 3.1 and detailed protocol can be found in Appendix.

Table 3.1. Brief task descriptions for inhibition tests.

Task	Description
Day-Night (Gerstadt et al., 1994)	Child was instructed to say “Day” when presented with a picture of Moon and to say “Night” when presented with a picture of Sun.
Grass-Snow (Carlson & Moses, 2001)	Child was instructed to point to a green paper when “Snow” was spoken and point to a white paper when “Grass” was spoken.
Knock-Tap (Luria, 1966)	Child was asked to perform the opposite hand movement from the experimenter, for example to tap the table with flat palm when the experimenter knock on the table.

Delay Choice Task (Prencipe & Zelazo, 2005): This was a standardised delay choice paradigm assessing young children’s delay of gratification. Children were asked to choose between an immediately available reward of small quantity and a delayed reward of larger quantity. A total of nine trials were administered; created by crossing three types of reward (stickers, animal erasers, cartoon stamps) with three types of choices (1 now vs. 2 later, 1 now vs. 4 later, and 1 now vs. 6 later). Both options were simultaneously and physically presented to children on a table. Children received the immediate reward if they chose it, and the delayed reward was placed in an envelope and remained inaccessible until the end of the study. Children waited approximately 2 minutes and the delay length was the same for all participants. Each trial was solved correctly when the child selected the delayed larger reward. Accuracy out of 9 trials were recorded. This delay choice task was selected because it was a widely used standardised developmental paradigm involving a series of dichotomous choice between immediate and delayed rewards, which was similar to the rotating tray task.

3.3.5 Analytic plan for rotating tray task and standardised developmental paradigms

Rotating tray paradigm

The choice per trial for each child was recorded as "correct" or "incorrect", with the correct choice being the reward of higher quality or larger quantity, whether it was immediate (control trial) or delayed (test trial). In the preference trials, 98.6% of British children and 97.3% of Chinese children selected correctly for quality condition and 96.7% of British children and 93.3% of Chinese children selected correctly for quantity condition. If a child failed to select correctly in the initial preference trials, they were administered with one follow-up trial for the specific condition that they failed - the pass rate for the follow-up trial was 100%. Given the methodological and analytical importance of test trials, I present the results of test trials in the manuscript and include the analyses for the test and control trials combined in the Table S3.1 and Table S3.2. I live coded as well as video recorded all experimental sessions unless parents requested no recording. A random selection of 20 % (N = 27) of videos was coded for inter-rater reliability. Cohen's Kappa was run to test for inter-rater reliability and there was good agreement, $\kappa = .828$, $p<.001$. The analysis aimed to investigate the general developmental trajectory and potential factors affecting children's performance in Bramlett et al. (2012) rotating tray task across both countries (British, Chinese). With Chinese pre-schoolers, I also explored whether performance in the rotating tray task correlated with the standardised inhibitory control tests and delay choice task.

Generalized Linear Mixed Models (GLMM: Baayen 2008) in R (version 3.4.3; R Core Team, 2014) were used to assess which factors influenced children's performance in terms of success rate in the rotating tray task. Success rate was the dependent variable in the models and was a binary variable indicating whether the child chose correctly (1) or not (0). In Experiment 1, the random effect included in the models were participant ID and fixed effects included age in years (categorical, ages 3-5 in individual years), country (Britain vs. China), the interaction effect of country and age (Britain vs. China and 3 to 5 years), condition (quality, quantity), order (quality-quantity, quantity-quality) and sex (male, female). For Experiment 2, the same fixed effects as Experiment 1 were included as well as adding the fixed effects of visibility (immediate reward visible, delayed reward visible, neither reward visible).

Likelihood ratio tests were adopted to compare the full models (all predictor variables, random effects and control variables) firstly with a null model, and then with reduced models to test each of the effects of interest (Forstmeier, & Schielzeth, 2011). The null models contained the random effects and control variables (i.e. no predictor variables) namely "sex" as this variable was not predicted to significantly effect performance. The reduced models comprised of all effects present in the full model, except the effect of interest. For the GLMMs, family = binomial, R package "lme4", "glmer" and "anova" functions were used (Bates et al., 2015). The log likelihood ratio of the following was compared; a) the full with null model, and b) the full with reduced model containing only the main effects to test the effect of the interaction term, and c) the final with reduced models to test each of the effects of interest, using maximum likelihood. The p-values in the models were derived from the likelihood ratio tests. Further analyses for the significant variables identified in the GLMMs were conducted where applicable, using Tukey contrasts for pairwise comparisons of age, and to compare performance against chance using non-parametric two-tailed statistics, namely Wilcoxon signed ranks, Mann Whitney U tests and binomial tests.

Standardised developmental paradigms

The total number of correct trials was recorded for each standardised inhibition task and the delay choice task. The scoring methods have been validated in previous research and were consistent with the vast majority of developmental studies (Carlson, 2005; Petersen et al., 2016). Specifically, for the scope of the present study, the use of sum scores of the standardised delay choice task were appropriate and sufficient in testing age-related performance as well as for correlational analysis. As the data violated the assumption of normality, non-parametric Kruskal-Wallis tests were selected to investigate the effect of age on children's performance with Bonferroni corrections applied for multiple comparisons (Lee & Lee, 2018; Rodger & Robers, 2013; Sheskin, 2003). Furthermore, Spearman's rank order correlations were conducted to test the relationship among the different tasks. Notably, both the standardised delay choice task and the quantity condition in Experiment 1 of the rotating tray paradigm used quantity rewards that were visible to the participants, therefore I included both the overall performance in the rotating tray task as well as performance in the quantity condition in Experiment 1 for the correlation analysis. Fisher Z test was conducted to compare correlations using the R package 'cocor' (Diedenhofen & Musch, 2015).

3.4 Results

3.4.1 Rotating tray paradigm – Experiment 1

The full model differed significantly from the null model (X^2 = 39.46, *df* = 7, *p* <.001). The full model (with interaction term) was not significantly different to the reduced model (main effects only; X^2 = 4.8, df = 2, *p* =.091). Therefore the interaction term (Age: Country) did not significantly improve the model and the final model reported is the best fit (Table 3.2). There was a significant main effect of **condition** (quality vs. quantity; Fig 3.3), **order** (quality-quantity vs. quantity-quality) and **age** (3 to 5 years; Fig 3.4), with no significant effect of country or sex (Table 3.2).

Notably, across both countries and all age groups, children's success rate was significantly higher in the quality than in the quantity condition, with above chance level performance within each condition (Wilcoxon signed ranks test: all *p* <.001). In terms of age, 5-year-olds significantly outperformed 3 and 4-year-olds, with no difference between 4- and 3-year-olds

Table 3.2. Generalized linear mixed models for Experiment 1.

Fixed Term	chi-square	df	p-value
Country	0.06	1	0.805
Condition	15.84	1	**<0.001**
Age in Years	9.14	2	**0.01**
Order	8.72	1	**0.003**
Sex	0.27	1	0.604

Generalized linear mixed models (final model) on factors affecting the number of correct *test* trials in children for Experiment 1 with British and Chinese dataset combined. N = Britain 61; China 75. P-values < .05 are highlighted in bold.

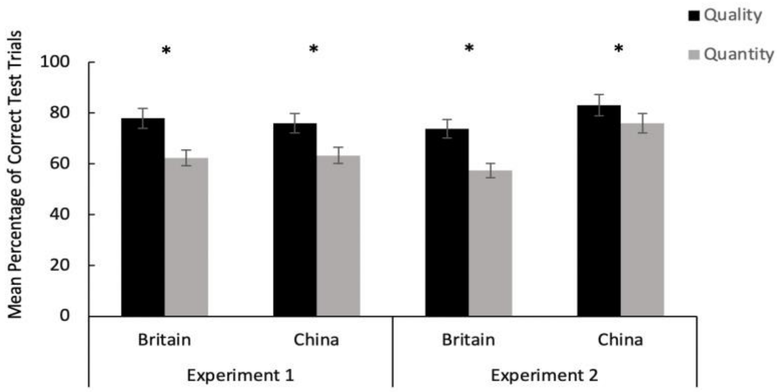

Fig 3.3: Mean percentage of correct test trials across age groups by condition (quality and quantity) in Experiment 1 & 2. * indicates performance above chance level (p < .05), error bars indicate standard errors.

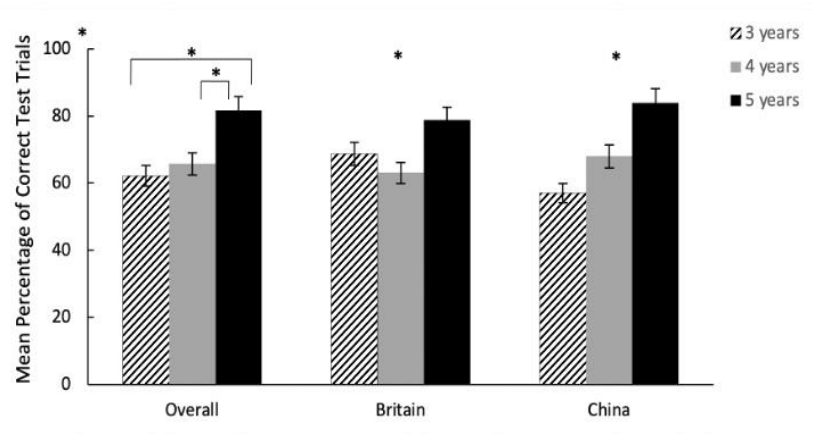

Fig 3.4: Mean percentage of correct test trials across conditions by age groups in Experiment 1. * indicates performance above chance level (p < .05), error bars indicate standard errors. Across countries, 5-year-olds outperformed 3- and 4-year-olds respectively, with no difference between 3- and 4- year-olds' performance, indicated by the significance lines.

(Tukey contrasts: age 5 vs age 4, z = 2.25, p = .024; age 5 vs age 3, z = 3.18, p = .001; age 4 vs age 3, z = 1.04, p = .298), though all three age groups performed above chance *(*Binomial tests: Age 3: p = .026; Age 4: p = .009; Age 5: p < .001). With regard to the main effect of order, children performed better when tested with the order of quality-quantity than quantity-quality with performance significantly above chance in both order groups (Wilcoxon signed ranks test: p <.001). Results using test and control trials combined dataset were presented in Table S3.1.

3.4.2 Rotating tray paradigm - Experiment 2

The full model differed significantly from the null model (X^2= 76.26, df = 9, p <. 001). Moreover, the full model (with interaction term) was significantly different to the reduced model (main effects only), and is the best fit model (X^2= 25.303, df = 2, p<.001) (AIC equal between models with main effects of age and country included or removed, hence removed for final model). Specifically, there was a significant main effect of **condition** (quality vs. quantity, Fig 3.3) and an interaction effect of **country** and **age** (Table 3.3, Fig 3.5). There was no significant effect of sex, order or visibility (Table 3.3).

Similar to Experiment 1, in Experiment 2, children's performance was better in the quality than in the quantity conditions with above chance level performance in both conditions (Wilcoxon signed ranks test: all p <.001). With the age and country interaction, Chinese 4- and 5-year-old children outperformed their British peers respectively, with no difference in performance between the Chinese and British 3-year-olds (British 5-year-olds vs Chinese 5-year-olds: z = -2.573, p = .010; British 4-year-olds vs Chinese 4-year-olds: z = -3.436, p = .001;

British 3-year-olds vs Chinese 3-year-olds: $z = -.141$, $p = .888$). Within country, for Chinese children, 4- and 5-year-olds performed significantly better than the 3-year-olds, with no significant difference between the 4- and 5-year-olds (Tukey contrasts: age 5 vs age 4, $z = 0.755$, $p = .45$; age 5 vs age 3, $z = 3.59$, $p < .001$; age 4 vs age 3, $z = 3.002$, $p = .003$). Comparing performance against chance level, only 4 and 5-year-old Chinese children scored significantly above chance with 3-year-olds showing below chance success rate (Binomial tests: Age 3: $p = .091$; Age 4: $p < .001$; Age 5: $p < .001$). In comparison, British 5-year-olds performed significantly better than 4-year-olds, with no difference between 5 and 3-year olds, or between 4 and 3-year olds (Tukey contrasts: age 5 vs age 4, $z = 2.68$, $p = 0.007$; age 5 vs age 3, $z = 1.495$, $p = .135$; age 4 vs age 3, $z = -1.184$, $p = .236$), with only 3- and 5-year-olds scoring significantly above chance (Binomial test: Age 3: $p = .011$; Age 4: $p = .625$; Age 5: $p < .001$). Results using test and control trials combined dataset were presented in Table S3.2.

Table 3.3. Generalized linear mixed models for Experiment 2.

Fixed Term	chi-square	df	p-value
Condition	16.59	1	**<0.001**
Country: Age	57.69	5	**<0.001**
Order	0.146	1	0.702
Sex	0.221	1	0.513
Visibility	3.12	2	0.21

Generalized linear mixed models (final model) on factors affecting the number of correct *test* trials in children for Experiment 2 British with Chinese dataset combined. N = Britain 61; China 75. P-values <0.05 are highlighted in bold.

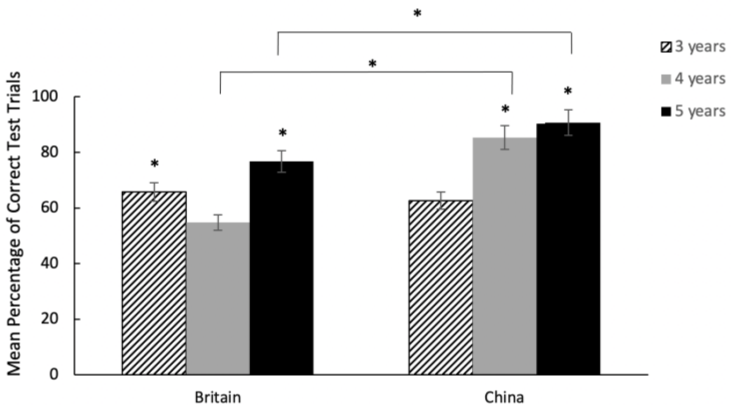

Fig 3.5: Mean percentage of correct test trials across condition by age groups in Experiment 2. * indicates performance above chance level (p<.05), error bars indicate standard errors. Chinese 4-

and 5-year-olds outperformed British 4- and 5-year-olds respectively, with no differences in performance between the 3-year-oldds, indicated by the significance lines.

To be noted, in the 4-year-olds British age group (total N = 21), three children scored zero in the test trials in Experiment 2. In comparison, not a single participant in the 3-year-olds age group failed all test trials. After removing the three participant outliers, additional analysis revealed that British 4-year-olds' success rate was above chance level (Binomial tests: p <.001). Moreover, there was still no difference between British 3 and 4-year olds' performance on the rotating tray task (Mann Whitney U test: z = -1.769, p = .077). Additional analyses were conducted using the dataset without the three British outliers. For the GLMMs, there was a significant main effect of condition and an interaction effect of country and age (Table S3.3). When outliers were removed from the analysis, Chinese 4-year-old children still outperformed their British peers (British 4-year-olds vs Chinese 4-year-olds: z = -2.903, p =.004). Reward visibility alone did not influence children's performance in the test trials on the rotating tray task.

3.4.3 Standardised developmental paradigms (Chinese sample only)

Across all standardised developmental tasks (three inhibitory control tasks and one delay choice task), Kruskal-Wallis tests revealed that age had a significant effect on performance (Table 3.4). Specifically, 5-year-olds outperformed 3-year-olds on all tasks (Mann Whitney U test against a Bonferroni-adjusted alpha level of 0.008 (0.05/6): all p <. 005). Moreover, 4-year-olds scored significantly higher on the Knock-Tap, Day-Night and Grass-Snow task than children aged 3-years-old (all p <. 008). To investigate the inter-task relationships, Spearman's rank order correlations were conducted and there were significant correlations between the inhibition tasks and standardised delay choice task (Table 3.5).

Notably, a novel finding in our study was that there was a significant correlation between the Knock-Tap task performance and the overall performance in the rotating tray paradigm (r = .249, p =.018, Table 3.5). Additionally, children's performance in the quantity condition in Experiment 1 in the rotating tray task was significantly correlated with performance in the standardised delay choice task - both tasks involving choices relating to reward quantity (r = .239, p =.021, Table 3.5).

Table 3.4. Descriptive statistics and effects of age on inhibition tests and delay choice task.

Task	3-year-olds	4-year-olds	5-year-olds	Age effects
Knock-Tap (range = 2-15)	10.79(3.16)	13.20(1.55)	14.24(0.88)	$\chi 2$ (2, n = 74) = 26.269***
Day-Night (range = 4-16)	10.16(3.01)	12.70(2.58)	12.20(2.65)	$\chi 2$ (2, n = 73) = 9.122**
Grass-Snow (range = 2-15)	9.43(4.18)	13.13(2.13)	13.48(2.20)	$\chi 2$ (2, n = 72) = 14.694***
Delay Choice (range = 1-9)	6.16(2.54)	6.68(2.46)	7.92(1.71)	$\chi 2$ (2, n = 75) = 7.948*

Note. Kruskal-Wallis tests were conducted with standard deviations in parentheses.
*** indicates *p*<.001, ** indicates *p*<.01, * indicates *p*<.05.

Table 3.5. Correlations between inhibition control and delay choice tasks.

	1	2	3	4	5	6
1. Knock-Tap	-	.274*	.378**	.392**	.249*	.113
2. Day- Night		-	.449**	.243*	.038	.078
3. Grass-Snow			-	.336*	.104	.047
4. Delay Choice Task				-	.193	.239*
5. Experiment 1 & 2 Test Total					-	.770**
6. Experiment 1 Quantity Test						-

Note. ***p* < .01. **p* < .05. Spearman's rank order correlations across age groups are presented.

Fisher's Z test of the significance of difference was conducted for the various correlations (for complete results see Table S3.4 & S3.5). Notably, children's overall performance on the rotating tray task was significantly related to Knock-Tap task (r = .249) while not associated with Day-Night task (r = .038), the difference between the two correlations were significant (Z = 1.638, p = .041). However, although children's overall performance on the rotating tray task was significantly related to Knock-Tap task (r = .249) while the association between Grass-Snow and rotating tray was non-significant (r = .104), there was no significant difference between these two correlations (Z = 1.157, p = .124). In addition, children's performance on the Delay Choice task was non-significantly related to children's overall performance on the rotating tray (r = .193) but significantly associated with children's performance in the quantity condition in Experiment 1 (r = .239), yet those two correlations were not significantly different from each other (Z = -0.604, p = .546).

3.5 Discussion

Previously in Chapter 2, Chinese pre-schoolers were administered with a comprehensive test battery measuring various components of future-oriented cognition. Although it is the first systematic investigation of children's future-oriented cognition outside the Western societies, findings from Chapter 2 could not answer questions about the potential cultural contrast between Eastern and Western children. To this end, the rationale of this chapter was to cross culturally compare children's performance on the same paradigm. Delay of gratification was selected because it involves future-oriented decision making and has important real-life implications (Ayduk et al.,2000; Caleza et al., 2016; Mischel et al, 1988; Michaelson & Munakata, 2020). Specifically, the 2 experiments reported in Chapter 3 adopt the 'rotating tray' task which was originally designed to test non-human primates' delay of gratification ability (Bramlett et al., 2012). The paradigm allowed for systematic manipulations of reward type and visibility. To elucidate the cognitive correlates of pre-schoolers' delayed gratification ability, Chinese children were also given several standardised inhibitory control tasks and a delay choice tasks to examine their relationship with the rotating tray task.

Findings of Chapter 3 add to the existing cross-cultural literature on cognitive development, revealing that Chinese children outperformed British peers in the rotating tray delay choice paradigm, though children in both countries performed above chance, when reward visibility was also manipulated. Overall there was age-related performance across all tasks, with a significant age effect in Experiment 1 and a significant interaction effect of age and country in Experiment 2. Pre-schoolers from both countries exhibited higher delayed gratification performance when rewards differed in quality over quantity, whereas occlusion of rewards had no significant effect. Furthermore, there were significant correlations between performance in the rotating tray task with a standardised motor inhibition task (Knock-Tap) and a delay choice task (in Chinese pre-schoolers only as British children were not tested on the standardised developmental tasks).

With the rotating tray paradigm, the significant age effect in Experiment 1 and interaction between age and country in Experiment 2 was consistent with previous findings employing standardised delay choice and delay maintenance paradigms measuring children's delay of gratification, including the marshmallow test (Mischel et al., 1972; Mischel & Ebbesen, 1970; Imuta et al., 2014; Prencipe & Zelazo, 2005; Thompson et al., 1997). An increased ability in older children to delay gratification suggests that they may be more future-oriented and better at projecting themselves to evaluate different outcomes associated with immediate and delayed actions and understanding the connection between their present actions and future outcomes (Boyer, 2008; Bulley et al., 2016; Burns et al., 2021; Lemmon & Moore, 2007). However, even the youngest children tested performed well as reflected in the high rate of above-chance performance in all age groups (Experiment 1 and 2). The short delay (15 seconds) between immediate and delayed rewards may have contributed to this finding by reducing necessary effort to wait. Future studies could increase this delay time to explore the effects on performance across ages. There were two cases where children's performance fell below chance level. First, in Experiment 2 where visual occlusion was manipulated, 3-year-old Chinese children scored below chance level, which may indicate responses based on guesses attributed to task difficulty and cognitive immaturity. Second, in Experiment 2, British 4-year olds' performance was below chance while the 3-year-olds scored above chance level. I detected three outliers in the British 4-year-old group who scored zero in all test trials, in comparison, all 3-year-olds British children scored at least 1 or above. Although removal of these outliers increased British 4-year-olds' performance to above chance level, it did not change the overall findings otherwise (S3 Table).

There was a significant age and country interaction effect in Experiment 2, when the reward visibility was manipulated, though not in Experiment 1, when both rewards were visible. Specifically, Chinese 4- and 5-year-olds outperformed British 4- and 5-year-olds on the rotating tray task, though that children from both countries performed better than chance level. Such findings were in line with previous research on Eastern children's outperformance on self-control (Ellefson et al., 2017; Lan et al., 2011; Sabbagh et al., 2006; Xu et al., 2020). It also supports the early prevalence of cross-cultural differences, as socialization and child-rearing strategies towards behavioural and emotional regulation are present for young children in China (Tarfdif, Wang, & Olson, 2009). At a broader societal level, the cultural differences are likely to reflect consequences of an emphasis on self-control and parental expectations of impulsive control and willpower in China, given the social pressure to compete for higher education resources (Phelps, 2005).

The significant effect of condition across age groups and countries (Experiment 1 and 2) indicates that children made more future-oriented decisions when reward differed in quality over quantity. This finding was in line with our predictions and previous related findings with British pre-schoolers (2020). This effect of reward type could be attributed to reward properties and task format. First, it was unlikely that children selected on the basis of which condition was associated with gaining rewards, as demonstration trials in both conditions removed uncertainty about future reward availability (Bramlett et al., 2012). Second, the possibility of a lack of numerosity discrimination was ruled out, considering the ability to differentiate items of various quantities is present from toddlerhood (Butterworth, 2005; Lipton & Spelke, 2004). Finally, the pre-test preference trials (no delay) ensured all children selected the higher quantity. Without a delay, 3-year-olds always opted for the larger reward even from a small difference like 1 versus 2 stickers (Lemmon & Moore, 2001).

Regarding the quantity condition, the present study adopted that 1:4 ratio of rewards. Previous research demonstrated that 4-year-olds showed a strong preference for the later reward using a 1:5 ratio (Lemmon & Moore, 2007). It is possible that, in our study, children found the quantitative numerical contrast less significant and appealing than the qualitative differences (a glittery animal sticker versus a plain sticker). Notably, the "consequences" of choosing immediate options differed between conditions and it is possible that children considered the plain sticker in the quality condition to be the least favourable, thus were least likely to select it. Additionally, children were able to accumulate rewards through multiple trials. The consecutive gains experienced may downplay their feeling of loss overall, especially in the quantity condition when they received at least one sticker per trial. Therefore, having multiple trials may have left the impression that "e*ven if I choose the smaller reward this round, I still have something nice, and in the next round I can go for the better one*". It is worth highlighting that our findings were consistent with a similar significant effect of reward type found in the related study with British children (Miller et al., 2020a). That said, it is important to highlight that both British and Chinese pre-schoolers exhibited more future-oriented behaviours with rewards differed in quality. The consistent influence of reward type between different cultures suggests the universality of contextual factors in influencing children's ability to delay gratification, at least in the context of a delay choice paradigm.

There was also a main effect of order (Experiment 1) indicating higher performance when they tested on quality-quantity condition than the quantity-quality one. This order effect may be explained in combination with the influence of reward type discussed above. Specifically, children who received the quality condition first may improve performance in later trials. In comparison, the feedback may not be as positive and salient when tested with the quantity condition first, thus it may undermine the subsequent performance in the quality condition. Additionally, with the quantity-quality test order, children received a substantial number of stickers first compared with the quality-quantity order. It is therefore possible that performance suffered more as the attractiveness and novelty of gaining stickers was gradually compromised as the task continued. As a result, motivation (to gain stickers) may decrease, which can influence children's future-oriented decision making (Mahy et al., 2020). There was no significant order effect in Experiment 2, so perhaps children gained sufficient experience through Experiment 1 (experiencing both conditions) so testing order no longer influenced performance.

Findings from the present study suggest no influence of reward visibility on children's delay of gratification performance, which was consistent with Garon et al. (2012) delay choice study, yet contrasts with Mischel and Ebbesen's (1970) delay maintenance study. These discrepancies may be due to fundamental differences in task designs: the maintenance task requires a continuous presentation of a tempting reward whereas the choice task involves a temporal perspective of immediately obtaining a less-valued reward. Therefore, visual occlusion may aid performance in the maintenance task by reducing the exposure to the arousing reward and decreasing the pre-potency of immediate gratifying responses (Metcalfe & Mischel, 1999; Mischel, 2004; Mischel & Ebbesen, 1970; Mischel et al.,1972; Mischel & Ayduk, 2002; Mischel & Mischel, 1987). Additionally, the delay period usually lasted for at least a few minutes (Carlson et al., 2018; Protzko, 2020) whereas in our delay choice study, the delay was only 15 seconds. Furthermore, baiting took place in full view of children so it was likely that they remembered the locations and did not require external visual cues when making choices. Memory tests were conducted to ensuring children could recall the location of rewards - this was further confirmed in Experiment 2 when both rewards were hidden.

In addition to the rotating tray task, a battery of standardised developmental inhibitory control tasks and one delay choice test was administered to Chinese pre-schoolers only. The methodological differences between the rotating tray paradigm and the standardised delay choice task are worth noting (Imuta et al., 2014; Lemmon & Moore, 2007; Prencipe & Zelazo, 2005; Thompson et al.,1997). Specifically, the elements of spatial and temporal distance were confounded in the rotating tray task as children may select the container based on how close in space and time they were, rather than on reward properties. To address this ambiguity, both control and test trials alternating the location of the most preferred rewards were used during testing, thus ensuring performance reflected ability to decide and act on which rewards were worth waiting for.

Consistent with existing literature, there were significant age-related performance and correlations between different tests. As a novel finding in our study, there was a significant correlation between performance on the delay choice task (Prencipe & Zelazo, 2005) and in the quantity condition in Experiment 1 of rotating tray paradigm. Both tests required children to select rewards varying in quantity with no visual barriers, so were most comparable, and the significant results implied convergent validity between these two measures of delayed gratification. Importantly, there was a significant correlation in performance between the Knock-Tap task (Luria, 1966) – a measure of motor inhibition, and the rotating tray task (Experiment 1 & 2). With the latter task, children were required to plan a reaching action to indicate their choices. Thus, in addition to delayed gratification, the rotating tray task also tapped into the ability to control and plan motor movements. The link between self-control and motor domains was not surprising, given their bidirectional interactions highlighted in the dynamic system theory as well as the overlapping brain regions associated with them (Diamond, 2000; Koziol et al., 2014).

The current study did not find evidence of correlations between the rotating tray task and measures of cognitive inhibition, namely Day-Night task and Grass-Snow task. Two indications can be drawn from these findings. First, this test required suppression of pre-potent responses which does not necessarily entail self-control (Beran, 2015). Second, the rotating tray task (Bramlett et al., 2012), which taps into inhibition and self-control, may share overlapping components with other inhibition tasks, for example the Knock-Tap task, while also being distinctive to different measures of cognitive and motor inhibition. This null finding was consistent with previous literature indicating a weak relationship between executive function inhibitory test and delayed gratification measures (Addessi et al., 2014; for a meta-analysis, see Duckworth & Kern, 2011).

It is also important to disentangle the separate cognitive demands implicated in Bramlett et al. (2012) rotating tray paradigm, as each component may have contributed differently to performance. Therefore, I present a finer analysis of the rotating tray task with reference to children's executive function profile as these are theoretically related constructs (Duckworth & Steinberg, 2015; Mischel et al., 2011). Specifically, working memory was significantly employed in Experiment 2 when reward occlusion was involved. To successfully pass the task, children needed to constantly update information of the spatial locations of the different rewards as control and test trials were administered in a counterbalanced order. Pre-schoolers' performance in working memory has been positively correlated with delay of gratification ability (Carlson et al., 2014; Hinson et al., 2003; Yu et al., 2016). Additionally, previous research has indicated that Chinese pre-schoolers demonstrate superior working memory to their European-American peers (Lan et al., 2011; Sabbage et al., 2006; Xu et al., 2020).

Thus, it was possible that our Chinese participants had better working memory than the British sample, which contributed to the 4-year-olds and 5-year-olds' superior performance to their British peers. This proposal may explain why there was no significant main effect of country in either experiment, nor any interaction effect with country in Experiment 1 (no visual occlusion) where the demand of working memory was less salient. On a different note, researchers have demonstrated that children with higher inhibition and working memory performed better in tasks of prospective motor control (Gentsch, Weber, Synofzik, Vosgerau, & Schütz-Bosbach, 2016). As aforementioned, motor demands were implicated in the rotating tray task. It is also possible that Chinese children's advantage in working memory and inhibition enabled them to outperform their British counterparts in a task involving motor movements.

In the rotating tray task, the rewards associated with different spatial locations changed per trial. A multiple-trial design placed substantial demands on children's ability to flexibly switch between options and not to preserve their previous selection. Children from Western societies have demonstrated greater inclination to stick with the same rules than Chinese peers (Ellefson et al., 2017; Sabbagh et al., 2006; Xu et al., 2020). Therefore, it is possible that British pre-schoolers' performance could be undermined by their less-developed cognitive flexibility. Overall, it is likely that the combined influence from these factors that have led to the outperformance of Chinese 4-year-olds and 5-year-olds over their British counterparts. Future work in exploring cross-cultural differences in delayed gratification may include working memory-based tasks with children from both countries and increase the difficulty of the delayed gratification task, such as longer delay lengths. It would also be useful to include measures of parental socialization goals or child-rearing practices (Lamm et al., 2018). This approach could be incorporated in designing training programs of self-control using qualitatively different rewards and introducing similar strategies into day-to-day parenting.

One notable limitation of the present study was that only the Chinese children were tested with the standardised developmental tasks, thus leaving it unable to compare British children's performance on the rotating tray task with the standardised tasks. This was not due to experimental design; the British dataset was collected first for Miller et al. (2020a) study and the Chinese dataset was collected later for the present study. Nonetheless, it would be more comprehensive to have included samples from both countries for all tasks, which could be addressed in future research. Second, the current study only tested children's ability to make prudent decisions from the first-person perspective. Whether Eastern and Western children differ in making future-oriented decision when taking the third-person perspective is open to questions, a topic particularly relevant to cross-cultural research given the distinctions between individualism and collectivism (Garon, Johnson, & Steeves, 2011; Prencipe & Zelazo, 2005; Wu & Keysar, 2007). People from individualistic cultures tend to focus on the self and independence and show stronger egocentric bias whereas people from collectivistic societies emphasis on interdependence and social connections with other-oriented bias (Greenfield, Keller, Fuligni, & Maynard, 2003; Kessler, Cao, O'Shea, & Wang, 2014). Therefore it would be interesting to investigate whether culture influence children's future-oriented cognition for another person. To address this issue, the next chapter tests and compares British and Chinese pre-schoolers' prediction of changes in preferences for themselves and for a peer.

Notwithstanding, the present study contributes to the field both methodologically and developmentally. From a broad cultural perspective, Chapter 3 built on Chapter 2's work of Eastern children's future-oriented cognition by further presenting the first East versus West comparison of pre-schoolers' delay of gratification. There were critical and replicated age-related performance with older children being more successful at forgoing small immediate rewards for larger valued rewards in the future. Additionally, Chinese 4- and 5-year-olds outperformed their British counterparts, when rewards were occluded. Meanwhile, there were correlations between Chinese children's performance in the rotating tray paradigm with some standardised developmental inhibitory control and delay choice tasks. The influence of reward type appears universal across Chinese and British children in that performance increased when they chose rewards differing in quality over quantity, while visual occlusion had no significant effect. Comparing to other components of future-oriented cognition, children's ability to delay gratification, at least measured by the rotating tray task in the current study, entails short and immediate future. Investigating children's decision making in more long-term contexts is equally important for researching the cognitive correlates and cultural contrast of future-oriented cognition. Indeed, this point will be addressed in the next chapter when British and Chinese children were tested for their ability to understand long-term changes in their preferences.

Experiment 1 (Test and control trials combined**)**

In the test and control trials, the full models differed significantly from the null models (X^2 = 149.46, df = 8, *p* <.001). In Experiment 1, the full model was not significantly different to the reduced model i.e. main effects only (X^2 = 2.533, df = 2, *p* = 0.282). Therefore the interaction term (Age: Country) did not significantly improve the model and the final reduced model reported is the best fit (Table S3.1). There was a significant main effect of **condition** (quality vs quantity), **age** (3-5 years) and **trial type** (test vs control) (Table S3.1).

Table S3.1. Generalized linear mixed models for Experiment 1.

Fixed term	Chi-square	df	p-value
Country	0.6445	1	0.4221
Trial type	1.795	1	**<0.0001**
Condition	12.846	1	**<0.001**
Age in years	8.867	2	**0.012**
Order	2.262	1	0.133
Sex	0.169	1	0.681

Generalized linear mixed models (final model) on factors affecting the number of correct test and control trials in children. *N* = Group 1: China 75; Group 2: UK 61. P-values <.05 are highlighted in bold.

Experiment 2 (Test and control trials combined)

In the test and control trials, the full models differed significantly from the null models (X^2 = 206.95, df = 10, p <.001). In Experiment 2, the full model was significantly different to the reduced model i.e. main effects only (X^2 = 151.9, df = 3, p<.001). Therefore the interaction term (Age: Country) significantly improved the model and the final reduced model reported is the best fit (Table S3.2). There was a significant main effect of **condition** (quality vs quantity), and **trial type** (test vs control), with a significant interaction effect of **country: age** (UK vs China: 3 to 5 years) (Table S3.2).

Table S3.2. Generalized linear mixed models for Experiment 2.

Fixed term	Chi-square	df	p-value
Trial type	137.27	1	**<0.001**
Condition	17.613	1	**<0.001**
Order	0.01	1	0.919
Sex	0.069	1	0.705
Visibility	1.907	2	0.386
Country: Age	54.97	5	**<0.001**

Generalized linear mixed models (final model) on factors affecting the number of correct test and control trials in children. N = Group 1: China 75; Group 2: UK 61. P-values<.05 are highlighted in bold.

Table S3.3. Generalized linear mixed models for Experiment 2 without outliers.

Fixed Term	Chi-square	df	p-value
Condition	16.83	1	**<0.001**
Country: Age	39.79	5	**<0.001**
Order	0.098	1	0.755
Sex	0.232	1	0.526
Visibility	3.159	2	0.206

Generalized linear mixed models (final model) on factors affecting the number of correct *test* trials in children for Experiment 2 with the 3 British 4-year-old outliers removed. *N* = Britain 58; China 75. P-values <.05 are highlighted in bold.

Table S3.4. Correlations between children's performance on the Knock-Tap task, Day-Night task, Delay Choice task, rotating tray task performance, and Fisher Z scores (*p* value in bracket) comparing the correlations.

	Knock-Tap	Day-Night	Fisher Z
Delay Choice Task	.392**	.243*	1.160 (.246)
Experiment 1 & 2 Test Total	.249*	.038	1.638* (.041)
Experiment 1 Quantity Test	.113	.078	0.248 (.400)

Note. ** $p < .01$. * $p < .05$. Spearman's rank order correlations across age groups are presented.

Table S3.5. Correlations between children's performance on the Knock-Tap task, Grass-Snow task, Delay Choice task, rotating tray task performance, and Fisher Z scores (*p* value in bracket) comparing the correlations.

	Knock-Tap	Grass-Snow	Fisher Z
Delay Choice Task	.392**	.336*	0.479 (.316)
Experiment 1 & 2 Test Total	.249*	.104	1.157 (.124)
Experiment 1 Quantity Test	.113	.047	0.515 (.303)

Note. ** $p < .01$. * $p < .05$. Spearman's rank order correlations across age groups are presented.

Chapter 4. Inhibition and Cognitive Flexibility are Related to Prediction of One's Own Future Preferences in Young British and Chinese Children[6]

4.1 Abstract

Future-oriented cognition not only involves foresight beyond the very next events but also extends to more long-term contexts. The ability to understand preference changes over time undergoes important changes during the preschool period. However, the relationship between executive function, theory of mind and the ability to predict future preferences of self and others has received little focus, particularly across different cultures. With two distinct cultural groups in Britain (N = 92) and China (N = 90), the current study investigated per-schoolers' understanding of their own versus a peer's current and future preferences. A battery of tasks measuring executive function (inhibition, cognitive flexibility, working memory) and theory of mind was used to examine the underlying relationship between these cognitive abilities and children's ability to predict future preferences. Consistent with previous literature, the current study found significant age-related performance in the future preference task. Furthermore, the findings indicate a universal developmental trajectory of British and Chinese children's future-oriented cognition. Across countries, children were more accurate when predicting for their peers than predicting for themselves. Also, their performance improved when they had the opportunity to identity their current preferences before anticipating the future. Notably, Chinese children outperformed their British counterparts on cognitive inhibition and cognitive flexibility tasks, with no country-related differences in their working memory, motor inhibition or theory of mind ability. After controlling for age, children's performance in the inhibition and cognitive flexibility tasks were significantly correlated with the prediction of their own – though not peer's - future preferences. These findings were discussed in relation to the conflicts between multiple perspectives and the cognitive correlates of future-oriented cognition.

Keywords: future-oriented reasoning, prediction, executive function, theory of mind, cross cultural research

[6] Chapter 4 has been submitted to *Cognition*. Ding N, Miller R, Clayton NS (in revision). Inhibition and cognitive flexibility are related to prediction of one's own future preference in young British and Chinese children.

4.2 Introduction

Thoughts about the future play an importance role in human lives, and anticipation of how the future will unfold can influence behaviours in various ways (D'Argembeau, Renaud, & Van der Linden, 2011). Future-oriented decisions are implicated in a range of situations, some entail future in the short term, such as the spoon paradigm and prospective memory in Chapter 2 and delay of gratification context in Chapter 3, while others tap into the future extended to a longer period, such as understanding of how preferences, values and feelings change over time. Inaccurate predictions of long-term mental states have been associated with impaired decision-making. Among adults, there is a tendency to underestimate the extent of changes that often lead to regrettable choices (Gilbert & Wilson, 2007; Quoidbach, Gilbert & Wilson, 2013). The phenomenon of intensity bias in which emotional reactions to future events are overestimated is present in both adults, children in middle childhood and pre-schoolers (Bamford & Lagattuta, 2020; Gautam, Bullet, von Hippel, & Suddendorf, 2017; Gilbert, Pinel, Wilson, Blumberg, & Wheatley, 1998; Kopp, Atance, & Pearce, 2017). Furthermore, future-oriented decisions are often shadowed by the current states and such "projection bias" (Loewenstein & Angner, 2003) affects the anticipation of not only psychological states but also physiological needs (Cheke & Clayton, 2019). For example, after consuming a salty pretzel, children predicted that they would choose water over pretzel the next day, because they have projected their current feeling of being thirsty into the future even though these states may change and no longer be relevant (Atance & Meltzoff, 2006; Kramer, Goldfard, Tashjian, & Lagattuta, 2017; Mahy, 2016; Mahy, Grass, Wagner, & Kliegel, 2014).

A recent line of research has focused on children's reasoning of changes in preferences, specifically the contrast between current and future preferences (Atance, Rutt, Cassidy, & Mahy, 2021; Bélanger et al., 2014; Kopp, Hamwi, & Atance, 2021; Lee & Atance, 2016). In the original future preference task (Bélanger et al., 2014), pre-schoolers were shown child-preferable and adult-preferable items and asked to choose what they preferred currently (self-now trials) and in the future (self-future trials). The researchers found an age-related developmental trajectory, namely that older children were increasingly better at predicting that they would hold different preferences when they were grown up, whereas 3-year-olds' decisions on future preferences were largely restricted by their current preferences. Additionally, children's ability to understand preference changes occurring within another individual (a same-aged peer) was assessed and the findings indicated similar age-related performance (Bélanger et al, 2014; Lee & Atance, 2016).

Furthermore, there is an "other-over-self" advantage in which pre-schoolers were more accurate at predicting the future preferences of their peers compared to themselves (Bélanger et al, 2014). Such an effect has been found in subsequent studies adopting the same paradigm (Bauckham et al., 2019; Lee & Atance, 2016; Renoult, Kopp, Davidson, Taler, & Atance, 2019), as well as tasks assessing the different component of children's future-oriented cognition. Notably, Russell et al. (2010) designed a "blow football task" which required children to select items for future use and 4-year-olds (but not 3- or 5-year-olds) were better at choosing the correct items when selecting for another child. In a different experiment, children aged between 3 and 7 years had difficulty overcoming their salient state of thirst, which impaired their future predictions but had more success when predicting for another individual, i.e. the experimenter (Mazachowsky, Koktavy, & Mahy, 2019).

Several researchers have argued that the conflicts experienced by children between their current states and future states underlie their difficulty of accurate future-oriented reasoning (Atance et al., 2021; Atance & Meltzoff, 2006; Bélanger et al., 2014). When adopting the alternative perspective of a third person, such as a same-aged peer, a "psychological distance" from one's own perspective was created thus reducing the cognitive resources to coordinate the different perspectives and facilitates children's prediction of future psychological and physiological needs (Lee & Atance, 2016; Mazachowsky et al., 2019). Another way to improve children's anticipation of future states is to satiate their current desires. Pre-schoolers were more likely to select the age-appropriate gift for their mothers as opposed to their own desired object when they were first asked to choose a gift for themselves (Atance, Bélanger, & Meltzoff, 2010). More remarkably, even the anticipation of desire fulfilment elevated children's performance. A similar effect was found with the future preference task: children who were asked to indicate their current preferences before predicting the future preferences outperformed their peers who were first asked to select the items they would like in the future (Bélanger et al., 2014).

A potential route to reduce the conflicts between the different perspectives is to inhibit irrelevant thoughts and perceptions from one perspective to interfere with the reasoning of the other perspective. Several researchers have linked executive function with future-oriented cognition and neuroimaging findings suggest that these two cognitive abilities share overlapping cortical areas such as frontal and prefrontal substrates (Addis et al., 2007; Atance & Jackson, 2009; Buckner & Carroll, 2007; Spreng et al., 2010; Suddendorf & Corballis, 2007). Executive function refers to a set of higher-order cognitive abilities and it is a unitary construct comprising three key components, namely working memory, cognitive flexibility and inhibition (also referred as inhibitory control) (Hughes, 2011; Miyake et al., 2000).

Theoretically, each executive function component has been hypothesized to relate differently to future-oriented cognition. The most intuitive link lies between inhibition and future-oriented cognition as the former depends on the control of attention and behaviours to suppress prepotent responses and select the more appropriate responses for different circumstances (Diamond, 2013). Inhibition is suggested to be highly relevant in future-oriented scenarios when both the current and future perspectives are involved and people need to put aside their current feelings and desires to make adaptive decisions (Hanson et al., 2014). Working memory involves holding and updating information and cognitive flexibility entails the capacity to switch between perspectives and adjust behaviours to changed demands. When thinking of the future, it is important to keep track of multiple perspectives while being able to flexibly shift and coordinate the different demands.

As noted in the general introduction, there have been inconsistent findings concerning the cognitive correlates of future-oriented cognition. Specifically, only a handful of studies have reported positive correlations between children's ability to plan for the future and executive function competency (Ünal and Hohenberger, 2017), while the most comprehensive investigation so far did not find significant correlations between different aspects of future-oriented cognition and children's executive function ability after controlling for age and language (Hanson et al. 2014). The disparity of results has been attributed to the task demands of the different future-oriented tasks. Specifically, past studies adopted tasks that assessed children's ability to plan and remember future events, which does not necessarily entail conflicts between the current and future perspectives (Hanson et al., 2014). Research has shown that executive function was most relevant when cognitive resources were actively employed to switch and coordinate different perspectives especially when one's own perspective was involved (Fizke, Barthel, Peters, & Rakoczy, 2014). For example, scenarios in the future preference task where children were asked to choose the items they like in future as opposed to their current desire of the child-typical items (Bélanger et al., 2014).

Recently, Atance et al. (2021) manipulated the level of conflicts between the current and future perspective in several future-oriented tasks, including the future preference task, and examined the association between future-oriented reasoning and inhibition competency. After controlling for age, there was a significant relationship between children's performance on inhibitory control tasks and their anticipation of future physiological states and need of tools, though not with their prediction of future preferences. However, Atance et al. (2021) only measured one aspect of executive function - children's inhibitory control - neglecting the potential role of cognitive flexibility and working memory in children's future-oriented reasoning.

Given their parallel developmental trajectories and overlapping neural structures, researchers have suggested theory of mind as an important cognitive correlate in young children's development of future-oriented cognition (Atance, 2008; Atance & Jackson, 2009; Atance & O'Neill, 2005; Hanson et al., 2014; Spreng et al., 2009; Suddendorf & Corballis, 2007). Theory of mind refers to the ability to perceive and attribute different internal mental states in oneself and others which entails the understanding of desires, beliefs, emotions, knowledge and intentions (Wellman et al., 2001). Intuitively, the centrality of both cognition involves shift in perspectives; in theory of mind it is the shift between one's own mental states to others' whereas with future-oriented cognition it is the projection from current standpoints to future perspectives. Thus, a better understanding of how mental states differ among people could, in principle, transfer or facilitate the ability to anticipate mental state changes within the same person at different temporal points.

Empirically, several studies have tested the relationship between children's ability to make future-oriented decisions and their theory of mind task performance and yielded mixed findings (Ford et al., 2012; Hanson et al., 2014; Metcalf & Atance, 2011). Notably, children's performance in the widely used "false belief" task was related to their saving behaviours for future resources (Metcalf & Atance, 2011) as well as their capacity to remember and act upon future events (Ford et al., 2012). However, Hanson et al. (2014) failed to find an association between standardised theory of mind tasks and a range of task measuring different aspects of future-oriented thinking. Reasons underlying such mixed findings may be that the extent of perspective shift was different between the tasks. Notably, in the classic theory of mind task, children were asked about another child's mental states which was in direct contrast of their own. For instance, in the false belief content task, the child knows that the objects within an egg box are toy balls while children who have not seen inside the box believed they are eggs. This is different from some future-oriented tasks that do not involve the distinction between the current perspective and future viewpoints, such as requiring children to plan for a zoo visit with sequential steps (McColgan & McCormack, 2008) or imagining themselves in different environments and anticipate physiological needs (Atance & Meltzoff, 2005). Therefore, further investigation is needed to elucidate the relationship between future-oriented cognition and theory of mind ability. Specifically, it is important to match the inter-task demand of perspective shifting between the measures.

A noteworthy characteristic of the research on children's future-oriented cognition is that the data has primarily come from European-American countries, so that our knowledge of its developmental trajectory and cognitive correlates may be culturally skewed and biased (Nielsen et al., 2017; Nielsen & Haun, 2016). Cognitive development is acknowledged as a malleable and context-specific process that is sensitive to social and cultural influences (Hong et al., 2000). There has been growing effort to advocate researchers to examine cognitive development outside Western societies (Henrich et al., 2010; Nielsen et al., 2017; Wang, 2016). To date, one consistent finding is that pre-schoolers from East Asian countries typically outperform their Western peers on measures of executive function, especially on inhibition task (Lan et al., 2011; Lewis, et al., 2009; Moriguchi, Evans, Hiraki, Itakura, & Lee, 2012; Oh & Lewis, 2008; Sabbagh et al., 2006; Schmitt et al., 2019; Thorell, Veleiro, Siu, & Mohammadi, 2013; for a review see Schirmbeck, Rao, & Maehler., 2020). Such a cultural contrast has been interpreted as the reflection of the differences between individualist culture and collectivistic culture as well as the emphasis of self-control in school environment and parenting behaviours in Asian countries (Chen et al., 1998; Eisenberg et al., 2009; Ellefson et al., 2017; Jaramillo et al., 2017; Liu et al., 2008; Xu et al., 2020).

Similarly, researchers have found cross-cultural variations between children's theory of mind performance, yet the findings were more mixed (for a meta-analysis, see Liu, Wellman, Tardif, & Sabbagh, 2008). Early studies have demonstrated that children from the Western societies were better at understanding and attributing different mental states than Eastern children (Sabbagh et al., 2006; Vinden, 1999), while there were also differences within Asian countries, such as Korean and Japan (Oh & Lewis, 2008). In addition to the acquisition of theory of mind ability, often marked by passing the false belief task, researchers have developed a scaling task that consisted of the sequential developmental steps (Wellman & Liu, 2004). A salient and intriguing finding was that the earliest evidence of theory of mind ability in Chinese and Iranian children loaded on their understanding of diverse knowledge, while, for Western children, it loaded on diverse beliefs (Liu et al., 2008; Shahaeian et al, 2011).

To date, only one study has examined and compared future-oriented cognition between different cultures. Redshaw et al. (2019) tested children from three cultural groups: Australia (Brisbane), Indigenous Australians and South African Bushman. Children completed a task that assessed their ability to understand and prepare for alternative future possibilities when an item was dropped into a forked tube with two open ends. Despite some differences in the youngest age groups approaching ceiling performance, overall, there was no specific cultural contrast, which may indicate universal developmental maturation. However, with only one cross-cultural comparison, further research is required as there may be robust cultural variations in other components of future-oriented cognition, or between other cultures.

Chapter 4 aimed to address these literature gaps with the following three aims. The first aim was to adopt the future preference task (Bélanger et al., 2014) to test pre-schoolers' reasoning of preference changes when conflicting perspectives were involved. Specifically, this task involved two baseline conditions focusing on current preferences (self-now, peer-now) and three experimental conditions with two test conditions focusing on future preferences (self-future and peer-future) and one control condition assessing children's general knowledge of adults' preferences (adult-now). The order of testing was counterbalanced so half of the children received the baseline-experimental conditions, while the other half received the experimental-baseline conditions. Unlike previous related studies, the current study used a within-subjects design for conditions, reducing any potential participant variation between groups. Pictures of random adults were used in previous studies (Bélanger et al., 2014) when questions about future preferences were asked. This procedure was simplified in the current study by only including verbal instructions in the future-related trials. Young children have been shown to understand temporal references and concepts, such as "adult" and "when you grow up in future" (Tillman, Marghetis, Barner, & Srinivasan, 2017), and other lines of research on children's future-oriented cognition has predominately adopted verbal instructions (McCormack & Hoerl, 2020). Therefore, it was worthwhile investigating whether changing the instruction format would influence children's reasoning of future preferences.

The second aim was to investigate the link between executive function (working memory, inhibition, cognitive flexibility), theory of mind and children's prediction of preference changes in British and Chinese pre-schoolers. The third aim was to compare British and Chinese pre-schoolers' future-oriented cognition to a) test Chinese pre-schoolers, as they have not been tested with this future preference task previously, and b) compare any developmental trajectory with British counterparts. British children and Chinese children represent a Western and Eastern culture and these two groups have been shown previously to differ in their executive function and theory of mind abilities (Hughes et al., 2018; Xu et al., 2020). It is worth emphasizing that the future preference task was of particular interest and relevance for cross-cultural research. That said, to compare performance on the task between two samples of children who have shown developmental variability on executive function and theory of mind, indeed the two cognitive abilities theorized to underline the development of future-oriented cognition.

Several studies have documented Chinese adults' advantage in perspective taking tasks, showing they have stronger other-oriented bias than European adults (Greenfield et al., 2003). Researchers have attributed such cultural differences to the distinctions between individualistic and collectivistic cultures, as well as to differences between socialization goals in Eastern and Western countries (Fiske, Kitayama, Markus, Nisbett, 1998; Kessler et al., 2014; Vinden, 1999). However, it has not been tested that whether the cultural contrast found in adults would also be evident in young children when tested on a task involving reasoning of future preferences. Considering the emphasis on other-oriented socialization, it is possible that children from collectivistic cultures are better at predicting future preferences changes for another person than children from individualistic societies, a question that can be directly investigated in the current study.

Based on previous literature in the future preference task, pre-schoolers were predicted to perform better when predicting the future preferences for a same-age peer (peer-future condition) over predicting for themselves (self-future condition) (Bélanger et al., 2014; Lee & Atance, 2016). Children who were asked to identify their current desires (baseline conditions) before anticipating their future preferences (test conditions) would have higher performance than those who predicted their future preferences before answering their current ones. With regards to the relationship between children's ability to understand preference changes and their executive function and theory of mind task performance, no specific predictions were made taken consideration of the limited literature with mixed findings. However, British and Chinese children were expected to differ in their executive function performance, specifically with Chinese children outperforming their British counterparts in inhibitory control tasks (Lan et al., 2011; Sabbagh et al, 2006). Finally, it was predicted that the children from both countries would show similar age-related performance and developmental trajectories in their understanding of preference changes within themselves and another individual.

The present study in Chapter 4 contributes to this thesis by testing a different component of future-oriented cognition, specifically the ability to understand preference changes and make adaptive decisions in a long-term future context. Previously, Chapter 2 and 3 have investigated reasoning and behaviours for the very next future events, such as prospective memory and delay of gratification. For research on Chinese children, Chapter 4 further helps to build a more comprehensive cognitive and developmental profile by measuring a different component of future-oriented cognition, which has been not reported in past literature nor in this thesis. Furthermore, the present study would extend existing research scope on the cognitive correlates and potential cultural contrast by testing and comparing two culturally diverse groups.

4.3 Methods

4.3.1 Ethics

There was no national regulation applying to foreign researchers and no relevant approval required to conduct data collection in mainland China. However, all procedures performed in the current study were in accordance with the ethical standards and approved by the University of Cambridge Psychology Research Ethics Committee (PRE. 2017. 108, for letter of ethical approval and complete application form see Appendix A & Appendix B). Headmasters at the participating nurseries were contacted first and I explained the purpose and procedure of the study (for contacting letter see Appendix C). Information sheets and consent forms (Appendix D & Appendix E) were provided to parents and written parental consent was obtained prior to participation of the children. Parents were told that they could withdraw before, during, and after the study without giving a reason. All children were told that they could stop at any time and they could choose not to complete any activities. Their verbal consent to participate was also obtained before each testing session. Participants received stickers and souvenirs at the end of study. Several steps were in place to ensure and protect participant confidentiality, which included using random and anonymised ID numbers and storing data in password-protected files and locked cabinets within the Department of Psychology. The length of testing session was age-appropriate and breaks were included to avoid over-tiring the participants.

4.3.2 Participants

A statistical power analysis was performed for sample size estimation calculated by G* Power and the effects sizes were obtained from previous literature (Atance et al., 2021; Bélanger et al., 2014; Lee & Atance, 2016). Specifically for detecting age-related effects, using parametric or non-parametric tests, a minimum sample of 72 was needed to reach a power of 0.8 with an alpha level at .05 and an effect size of 0.5 (Faul et al., 2007). G* Power suggests that for multiple regression with 5 predictors with an alpha level at .05, a power of 0.8 and an effect size of 0.3, a total sample size of 49 was required. Specifically, for Generalised Linear Mixed Models, the regression-based technique uses every single response from all the participants and each participant completed 25 control and testing trials, ensuring sufficient power for statistical analysis including interaction effects (Kumle et al., 2021; Verma & Verma, 2020). Moreover, sample size in the current study greatly exceeded previous research that adopted the same task of future-oriented cognition (Atance et al., 2021; Bélanger et al., 2014; Lee & Atance, 2016). For correlational analysis, a minimum sample of 67 was required to reach a power of 0.8 with an alpha level at .05 and an effect size of 0.3 (Bonett & Wright, 2000;

Faul et al., 2009). Thus the final sample size of 182 would be more than adequate for the main objective of this study.

The participants were 182 children aged between three and five-years-old. In Britain, we recruited 92 children: 30 3-year-olds (Mean = 3.54 years, Range = 3.03-3.98 years), 32 4-year-olds (M = 4.43 years, R = 4.01-4.95 years) and 30 5-year-olds (M = 5.40 years, R = 5.03-5.90 years), of which 43 were male and 49 were female. All participants were typically developing children. The UK data collection took place from March to July 2019, and the Chinese data collection took place from October to December 2019.

The British participants were recruited at nurseries and schools in Northeast Somerset and central London, which served predominantly white, middle-class backgrounds. All participants were normally developing children. In Northeast Somerset, 97% of people classify themselves as belonging to the white ethnic group and 64.5 % of resident are aged between 16-64 years old (ONS, 2018). 51.9 % of the Northeast Somerset population have NVQ4 or above for their educational attainments. In central London, 71.4% of its residents are aged between 16-64 with 60.2% of population identify as the white ethnic group and 65% of the central London population have NVQ4 or higher for their educational attainment (ONS, 2018). All children participated in the British site were non-Asian background. In China, 90 children took part in the study: 30 3-year-olds (M = 3.56 years, R = 3.05-3.99 years), 30 4-year-olds (M = 4.59 years, R = 4.09-4.99 years), 30 5-year-olds (M = 5.59 years, R = 5.15-5.97 years), of which 46 were male and 44 were female. The Chinese participants were recruited in Kunming, Yunnan Province, a typical regional and new first tier city based on its population, economy and urbanisation (Wu et al., 2015). The total population of Kunming is 8.46 million with 86.16% as the Han Chinese, the most dominant ethnic group in China (2020 Chinese Census). Specifically, 74.53% of the total population are aged between 15-64 years old and 26.97% of people have university or higher degrees. Participants were all normally developing children and they were recruited from a university-affiliated public nursery. Children who admitted to the nursery must have at least of the parents working as university academia or staff (with at least university degrees).

4.3.3 Procedure

The study included a single experimental session of 45 minutes and children were tested individually with a female experimenter in a separate room within the nurseries and schools. In addition to the future preference task (Bélanger et al, 2014), a battery of tasks was administered to measure children’s executive function and theory of mind ability. Specifically, the executive function tasks were tests of inhibition (Day-Night, Gerstadt et al., 1994; Knock-

Tap, Luria 1996), working memory (Spin the Pots, Hughes & Ensor, 2005), and cognitive flexibility (Dimensional Change Card Sort Task, DCCS, Zelazo, 2006). Children's theory of mind ability was measured with tasks of Diverse Desire (Wellman & Liu 2004), Diverse Belief (Wellman & Liu, 2004), Knowledge Access (Pratt & Bryant, 1990), False Belief Content (Flavell et al.,1989) and False Belief Location (Baron-Cohen et al., 1985). The brief task descriptions were outlined in Table 4.1 and the detailed administration protocols were included in Appendix. All participants completed the future preference task first followed by the battery of executive function and theory of mind tasks in a fixed order (Table 4.1).

Future preference task (adapted from Bélanger et al., 2014)

The future preference task assessed pre-schoolers' understanding of changes in their preferences, specifically that their current ones would be different from their own future preferences. This task has also been used to test young children's understanding of preference changes within another individual, i.e. a peer. The task involved presenting children with various parings of items and asked them to choose the item that they liked for themselves or for a peer. The future preference task consisted of baseline conditions and experimental conditions, and children were given specific verbal instructions accordingly. There were 2 baseline conditions involving questions of current preferences. Specifically, in the self-now baseline conditions, the children were asked about their *own* current preferences: "Which one do you like best right now, a picture book or a newspaper?". In the peer-now baseline condition, children were asked about the current preference of a same-aged and same-sex peer - example: "Sally is a little girl and she is 4-year-olds. Which one does she like best right now, an animal puzzle or a crossword?".

The experimental conditions included two test conditions, namely the self-future condition and the peer-future condition, and one control condition of adult-now. In the self-future test condition, children were told: "Right now, you are 3/4/5 years old. But one day, you will grow up and become an adult. You are going to be as big as your mummy and daddy and your teachers. I am going to show you some things and I want you to tell me which one you will like best in the future when you grow up, a picture book or a newspaper?". In the peer-future test condition, the questions were about the future preferences of a same-aged and same-sex peer and the instructions were: "Sally is a little girl. She is 3/4/5 years old right now. But one day Sally will grow up and become an adult. She will be as big as your mummy and daddy and your teachers. I am going to show you some things and I want you to tell me which one Sally will like best in the future when she grows up, an animal puzzle or a crossword?". In addition to these two test conditions of future preferences, we used an adult-now control condition to test children's understanding of what adults generally like. Children were told: "You are 3/4/5 years old and you are a child. Your Mommy, daddy and the teachers are much bigger and older, and they are adults. I am going to show you some things and I want you to tell me which one do adults like, Bing or gardening shows?".

Each condition consisted of 5 trials and children completed all 5 trials in one block. In each trial, the experimenter presented two identical exemplars of a child-preferable item and two identical exemplars of an adult-preferable item. Pairs of items, rather than single items, were used so that children did not perceive the task as involving limited resources. Within-subject

Table 4.1. Brief task descriptions for executive function and theory of mind tasks.

Task	Description
Executive function	
Day-Night (Gerstadt et al., 1994)	Child was instructed to say "Day" when presented with a picture of Moon and to say "Night" when presented with a picture of Sun.
Knock-Tap (Luria, 1966)	Child was asked to perform the opposite hand movement from the experimenter, for example to tap the table with flat palm when the experimenter knock on the table.
Spin the Pots (Hughes & Ensor, 2005)	Child was instructed to find stickers hidden underneath cups of different colours on a lazy Susan tray.
DCCS (Zelazo, 2006)	Child was instructed to sort cards by one rule (colour) and then was asked to sort cards by a different dimension (shape).
Theory of mind	
Diverse Desire (Wellman & Liu, 2004)	Child was asked to choose a drink for a puppet whose preference was stated to be the opposite of their own desire.
Diverse Belief (Wellman & Liu 2004)	Child indicated where a puppet would look for a bunny after being told the puppet hold the opposite belief to themselves.
Knowledge Access (Pratt & Bryant, 1990)	Child saw inside a box which contains a toy dinosaur, and then was asked whether a puppet who had not seen inside the box know what was inside.
False Belief Contents (Flavell et al., 1989)	child saw inside an eggbox which contained unexpected item of bouncing balls and child were asked whether a friend who has not seen inside the box know what the content would be.
False Belief Location (Baron-Cohen et al., 1985)	The classic "Sally-Ann" task which assessed child's understanding of mental states in different people with false belief questions.

design was adopted and each participant completed all conditions. There were manipulations of the order in which children received the baseline conditions (self-now and peer-now) and test conditions (self-future, peer-future, adult-now). Half of the children were first asked about the current preferences then future preferences, and vice versa for the other half of children. Notably, the order in which children were asked about their own preferences or peer's preferences in the baseline conditions was fully counterbalanced, as well as the order of conditions of self-future, peer-future and adult-now in the experimental conditions. Furthermore, the order of item presentation and verbal introduction of the child-typical item and adult-typical item were counterbalanced.

In total, there were 15 pairings of items that created across 3 different categories with 6 pairs in the Drink & Snack category, 5 pairs in the Reading & Watching category, and 4 pairs in the Leisure & Game category. Each paring of items consisted of one typical adult or adult-preferable item and one typical child or child-preferable item. The two items in one pairing were from the same category but were typically preferred or consumed by different age groups, for example, the "Peppa pig" smoothie versus "Starbucks" coffee in the Drink & Snack category. The 15 pairings were then evenly grouped into 3 sets with 5 pairings in each group, ensuring that each group covered all three categories of items. Across the 3 groups of item parings, one group was used for the self-now and self-future condition, one for the peer-now and peer-future condition and one for the adult-now condition. For the self and peer conditions, the same parings of items were used respectively. This was to measure whether children chose child-typical items for their current preferences in the baseline trials, and understand that their future preferences would be different by selecting the corresponding adult-typical items in the test trials. The 3 groups of item parings across conditions were counterbalanced so that the children in the same condition would be presented with different item parings to minimise any potential influence of specific item category or pairings. To accommodate any potential cultural differences in the popularity and familiarity of items, prior to testing, pilot work in the UK and mainland China has been conducted to ensure the selected items were suitable and representative. A full list of item pairings is presented in Table S4.1.

4.3.4 Analytic plan for the future preference, executive function and theory of mind tasks

In the future preference task, there were 5 baseline trials each for the self-now and peer-now conditions. Children's choices on any given self-future and peer-future test trials were only included in the analysis if the child-preferable item was chosen on the corresponding baseline trials. Therefore, this approach excluded the cases in which children may have selected the adult-preferable items in the test trials due to their atypical current preferences rather than adopting the future perspective of self and peer. The majority of children successfully selected the child-typical items for themselves (UK 95.6% children; China 83.4% children) and for peers (UK 88.3% children; China 91.1% children) in the baseline conditions, choosing either 4 or 5 child-preferable items correctly. All experimental sessions were live coded as well as video recorded unless parents requested no recording. A random selection of 20% (N = 36) of videos was coded for inter-rater reliability and Cohen's Kappa test shown excellent inter-observer rating agreement, $\kappa = .902$, $p<.001$.

Notably, two scoring methods were adopted to analyse children's performance in the future preference task. Specifically, the choice per trial for each participant was first recorded as "correct" or "incorrect" and every single trial was used for the Generalized Linear Mixed Models (GLMM). GLMM has been suggested to be statistically robust in analysing binary data with unequal trials for each subject (Ibrahim, Chen, & Lipsitz, 2001; Ng, Carpenter, Goldstein, & Rasbash, 2006), which was particularly suitable for the future preference task as the number of test trials for each child depended on their performance in the baseline conditions. Second, consistent with existing research (Atance et al., 2021; Bélanger et al., 2014; Kopp et al., 2021; Lee & Atance, 2016), children's scores were calculated based on proportional measures by dividing the number of correct test trials in the self-future and peer-future conditions by the number of child-preferable items selected on the corresponding baseline conditions. For the adult-now control condition, the number of correct trials was divided by the number of total trials (out of 5). The proportional scoring method resulted in a single score ranging from 0 to 1 per experimental condition per participant. This approach allowed us to conduct post-hoc comparisons between different experimental conditions and correlational analysis between performance in the future preference task, executive function and theory of mind tasks.

GLMM analysis was conducted (using R version 3.4.3) to assess which factors influenced children's success rate in the future preferences task. Success was a binary variable indicating whether the participant correctly solved the trial (1) or not (0), and was entered as a dependent variable in the models. The random effect included participant ID, fixed effects of age in years (categorical: ages 3-5 in individual years), condition (self-now, peer-now, self-future, peer-future, adult-now), country (China, UK), sex (male, female), order (baseline then test, test then baseline), trial type (baseline, test) and trial number (1-25). Two separate models were run: 1. all trials; 2. test trials. Likelihood ratio tests were used to compare the full model (all predictor variables, random effects, and control variables) firstly with a null model, and then with reduced models to test each of the effects of interest (Forstmeier & Schielzeth, 2011). The null model consisted of random effects, control variables and no predictor variables. The reduced model comprised of all effects present in the full model, except the effect of interest (Bates et al., 2015). I further tested models containing the interactions term (Country: Condition) to investigate whether children from Eastern and Western cultural backgrounds would show contrasted future prediction ability in questions of different perspectives, e.g., first person in the self-future condition vs. third person in the peer-future condition. I did not test other interaction terms because first the variables of interests in the current study were not expected to interact with each other to influence children's task performance, and second and more importantly to avoid the poor practice of p hacking (Head, Holman, Lanfear, Kahn, & Jennions, 2015). Further exact two-tailed post-hoc comparisons were conducted for significant factors with proportional scores using Wilcoxon signed ranks tests with Bonferroni corrections, and compared performance against chance using binomial tests (Kim, 2015; Lee & Lee 2018; Rodger & Roberts, 2013; Sheskin, 2003). The experimental conditions were of key interest in the current study, therefore GLMM results based on children's responses in the experimental conditions were presented here and results that including both the experimental and baseline trials combined were reported in Table S4.2 for completeness.

Raw scores of children's performance on the executive function tasks were normally distributed yet failed the assumptions for parametric analysis, therefore non-parametric Kruskal-Wallis and Mann-Whitney U tests were adopted to investigate the effect of age on children's executive function task performance (Sheskin, 2003). Success in the theory of mind tasks were binary outcomes and Chi-square tests were conducted to examine which factors affected the children's task performance. Composite scores of executive function and theory of mind were created by firstly averaging the raw scores across all the tasks then converting them to standardised Z scores. The composite score of inhibition for the Day-Night task and Knock-Tap task were created with a similar method.

The correlational analysis investigated the relationship between children's performance in the future preference task with children's performance in the executive function and theory of mind tasks. Notably, Pearson product-moment correlations with age being controlled were conducted for tasks measured or recorded in interval. These included the proportional scores of self-future and peer-future conditions and each executive function task as well as the executive function composite score, inhibition composite score and theory of mind composite score. Fisher Z test was conducted to compare correlations using the R package 'cocor' (Diedenhofen & Musch, 2015).

4.4 Results

4.4.1 Children's performance in the future preferences task

In the experimental trials only, the full model differed significantly from the null model (X^2 = 331.41, df = 6, p <0.001). There were significant main effects of **age in years, condition** and **order** on success rate (Table 4.1). There were no significant main effects of country or sex on success rate. Furthermore, the full model (with interaction term Country: Condition) was not significantly different to the reduced model (main effects only; X^2 = 0.7084, df = 2, p =.702). Therefore the interaction term (Country: Condition) did not significantly improve the model and the final model reported is the best fit (Table 4.1). Specifically, performance improved with age (Fig 4.1), and children in order 1 (baseline-experimental) outperformed than those in order 2 group (experimental-baseline) (Fig 4.2). Specifically, across all experimental trials, children's performance improved with age (Mann-Whitney U tests against a Bonferroni-adjusted alpha level of 0.008 (0.05/6): 3 vs 4 years: z = -3.604, p <.001; 3 vs 5 years: z = -6.846, p <.001; 4 vs 5 years: z = -3.982, p <.001). Performance was higher in baseline than in experimental trial types (Wilcoxon signed ranks test: z = -7.905, p <.001). Results using baseline and experimental trials combined dataset were presented in the Table S4.1.

Table 4.1. Generalized linear mixed models on factors affecting success rate (test trials) in future preference task in children (n = 182). P-values <0.05 are highlighted in bold.

Fixed term	**Estimate**	**z-value**	**p-value**
Age in years	1.439	9.081	**<0.001**
Condition	0.993	13.659	**<0.001**
Order	-1.047	-6.958	**<0.001**
Country	-0.016	-0.142	0.887
Sex	-0.110	-0.762	0.446

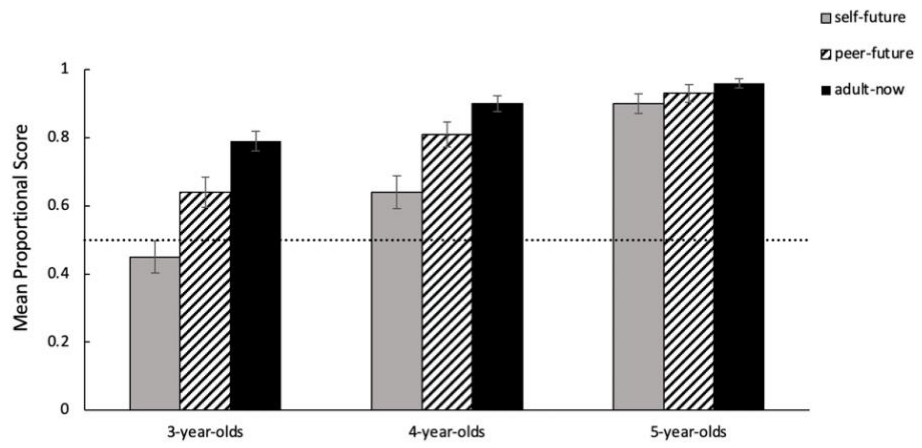

Fig. 4.1: Children's proportional score for each age group by experimental conditions. Error bars represent standard errors of the mean proportional score. Reference line corresponds to chance responding (i.e. mean proportional score of 0.5).

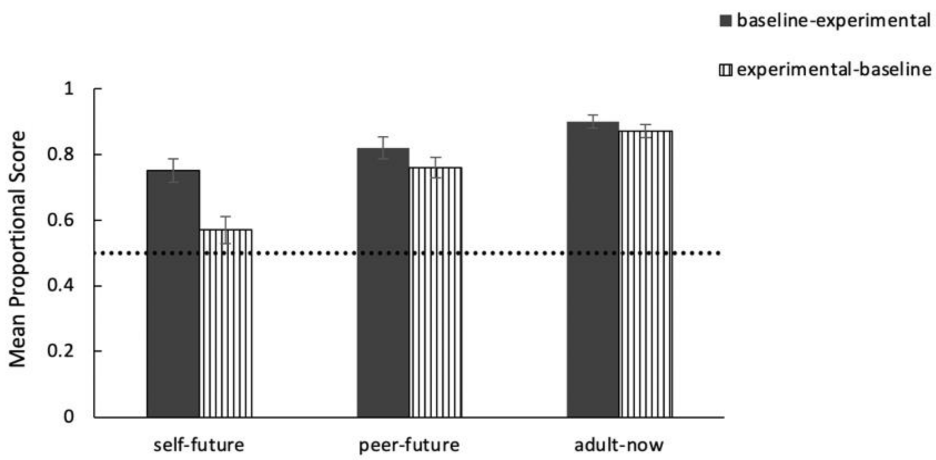

Fig. 4.2; Children's proportional score for testing order 1 (baseline-experimental) and testing order 2 (experimental-baseline) by test conditions. Error bars represent standard errors of the mean proportional score. Reference line corresponds to chance responding (i.e., mean proportional score of 0.5).

Within the experimental conditions, performance was higher in the control condition (adult-now), compared with the self- and peer-future test conditions (Wilcoxon signed rank test against a Bonferroni-adjusted alpha level of 0.025 (0.05/2): self-future vs adult-now: $z = -7.456$, $p < .001$; peer-future vs adult-now: $z = -4.067$, $p < .001$). Within the test conditions, children performed better when asked about future preferences of peers (peer-future) than their own future preferences (self-future) (Wilcoxon signed rank test: $z = -5.885$, $p < .001$). Furthermore, binomial tests were conducted to compare children's performance against chance level (set at

0.5). Notably, all age groups' success rate were above chance level (all p <.001), except for the 3-year-olds in the experimental-baseline order (p = .056).

4.4.2 Children's performance in the executive function and theory of mind tasks

Descriptive statistics of children's performance on the executive function and theory of mind assessments were presented in Table 4.2. Mann Whitney U tests and Chi-square tests indicated that children's performance did not vary as a function of sex, so we collapsed across data for all subsequent analysis (p > .05). Overall, there were significant developmental changes with older children showing increasingly higher performance in all executive function and theory of mind tasks (Table 4.2). Moreover, multiple comparisons have been conducted against the Bonferroni-adjust alpha level of 0.008 (0.05/6). Specifically, across countries, 5-year-olds significantly outperformed 4-year-olds and 3-year-olds respectively on all executive function tasks (all p <.008), as well as in all theory of mind tasks (all p <.001). Notably, there were significant **country** effects that Chinese pre-schoolers outperformed their British peer on the Day-Night task (Mann Whitney U test: z = 2.955, p = .003) and DCCS task (z = 3.242, p = .001). Specifically, Chinese 3-year-olds and 5-year-olds scored higher than their British peers respectively on the Day-Night task with no significant country difference between the 4-year-olds (Mann-Whitney U test: Chinese 3-year-olds vs British 3-year-olds: z = 2.439, p = .015; Chinese 4-year-olds vs British 4-year-olds: z = 1.411, p =.158; Chinese 5-year-olds vs British 5-year-olds: z = 2.855, p =.004).

Additionally, Chinese 4-year-olds and 5-year-olds had better performance on the DCCS task than their British peer while no differences between the youngest age group were detected (Mann-Whitney U test: Chinese 3- year-olds vs British 3-year-olds: z = 0.374, p = .709; Chinese 4- year-olds vs British 4-year-olds, z = 3.524, p <.001; Chinese 5-year-old vs British 5-year-olds: z = 3.353., p<.001). There was no significant difference between Chinese children and British children in terms of their competency in the Knock-Tap task and Spin the Pots task (Knock-Tap: z = 1.236, p =.216; Spin the Pots: z = 1.429, p =.153). With respect to each theory of mind task and the composite theory of mind score, children's performance did not vary as a function of country (all p >.05).

Table 4.2. Descriptive statistics and effects of age on executive function and theory of mind tasks.

Task	3-year-olds	4-year-olds	5-year-olds	Age effects
Executive function				
Day-Night (range = 4-16)	9.32(2.78)	11.61(2.67)	13.82(1.92)	χ2 (2, n = 182) = 57.965***
Knock-Tap (range = 4-15)	10.15(2.66)	12.27(2.17)	13.80(1.46)	χ2 (2, n = 181) = 53.588***
Spin Pots (range = 4-12)	7.02(2.18)	8.76(2.45)	10.32(1.73)	χ2 (2, n = 182) = 49.836***
DCCS (range = 0-6)	3.40(1.28)	4.92(1.46)	5.58(.96)	χ2 (2, n = 182) = 73.037***
Theory of mind				
Diverse Desire (range = 0-1)	.77(.43)	1(0)	1(0)	χ2 (2, n = 182) = 30.84***
Diverse Belief (range = 0-1)	.63(.49)	.77(.42)	1(0)	χ2 (2, n = 182) = 25.89***
Knowledge Access (range = 0-1)	.27(.47)	.73(.45)	1(0)	χ2 (2, n = 182) = 73.02***
False Belief Content (range = 0-1)	0 (0)	.32(.47)	.80(.40)	χ2 (2, n = 182) = 83.09***
False Belief Location (range = 0-1)	.12(.32)	.55(.50)	.87(.34)	χ2 (2, n = 182) = 68.06***

Note. Kruskal-Wallis tests were conducted for executive function tasks and Chi-Square tests for the theory of mind tasks. Standard deviations are in parentheses. *** indicates p <.001.

4.4.3 Relationship between future reference task, executive function and theory of mind tasks

The inter-task correlations within the battery of executive function and theory of mind tasks were examined. All four tasks of executive function (Day-Night, Knock-Tap, Spin the Pots and DCCS) were significantly correlated with each other after controlling for age (Table S4.3). The five measures in the theory of mind task battery (Diverse Desire, Diverse Belief, Knowledge Access, False Belief Content, False Belief Location) were also significantly inter-correlated (Table S4.3). Within the future preference task, after controlling for age, there were significant correlations between children's scores in the different experimental conditions of self-future trials, peer-future trials and adult-now trials (self-future and peer-future, r = .635, p <.001; self-future and adult-now, r = .417, p <.001; peer-future and adult-now, r = .376, p <.001).

Children's scores in the self-future condition and peer-future conditions were used to examine the relationship between children's reasoning of preferences changes and their executive function and theory of mind task performance. Notably, we found significant relationships between children's performance in the **self-future** condition and their executive function competency, after age was controlled. Specifically, with Day-Night (r = .169, p =.023), Knock-Tap (r = .224, p = .002), DCCS (r = .182, p =.014), executive function composite score (r = .199, p =.007) and inhibition composite score (r = .230, p =.002, Table 4.3). In contrast, no executive function tasks were significantly related to children's scores in the **peer-future** condition. Furthermore, there was no significant correlation between children's theory of mind and performance in the self-future condition (r = -.033, p = .662) and peer-future condition of the future preference task (r = -.002, p =.983, Table 4.3).

Table 4.3. Correlations between children's performance on the future preference task separated by test conditions, executive function tasks and theory of mind composite score, and Fisher Z scores (*p* value in bracket) comparing the correlations between self-future and peer-future condition.

	Self-future	Peer-future	Fisher Z
Executive function composite	.199**	.086	1.859* (.032)
Inhibition composite	.230**	.099	2.167* (.015)
Day-Night	.169*	.042	2.081* (.019)
Knock-Tap	.224**	.130	1.555 (.060)
Spin Pots	-.004	.036	-0.648 (.517)
DCCS	.182**	.015	2.745** (.003)
Theory of mind composite	-.033	-.002	-0.502 (.615)

Note. * indicates p <.05. ** indicates p <.01, *** indicates p <.001.

4.5 Discussion

Chapter 4 investigated British and Chinese per-schoolers' future-oriented reasoning, specifically the ability to understand that their future preferences would be different from the current ones for themselves and for another person. Using a within-subject design, the current study adopted the future preference task designed by Bélanger et al. (2014) and, for the first time, tested Chinese pre-schoolers in comparison to British pre-schoolers. The task contrasted with those included in Chapter 2 and 3 which only asked children to make future-oriented decision from the first-person perspective. Furthermore, understanding long-term preference changes is different to the ability of planning for the near and immediate future which Chapter 2 and 3 have measured. By focusing on a different component of future-oriented cognition, the current study extends this thesis's research scope on elucidating its cognitive correlates and examining potential cultural contrast in British and Chinese children.

The current study replicated previous research showing age-related performance in young children's understanding of changes in preferences (Atance et al., 2021; Atance & Lee, 2016; Bélanger et al., 2014; Kopp et al., 2021). Children who were firstly asked about their current preferences outperformed those who answered questions on the future preferences first (i.e. order effect). Across age groups, children's anticipation of the future for a peer was more accurate than their prediction for themselves (condition effect). A battery of standardised tasks of executive function and theory of mind was administered to both Chinese and British children to investigate the cognitive correlates of children's ability to understand preference changes. After controlling for age, pre-schoolers' inhibition and cognitive flexibility was significantly related to the prediction of children's own future preferences, though not correlated with their prediction for another individual. Chinese children outperformed British children in the cognitive inhibition (Day-Night) and cognitive flexibility (DCCS) tasks, but there were no country differences between British and Chinese children in their performance on the future preferences task, or on working memory (Spin Pots), motor inhibition (Knock-Tap) or theory of mind tasks. Hence, the current study adds the growing literature on the development of future-oriented cognition, revealing the universal developmental trajectory among British and Chinese children, as well as highlighting the role of inhibitory control and cognitive flexibility in children's reasoning with conflicting perspectives.

The age effect found in the current study was consistent with previous research using the same task (Atance et al., 2021; Bélanger et al., 2014; Kopp et al., 2021; Lee & Atance, 2016), as well as studies measuring other aspects of future-oriented cognition (Atance et al., 2017; Atance & Meltzolf, 2005; Prencipe & Zelazo, 2005; Russell et al., 2010; Suddendorf et al., 2011). The fact that the current study replicated the findings of 5-year-olds' performance being higher than the younger age groups suggests that the future preference task was an age-sensitive measure that captured the gradual developmental variability during the preschool years. Older children were increasingly more accurate in understanding that preferences would vary as a function of time (i.e. current vs future). The increased ability to predict people's changes of preferences was likely to be the combined results of several underlying cognitive abilities developing around the same time. For instance, understanding that different people have different desires and that the future lies ahead of the current moment may be the prerequisite or parallel cognition to the understanding that preference changes could occur within the same and different individual at different temporal points (Lagattuta, Tashjian, & Kramer, 2018; Repacholi & Gopnik, 1997; Wellman & Woolley, 1990).

By the age of 5, children are capable of attributing different mental states as well as understanding the link and distinction between past, present and future events and emotions (Grant & Suddendorf, 2010; Lagattuta, 2014), which enable them to make more adaptive future-oriented decisions. In comparison, 3-year-olds were unable to accurately anticipate their own future preferences as reflected in their below chance level performance in the experimental-baseline condition group, echoing the original finding in Bélanger et al. (2014). Young children's difficulty with desire reasoning in imagining that another object and activity could be desirable with the extra complexity of imagining preferences for a future perspective may be particularly hard for the 3-year-olds (Cassidy et al., 2005). 3-year-olds' failure in the future preference task was unlikely to be due to their linguistic incompetency. The language comprehension ability of future tense with the auxiliary "will' in English and the temporal adverbs indicating future in Chinese were already present in 3-year-olds (Fraser, Bellugi, & Brwon, 1963; Harner, 1981; Liang, Wu, & Li, 2019).

The effect of condition across age groups and countries in the future preference task suggests that future-oriented cognition differed as a matter of perspective; children's performance in the peer-future trials were higher than those in the self-future trials. This finding was in line with my prediction as well as past studies adopting the same task (Bélanger et al. 2014, Lee & Atance, 2016). Notably, unlike previous research using a between-subjects design, in the current study, the comparison between the different test conditions were conducted within the same individuals, thus reducing any potential participant variations between groups and highlighting the effect of perspective taken when predicting future preferences. Notably, different lines of research have demonstrated that reasoning about one's own perspective was linked with reasoning of other's perspective (Buckner & Carroll, 2007; Hassabis & Maguire, 2007; Spreng et al., 2009). However, at least with pre-schoolers in certain scenarios, children's future-oriented decisions were more accurate when they took the perspective of another person, usually a peer. Russell et al. (2010) revealed that only 4-year-olds, whereas not 3- or 5 years-olds, displayed the other-over-self advantage when they were asked to select tool for future use. Researchers have attributed the asymmetrical results to the 4-year-olds' "growth error" of over applying newly developed visual perspective taking skills (Flavell, Everett, Croft, & Flavell, 1981). Additionally, when asked to predict future physiological states, per-schoolers were more accurate when they took the perspective of a third person, i.e the experimenter, than predicting from their own perspective (Mazachowsky et al., 2019).

One interpretation more closely related to children's prediction of future preferences focused on the notion of "psychological distance'. Researchers have manipulated the level of social familiarity of the person who children predicted for (Lee & Atance, 2016). Setting oneself as an egocentric reference point, psychological distance involves mentally separating oneself from the immediate situation and environment, allowing greater flexibility in thoughts and actions (Trope & Liberman, 2011). Although the influence of psychological distance was less profound in pre-schoolers than in adults (Bauckham et al., 2019; Lee & Atance, 2016), children's future-oriented reasoning was nevertheless more accurate for peers than for themselves. Likewise in the current study, the peer in the questions was described as the same-age and same-sex of the children, without inferring any social closeness with the children. It is possible that anticipating one's own future preferences did not create adequate psychological distance and results in decisions being more prone to the conflicts and interference from the current perspective, in other words, egocentric bias.

Further evidence that children's difficulty in the task could partially arise from conflicting perspectives was supported by the order effect. In the current study, children who received the testing order of baseline-experimental trials, i.e. predicting current then future, outperformed those with the experimental-baseline order, i.e. predicting future then current. The findings were in line with previous literature and my predictions (Bélanger et al., 2014). Notably, similar results have been reported in Atance et al. (2010) in a gift selection scenario where pre-schoolers were more likely to select the age-typical and appropriate gift for their mothers if they were asked first what themselves liked. Intuitively, when presented with choices involving conflicting perspectives, cognitive resources could be freed up by recognising, fulfilling, even the anticipation of desire fulfilment of one perspective (Atance et al., 2010). In turn, this reduces the cognitive demand and facilitates the quality of decision-making for another perspective. Guan and her colleagues reported that prior desire fulfilment did not enhance Chinese pre-schoolers' selection of a gift for another person, e.g., mothers and teachers (Guan, Deák, Huangfu, & Xu, 2020). However, it is critical to consider the difference in task demand between the future preference task and the gift selection paradigm. Specifically, the former required the perspective taking of a different person at a different time whereas the gift selection paradigm taps into Level 2 perspective taking of desires. It is possible that the benefits of acknowledging current desires or perspectives are particularly heightened when children are faced with more complicated decisions, such as in the future preference task when there are interactions between different perspectives (self and other), and different times (current and future). Practically, findings of the current study have educational implications in guiding effective parenting and pedagogical practice, such as to acknowledge children's negative emotions before discussing any misconduct behaviours or inappropriate emotional reactions.

A particularly novel contribution of the current study was presenting the first Eastern and Western comparison in pre-schoolers' understanding of preference changes, while additionally testing its relationship with executive function and theory of mind. Despite cumulative evidence concerning the cultural contrasts of perspective taking ability in adults as well as distinctive socialization goals between Eastern and Western populations (Greenfield et al., 2003; Kessler et al., 2014; Wu & Keysar, 2007), findings of the current study suggest that there was no difference between British and Chinese children's performance on the future preference task, indicating a universal developmental trajectory during the preschool years. Across both countries, children performed better in the peer-future trials than the self-future trials, and when they identified their current desires before predicting future preferences. Taken together, conclusions drawn from the cross-cultural comparison is that the capacity to envision future perspective emerges around the same time in children from different cultures. Additionally, this ability is similarly influenced by the perspective taken for the future-oriented decision as well as the extent of conflicts between multiple perspectives.

Broadly, the lack of cross-cultural variations was consistent with Redshaw et al. (2019). Researchers reported an universal developmental trajectory among children from three cultural groups (Australians living in Brisbane, Australian aboriginals, and South African Bushmen) in their ability to prepare for a future event with mutually exclusive outcomes. With only two existing studies focusing on different aspects of future-oriented cognition, any conclusion on the universality of children's ability to understand and plan for future is undoubtedly presumptuous without further empirical evidence. As Atance & Jackson (2009) noted, future-oriented cognition entails different scenarios and future cross-cultural comparison would benefit by adopting a wide range of tasks, such as the Picture Book task (Atance & Meltzoff, 2005) and Blow Football test (Russell et al., 2010). Furthermore, cultural variations in children's cognitive development may be subtle to detect and sensitive to the type of measure. That said, a potentially fruitful path for future research is to incorporate continuous measures and to examine whether children acquire various future-oriented cognition in different steps and order (Kopp et al., 2021). For instance, the contrast in theory of mind scaling task between Eastern and Western children (Shahaeian et al., 2011; Wellman et al., 2006).

In the current study, there was evidence on the cross-cultural differences in children's executive function ability. Chinese pre-schoolers' performance on the cognitive inhibition and cognitive flexibility tasks were higher than their British peers, a finding consistent with existing literature (Ellefson et al., 2017; Lan et al., 2011; Oh & Lewis 2008; Sabbagh et al., 2006; Schirmbeck et al., 2020; Xu et al., 2020). The cultural differences in young children's inhibition ability are likely to reflect the consequences of socialization goals. For example, parental emphasis on training children to inhibit behaviours and control attention in family and educational settings in Eastern cultures (Chen et al., 1998; Eisenberg et al., 2009; Jaramillo et al., 2017; Liu et al., 2005). However, the Chinese children did not outperform their British counterparts on measures of motor inhibition or working memory, which may be attributed to other aspects of the various tasks. For example, the Knock-Tap task only involved two motor responses elicited by prepotent visual stimuli. Research showing Eastern and Western contrasts on motor inhibition have typically adopted more complicated tasks, such as the Head-Toes-Knees-Shoulders task (Lan et al., 2011). To be noted, the lack of contrast between British and Chinese's working memory was consistent with previous studies (Lan et al., 2011; Sabbagh et al., 2006; Thorell et al., 2013). Anecdotally, there were cases in both countries when children indicated to the experimenter in general conversation that they have played memory retrieval games with similar designs as in the Spin the Pots test. It is therefore possible that the prior experience with task structure could have masked any subtle cross-cultural differences in working memory ability.

There was no evidence of differences between Chinese and British children's theory of mind ability. Contrary to the more consistent findings of Eastern children's advantage on executive function, cross-cultural research on theory of mind have yielded mixed findings (Naito & Koyama, 2006; Oh & Lewis, 2008; Shahaeian et al., 2011; Wellman et al., 2006). That said, our results still echoed those of a large-scale study (Duh et al., 2016) and meta-analysis (Liu et al., 2008). Specifically, children from the mainland China (like the participants in the current study) were parallel to their Western peers in the overall acquisition of theory of mind ability. Notably, the current study revealed no significant correlation between pre-schoolers' future preference task performance and their theory of mind task performance, which was in line with Hanson et al.'s results (2014). One possibility is that these two domains of cognition develop separately during the preschool years. Although they both require perspective-taking, the nature of perspective-taking differs in theory of mind and future-oriented scenarios. The former taps into children's ability to attribute mental states in different people whereas the latter requires children to reason about inter- and intra- differences between people at different temporal points. Thus, their parallel developmental trajectories during the preschool years could reflect a common cognitive maturation rather than two associated abilities. That said, it is possible that the association between theory of mind ability and children's prediction of the future may become clearer later in the development, which is worth future exploration.

Importantly, the current study presents the first evidence to date on the relationship between children's executive function competency and their understanding of preference changes. Unlike previous research using tasks with no conflicting perspectives (Ford et al., 2012; Hanson et al., 2014), the future preference task explicitly contrasted children's current and future perspective. Notably, children's cognitive flexibility (DCCS task) and inhibition control (Day-Night and Knock-Tap tasks) was associated with the prediction of children's own future preferences, even after controlling for age. These findings are critical in light of the argument suggesting that difficulty of future-oriented decisions may be caused by conflicting perspectives. Children's performance partly depended on their ability to switch between contrasting perspectives and to inhibit interference from the current perspective (Atance et al., 2021; Buckner & Carrol, 2007). In the current study, different components of children's inhibitory control were measured, specifically cognitive inhibition (Day-Night task) and motor inhibition (Knock-Tap task). In the future preference task, children indicated their choice of items by naming it or pointing to it and most children used both simultaneously. Therefore, in addition to the involvement of cognitive inhibition, in the test conditions, children needed to control their motor movement to *not* point to the items which they typically like at the current moment, thus requiring motor inhibition.

There was no correlation between executive function task performance and prediction of a peer's future preferences, with several possible explanations. First, executive function has been shown to be strongly related to pre-schoolers' coordination of different perspectives in mental states ascription, particularly when children's own perspective was involved (Fizke et al., 2014). Second, in the current study, unlike Bélanger et al. (2014) no pictures were used for illustration purpose but relied on verbal instructions when the peer was introduced. Therefore, this procedure may have resulted in children not feeling as socially close and familiar with the peer. The greater psychological distance may have contributed to the more accurate predictions in the peer-future condition (Lee & Atance, 2016). It is possible that predicting for an unfamiliar child may not require the same extent of inhibition and cognitive flexibility as for predicting for oneself or a familiar person. Future studies could test this hypothesis by investigating the role of executive function when predicting for a close friend or family member.

The findings concerning the relationship between inhibition tests and future preference task contrasted with Atance et al. (2021) who reported null results among those tasks. This may be due to scoring differences of the inhibition tasks and the standardised approach (Carlson, 2005; Carlson & Moses, 2001). Moreover, Atance et al.'s (2021) based their correlation analysis on one composite score of inhibitory control, though this composite score was created from two tasks measuring different components of executive function, specifically the Sun/Moon Stroop task for inhibition and DCCS task for cognitive flexibility. Given that each executive function component could support future-oriented cognition differently (Buckner & Carroll, 2007), the current study used the executive function composite score as well as children's performance on each executive function task separately for analysis. Additionally, Atance et al. (2021) manipulated the level of conflicts in the future preference task by changing the questions in the test conditions and included control questions to reduce children's bias in answering yes/no type questions. However, these control questions nevertheless targeted on children's semantic knowledge (whether fish have legs) and did not resemble the test questions in the future preference task that involved the understanding of mental states.

There was no relationship between children's performance on the working memory task and the future preference task. This finding could arise from a protocol feature that in the future preference task children were reminded on each trial to make future-oriented decisions, which may have minimised the involvement of working memory. It is possible that the link between being able to mentally store and manipulate information, and to understand and plan for the future is mostly highlighted in scenarios when there is a need to sustain and consider the future perspective over a period of time. For example, in the prospective memory task (Kvavilashvili et al., 2001) and in the future planning task of tool use (Ünal and Hohenberger, 2017).

The cross-cultural comparison of children's performance in the future preference task was of particular theoretical interest to the research on the cognitive correlates of future-oriented cognition. The current study demonstrated that there were significant relationships between children's ability to predict their own future preferences and their performance in the inhibition and cognitive flexibility task. However, the Chinese children's advantage on the executive function skills did not lead them to outperform their British counterparts in the future preference task. This may suggest that inhibition and cognitive flexibility may be one of the several scaffolding abilities that support children's reasoning with conflicting perspectives. Therefore, the possibility remains that children's future-oriented reasoning is related to other cognitive abilities that haven't been tested in the current study, pointing to a potentially promising direction for future research.

Built on Chapter 3's cross-cultural study of delay of gratification, Chapter 4 further extends research scope by presenting the first Eastern versus Western comparison of pre-schoolers' ability to understand preference changes. In accordance with previous studies, there were significant age-related performance within British and Chinese children with no country-related differences, indicating a possible universal developmental trajectory. Additionally, children in different cultures were similarly influenced by the perspectives adopted in the future preference task. Specifically, prediction for peers was more accurate than children's predictions for themselves, and performance was improved when they had the opportunity to identify their current preferences before anticipating the future.

Chapter 4 further contributes to the thesis's overarching aim by showing that children's prediction of their own future preferences (though not of others) was significantly related to their inhibition and cognitive flexibility abilities. Notwithstanding, the future preference task only measured children's ability to understand preference changes in a long-term future context and the findings may not apply to other future-oriented contexts, such as the Spoon paradigm (Tulving, 2005). These tasks differ greatly in their theoretical focus and task demand, therefore may well be reliant on different cognitive correlates. To this end, in the next chapter, I extend the investigation to elucidate the cognitive correlates in a different future-oriented scenario, specifically flexible planning in a tool use context, while additionally addressing existing methodological critiques.

Table S4.1. List of item pairings in the UK and China.

	UK		China	
Category	child-preferable	adult-preferable	child-preferable	adult-preferable
Drink-Snack	Ribena fruit juice	Twining Tea	cartoon theme juice	Chinese green tea
	Percy & Penny biscuit	whole grain flatbread	animal theme cookie	ginger flavour cracker
	carton theme smoothie	Coffee	cartoon theme milk	coffee
	fruit flavour gums	whole nuts	marshmallow	roasted pumpkin seeds
	sweets	Olives	Lollipop	hotstrip gluten food
	Animal theme yoghurts	Wine	Animal theme yoghurts	beer
Reading-Watching	picture book	newspaper	picture book	newspaper
	crayons	fountain pen	crayons	fountain pen
	Peppa Pig	cooking shows	Peppa Pig	cooking shows
	Bing	gardening shows	Paw Patrol	National Treasure
	cartoon	documentary	cartoon	documentary
Leisure-Game	sticker book	travel magazine	sticker book	travel magazine
	animal puzzle	crossword puzzle	character puzzle	Mahjong
	watching cartoon	going to concert	watching cartoon	going to concert
	colouring	poker games	colouring	poker games

Children's performance in the future preferences task (both test and baseline trials)

Across all trials, the full model differed significantly from the null model (X^2 = 428.39, df = 6, *p* = <.001). There were main effects of **age in years, condition, order** and **trial type** on success rate, with no main effects of country, sex or trial number (Table S4.2).

Table S4.2. Generalized linear mixed models.

Fixed term	Estimate	z-value	p-value
Age in years	0.879	8.011	**<0.001**
Condition	0.701	4.874	**<0.001**
Order	-0.426	-3.704	**<0.001**
Trial type	-3.239	-17.634	**<0.001**
Country	-0.155	-1.732	0.083
Sex	0.102	0.917	0.359
Trial number	0.024	0.849	0.396

Generalized linear mixed models on factors affecting success rate (baseline and experimental trials) in future preference task in children (N = 182). P-values <.05 are highlighted in bold.

Table S4.3. Correlations between executive function (EF) and theory of mind (ToM) tasks.

Task	2	3	4	5	6	7	8	9	10	11	12
1. EF Composite	.900***	.782***	.742***	.661***	.554***	.026	.227**	.247**	.491**	.539**	.403**
2. Inhibition Composite	-	.862***	.833***	.326**	.354***	-.007	.198**	.217**	.414**	.446**	.322**
3. Day-Night		-	.438***	.286**	.329***	.031	.194**	.206**	.438***	.401***	.303***
4. Knock-Tap			-	.266**	.268**	-.046	.146**	.168**	.263***	.384***	.267**
5. Spin the Pots				-	.244**	.065	.163**	.185**	.371**	.409**	.319**
6. DCCS					-	.030	.185**	.134**	.458***	.513***	.389***
7. ToM Composite						-	.460**	.598***	.782***	.827***	.848***
8. Diverse Desire							-	.374***	.363***	.223***	.295***
9. Diverse Belief								-	.407***	.298***	.342***
10. Knowledge Access									-	.476***	.563***
11. False Belief Content										-	.665***
12. False Belief Location											-

Note. * indicates p<.05. ** indicates p<.01, *** indicates p<.001

Chapter 5. A Novel Test of Flexible Planning in Relation to Executive Function and Language in Young Children[7]

5.1 Abstract

Decisions involving the choice and use of tools for future events are considered to be an important component and behavioural hallmark of future-oriented cognition. Previous studies suggest some non-human species are capable of flexible future planning, however, these experiments often cannot fully exclude alternative learning explanations. Here, a novel tool-use paradigm modified from animal research was used while addressing these critiques to test flexible planning in pre-schoolers (aged between 3 and 5 years, $N = 87$). In the flexible planning task, children were not verbally cued during testing and the format of single trials avoided consistent exposure to stimulus-reward relationships. Furthermore, training trials provided experience of a predictable return of reward. Notably, unlike most standard developmental studies, short delays before and after tool choice were incorporated. The critical test choice included two tools with equal prior reward experience - each only functional in one apparatus. Additionally, several standardised tasks of executive function and language ability were administered to investigate the cognitive correlates in relation to children's ability to select tools to solve anticipated future problems. The results echoed standard developmental research that 4 and 5-year-olds outperformed 3-year-olds on the flexible planning task, and 5-year-old children outperformed younger children in most executive function and language tasks. Children's performance on the flexible future planning task was unrelated to their executive function and language competency. This paradigm taps into pre-schoolers' future-oriented cognition and could be potentially used to investigate flexible planning in a tool-use context in non-human animals and cross-species research.

Keywords: flexible planning, future-oriented cognition, executive function, language, comparative cognition

[7] Chapter 5 has been published. Miller, R., Frohnwieser, A., Ding, N., Troisi, C. A., Schiestl, M., Gruber, R., & Clayton, N. S. (2020). A novel test of flexible planning in relation to executive function and language in young children. *Royal Society Open Science*, *7*(4), 192015.

5.2 Introduction

Future-oriented cognition occupies a prominent position in our mental lives and it comprises various aspects of reasoning and behaviours (Baumeister, Vohs, & Ottingen, 2016; Hudson et al., 2011). From a developmental perspective, a substantial body of literature has highlighted preschool years as a critical period of children's ability to understand and plan for the future (Atance, 2015). Indeed, findings from the preceding chapters further suggest that the developmental trajectory of Chinese children resembles their Western peers, suggesting a unified picture of children's development of future-oriented cognition across different cultures. Notably, the previous chapters have adopted tasks which were specifically developed to assess young children's future-oriented cognition (developmental tasks in Chapter 2 and 4) and tasks originally designed to measure future-oriented self-control in animals (rotating tray task in Chapter 3). Developed with different theoretical focus, these tasks vary greatly in cognitive demand and structure and there has been ongoing debates about their strengths and limitations (Hudson et al., 2011; McCormack & Hoerl, 2021). So far, this thesis has focused on the developmental patters of future-oriented cognition while the issue of methodological challenges has not been directly addressed. In the last empirical chapter in this thesis, the aim was to modify a paradigm from animal research while taking existing methodological critiques into consideration and additionally to examine the cognitive correlates of children's future planning ability in a tool-use context.

Despite substantial research effort, there is still no consensus on the "gold standard" task to measure future-oriented cognition in young children. Tulving (2005) proposed the influential spoon paradigm which has become the most representative and well-known task in developmental and comparative psychology (Clayton, 2015). The spoon paradigm was inspired from an Estonian tale: a young girl had a dream of not being able to enjoy her desert, her favourite chocolate pudding, because she had not brought a spoon with her, and no spoons were available at the party, so the next night she took a spoon to bed and cached it under her pillow in order to avoid the anticipated frustration at another such party. The spoon paradigm measures episodic future thinking and centres on the ability to recall past experience, envision the future and select items or tools to satisfy a future need or state. In a typical spoon test context, the critical features include children taking actions at the present in anticipation of a novel future scenario. What is also important is that the spoon, or any items needed in the future, should be obtained in another place and at another time in a separate event and not just a continuation of the current experience.

Inspired by the spoon paradigm, subsequent studies have shown that 4- and 5-year-olds were able to link past events from 15 minutes ago to deferred future problems and to select correct tool in the present to solve anticipated problems (Redshaw & Suddendorf., 2013; Suddendorf et al., 2011). In contrast, 3-year-olds could only choose the appropriate tool to address needs that were of immediate concern, indicating that the delay between past event and future-directed action influenced children's performance. Research has consistently reported that children's performance was influenced by their memory capacity (Atance & Sommerville, 2014; Payne et al., 2015). Nevertheless, emerging evidence suggest that failure to select for a future solution and to link past and future episodes, not memory or delay length *per se*, underlie younger children's underperformance in the spoon task (Caza & Atance, 2019; Prabhakar & Ghetti, 2020). There is general agreement that 4 years of age is the critical age for passing the spoon task; children younger than 4 appear to have difficulties in foreseeing future events and choosing correct items to address their future need (Atance, 2015; Atance & Meltcalf, 2013; Russell et al., 2010).

The development of non-linguistic behavioural based paradigms has significantly fuelled the field of future-oriented cognition research over the past two decades. Specifically, minimising the linguistic component has allowed researchers to investigate future-oriented behaviours in children with limited language ability and to extend the paradigms to test non-human animals (Clayton, 2015). Specifically, the ability of using past information to prepare current actions for a future problem is present both in young children and animals (Boeckle et al., 2020; Raby et al., 2007; Suddendord et al., 2011). For example, corvids (members of the crow family) have shown impressive flexible planning skills in caching tasks, such as learning what to cache and what not to cache based on the foods available at the time of cache recovery (Cheke & Clayton, 2011; Clayton, Dally, & Emery, 2007; Clayton, Dally, Gilbert, & Dickinson, 2005; Clayton & Dickinson, 1999; Correia et al., 2007). Studies on corvids and other species have also indicated flexible planning behaviours beyond natural behavioural predispositions, i.e. outside of the caching context (Dufour, Wascher, Braun, Miller, & Bugnyar, 2012; Mulcahy & Call, 2006; Osvath & Osvath, 2008). Recently, ravens were shown to be able to plan for future tool-use and barter with delays up to 17 hours (Kabadayi & Osvath, 2017).

However, some of the non-human studies face several critiques relating to possible learning explanations (Redshaw, Taylor, & Suddendorf, 2017). Namely, the use of multiple trials could reinforce the repeated exposure to the same stimulus-reward relationship. Additionally, by pairing a non-functional tool with a non-reward situation, participants might choose the correct tool based on its desirability and prior reward history, rather than flexibly thinking about the future (Redshaw et al., 2017). Importantly, influential experimental criteria have been proposed to guide the design of behavioural tests (Suddendorf et al., 2011; Tulving, 2005). Notably, researchers recommended the use of single trial and novel problems, and to separate the temporal and spatial contexts between the present future-oriented decision and the anticipated future problem. Note that for Kabadayi & Osvath's (2017) study, the same task was used during training and testing, rather than a novel problem that precludes learning. Furthermore, the ravens were not given any prior reason to expect to use the selected items in a future event.

In the spoon tests with children, positively associated object may be chosen in the absence of possible future events. For example, after seeing the empty puzzle board, children's selection of puzzle pieces could be attributed to the associations between the two objects without experiencing any anticipated boredom (Atance & Meltzoff, 2005; Boeckle et al., 2020). Therefore, in these tasks, 4-year-olds may use a simpler mechanism to solve the task without necessarily possessing flexible planning ability. Importantly, Dickinson and colleagues (2018) designed a test to control for the association between a choice and its salience in a future planning task. Specifically, children were presented with a choice between two high-value objects after encountering a specific room and only one object could be used to solve the observed problem. Researchers reported than only children aged between 5 and 7 years old passed the test while 4-year-olds failed.

As Redshaw and Suddendorf (2013) noted, planning for an immediate problem is less difficult than for a deferred future problem as the latter requires more executive resources. Executive function is an umbrella term that refers to a set of higher-order cognitive abilities which regulate goal-directed actions and adaptive responses in novel and complex situations (Hughes, 2011). Considered as a unitary construct, it comprises three core components; inhibition, working memory and cognitive flexibility (Hughes, 2011; Miyake et a., 2000). Several theoretical accounts, along with neuroimaging studies, have linked future-oriented cognition with executive function (Addis et al., 2007; Buckner & Carroll, 2007; Suddendorf & Corballis, 2007). Existing literature reviewed in the general introduction, along with previous chapters in this thesis, suggest that inhibition and cognitive flexibility may be the most relevant cognitive correlates of future-oriented cognition, as flexibly planning for the future requires focusing on the simulated future events whilst suppressing ongoing events in the present (Atance & Jackson, 2009; Atance & Metcalf, 2013).

Although there has been increasing attention to elucidate the cognitive correlates of future-oriented cognition in young children, most of the research adopted tasks measuring future prediction, delay of gratification, and prospective memory with considerably less study using spoon paradigm (Atance et al., 2021; Ford et al., 2012; Hanson et al., 2014). Notably, Atance and colleagues (2021) reported that inhibitory control was related to task performance in a typical spoon test. In a different study, Ünal & Hohenberger (2017) found that the after controlling for age pre-schoolers' ability to select item to address a future need from a different spatial perspective was associated with spatial working memory and temporal language ability. However, children's language ability has been predominantly used as a control variable in previous research (Hanson et al., 2014; Atance et al., 2021). As noted in the general discussion, language itself has been suggested to not only scaffold the development of future-oriented cognition but also the "broadcaster, communicator, and manifestation" of future-oriented thinking and behaviour (Atance & Metcalf, 2013; Suddendorf et al., 2009; Suddendorf & Corballis, 2007). Specifically, children acquire the understanding of temporality thorough the learning of temporal and deictic time words, and narratives of past events provide building blocks for constructions of future events (Busby & Suddendorf, 2005; Grant & Suddendorf, 2010; Hudson, 2006; Nielson & Fivush, 2004; Tillman et al., 2017). Moreover, recent evidence suggests that children's elaborative style (asking questions to request and provide information) during parent-child dyadic talk predicted 4-year-olds' performance in the Picture Book task (Atance & Meltzoff, 2005; Shin, Leech, & Rowe, 2020). Also, engaging in future-oriented talk improved pre-schoolers' prospective memory and the ability to anticipate and address future needs (Chernyak et al., 2017).

Therefore, the aim of our study was to design a novel experimental paradigm that addresses some of the critiques related to human and non-human studies to test flexible planning in young children, while additionally examining the relationship between executive function competency, language ability and children's future planning in a tool-use context. As noted by Nielsen and Huan (2016), approaches that draw together developmental and comparative research is particularly scant while being significantly valuable to understanding the ontogeny and evolution of cognitive development. Therefore, it was important that our novel methodology could potentially be used comparatively to test non-human species and meanwhile addressing the critiques mentioned above. Differences in testing methodologies, such as the number and length of delays can make it difficult to make comparisons between human and non-human studies (Scarf et al., 2014). Therefore, the apparatus and trials were designed in such a way to ensure that they could be used with humans as well as animals, such as tool-using corvids.

Importantly, the current study provided training trials with delays to provide experience of a predictable return of reward situation. Furthermore, two delays were incorporated to be comparable with most non-human animal research – one delay following apparatus presentation, before the critical tool choice, and one delay after the tool choice before tool-use. This was different to most previous child studies that incorporated delays (e.g. 5 minutes to 24 hours) only between the problem and selection, though no delay between selection and use (Atance et al., 2015; Atance & Sommerville, 2014; Redshaw & Suddendorf, 2013; Suddendorf et al., 2011). The current study tested whether 3-to-5-year-old children could use information from past events to guide their present choice to address anticipated future problems. In the testing trials, children were asked to choose between two tools for which they had equal prior positive stimulus-reward experience, only one of which was functional in a particular condition.

While there is already extensively established future-oriented cognition developmental research using other tests, very few paradigms have been modified from animal and comparative research (Atance et al., 2015; Clayton, 2015). Chapter 3 reported two experiments using the rotating tray task which was originally designed to test primates' self-control ability and children show standard developmental patterns with the task. Similarly, the current study took inspiration from animal research and sought to modify a paradigm while addressing some existing methodological critiques. To validate the novel paradigm, the task was administered to a specific age group, namely British pre-schoolers aged between 3 and 5 years, with which that other tasks have reported typical and consistent age-related performance and developmental trajectories of future-oriented cognition. Furthermore, Chapter 5 aimed to further elucidate the cognitive correlates of future-oriented cognition by investigating the relationship between children' future planning ability in tool-use context, executive function ability and language competency. There are substantial differences in task structure and cognitive demand between the novel paradigm in the current study and tasks adopted in the preceding chapters. Therefore, Chapter 5 would further enrich our understanding of the cognitive correlates implicated in different future-oriented contexts.

Notably, five age-sensitive and appropriate executive function tests were selected, each tapping into the distinctive components of inhibitory control, cognitive flexibility and working memory as well as one language ability task. With the novel flexible planning task, prediction was that there would be significant age difference between 3-year-olds and older children, in line with previous developmental research using established spoon tests (Atance et al., 2015; Scarf et al., 2014). With regards to the relationship between children's performance on the flexible future planning task and their executive function competency and language ability, against the backgrounds of limited and inconsistent findings, no specific predictions were made.

5.3 Methods

5.3.1 Ethics

All procedures performed in the present study were in accordance with the ethical standards of and were approved by the University of Cambridge Psychology Research Ethics Committee (PRE. 2013.109, for an example of ethics application, see Appendix A & Appendix B). Headmasters at the participating nurseries were contacted first and I explained the purpose and procedure of the study (for an example see Appendix C). Information sheets and consent forms were provided to parents and written parental consent was obtained prior to participation of the children (for examples see Appendix D & Appendix E). Parents were told that they could withdraw before, during, and after the study without giving a reason. All children were told that they could stop at any point and they could choose not to complete any activities. Written consent was also obtained from parents to video-record the experimental sessions (for an example see Appendix E). To protect participant confidentiality, I used random and anonymised ID numbers and securely stored data and videos in password-protected files and locked cabinets within the Department of Psychology. The length of testing session (each session no longer than 40 minutes) was age-appropriate and breaks were included to avoid over-tiring the children.

5.3.2 Participants

A statistical power analysis was performed for sample size estimation in G* Power and the effects sizes were obtained from previous literature (Atance & Sommerville, 2014; Payne et al., 2015; Redsnaw & Suddendorf, 2013; Suddendorf et a., 2011). Specifically for detecting age-related effects on the novel tool-use task and executive function tests, using parametric or non-parametric tests, a minimum sample of 72 was needed to reach a power of 0.8 with an alpha level at .05 and an effect size of 0.5 (Faul et al., 2007). G* Power suggests that for multiple regression with 5 predictors with an alpha level at .05, a power of 0.8 and an effect size of 0.3, a total sample size of 49 was required. Specifically, for Generalised Linear Mixed Models, the regression-based technique uses every single response from all the participants and each participant completed 2 training and 2 testing conditions, ensuring sufficient power for statistical analysis (Kumle et al., 2021; Verma & Verma, 2020). For correlational analysis, a minimum sample of 67 was required to reach a power of 0.8 with an alpha level at .05 and an effect size of 0.3 (Bonett & Wright, 2000; Faul et al., 2009). Therefore, the final sample size of 87 would be sufficient for the main objective of this study.

Participants were 87 children aged between three and five years old: 30 3-year-olds (Mean = 3.82 years; Range = 3.3-3.99 years), 28 4-year-olds (M = 4.53 years; R = 4.03-4.99 years) and 29 5-year-olds (M = 5.49 years; R = 5.1-5.88 years), of which 44 were male and 43 were female. All participants were normally developing children. Children were recruited and tested at five nurseries and primary schools in East Cambridgeshire, serving predominantly white, middle-class communities between February and March 2018. Specifically, 60.6% of the population in East Cambridgeshire are aged between 16-64 years old and 39.5 % of its population's educational attainment are NVQ4 or above (ONS, 2018). In terms of ethnicity, 66.1% of the Cambridge residents identifying themselves as the white ethnic group. All participants were normally developing children. Notably, all children in this sample had previously been tested in a second study using a tool-use task with no flexible planning element (Miller et al., 2020b). Children were tested in temporary visual isolation from other people, or, for some of the younger children, with a staff member present who did not interact with the child.

5.3.3 Apparatus

Three different apparatuses were used in the flexible planning task - each apparatus had one type of functional tool, with the tools selected to be familiar to the participants (Fig. 5.1). The horizontal tube apparatus (Fig. 5.1a) comprised of a transparent tube with two open ends. The reward rested in the centre of the tube and could be retrieved by inserting a pencil to rake or push the reward through either opening. The drop-down apparatus (Fig. 5.1b) comprised of a transparent box with a collapsible platform and an open vertical tube. Dropping a stone of sufficient weight into the vertical tube caused the platform to collapse and release the reward. The feeder apparatus (Fig. 5.1c) was remotely controlled by the experimenter, and dropping a paperclip into a designated tube would release the reward. Stickers were used for the most preferred (picture sticker) and least preferred (white sticker) rewards, with a medium quality sticker (yellow smiley sticker) for some parts of the pre-experience steps. Trials were timed with a stop-watch, and there were two separate locations (A & B), which were either two adjacent rooms or two areas separated by visual barriers, depending on the space available at each school.

5.3.4 Procedure

Participants were tested in two sessions: in session 1, participants received several pre-experience steps; in session 2, participants received training and test trials. Session 1 lasted 8 to 10 minutes and was run in the same order for all participants. Session 2 lasted approximately 30 minutes and condition order was counterbalanced across participants. 80 of the 87 participants received the training and test session on the same day with a minimum interval of 1 hour. Due to school arrangement and availability of participants, 7 children received the test session one or two days after the training session.

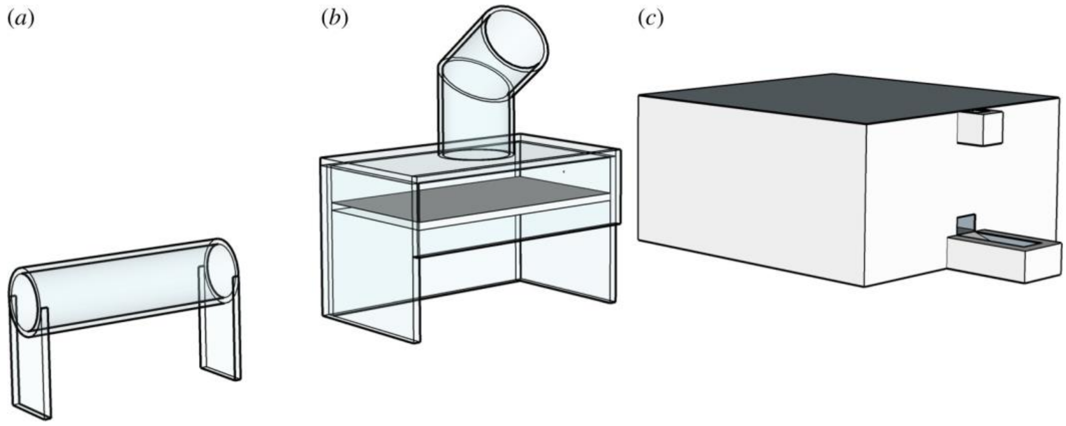

Figure 5.1: a) Horizontal tube with stick tool, b) drop-down with stone tool, c) remote-controlled feeder apparatus with paperclip tool (Miller et al., 2020c).

Flexible future planning task

Session 1 (pre-experience phase)

Step 1, tool transport: participants were asked to select a tool in location A and then use it immediately on an apparatus in location B. They were not required to make a choice as only the functional tool was presented, and they received one trial per apparatus. The apparatuses were baited with the medium quality reward.

Step 2, reward preference test: participants were asked to select the 'best' sticker from a choice between the most and least preferred options. The stickers were presented in front of the participants and the position (right/left) of the stickers was counterbalanced across trials. The reward preference task was conducted twice, with one trial during the pre-experience phase in session 1 and one trial at the end of testing in session 2. All children preferred the picture stickers over the white stickers.

Step 3, delay of gratification: the drop-down apparatus was baited with the most preferred reward and participants were presented with a choice between the least preferred reward and the functional tool (stone). Participants were required to select the tool to access the most preferred reward over the immediately available least preferred reward in two consecutive trials. If they failed to select the tool in these two trials they received two additional trials before proceeding to the next step.

Step 4, tool functionality: the medium reward was placed inside one of the three apparatuses and participants were asked to select the functional tool from a choice of two tools (one functional, one non-functional). Participants received two trials per apparatus, with three additional trials run if they failed, i.e. selected the incorrect tool in any of the previous trials, starting with the apparatus that they failed on. The presentation order of apparatuses and the location of tools was counterbalanced across participants and trials.

Session 2 (training and test trials)

Participants received two training conditions and two test conditions, with one trial per condition (Table 5.1). The training conditions provided participants with experience of a predictable return of reward situation in a future event (see Fig 5.2 for an illustration of the training and test procedure). The test trials investigated whether participants could select the correct tool to solve an anticipated future problem. In each condition, participants were first shown the baited apparatus in location A (Fig. 5.2, steps b1, c1, d1 and e1). Participants then waited in location B for a set delay time, after which they could select one of two items (training trials: tool or reward, test trials: choice between a functional and a non-functional tool) to use later (Fig. 5.2, steps b2, c2, d2 and e2). After a second delay, they returned to location A and could use this item to try to access the reward from the apparatus (Fig. 5.2, steps b3, c3, d3 and e3). In the training conditions, the reward inside the apparatus was either high quality or low quality, and the children made a choice between the corresponding reward and the functional tool (Fig. 5.2, conditions B and C). In the training conditions, though not in the test conditions, a short verbal cue was provided prior to the item choice to inform children that they would be returning to location A later.

In the test conditions, the most preferred reward was inside the horizontal tube or remote-controlled feeder apparatus (Fig. 5.2, conditions D and E). Participants had no prior experience of a delay between tool choice and use for these two test apparatuses, though were otherwise

Table 5.1. Training and test conditions for flexible planning task.

Condition	1	2	3	4
Trial type	Training	Training	Test	Test
Apparatus	Drop-down	Drop-down	Horizontal tube	Feeder
Reward type inside apparatus	MP	LP	MP	LP
Items presented	Stone vs. LP	Stone vs. MP	Pencil vs. paperclip	Pencil vs. paperclip
Correct choice	Stone	MP	Pencil	Paperclip

Note. MP = most preferred, LP = least preferred.

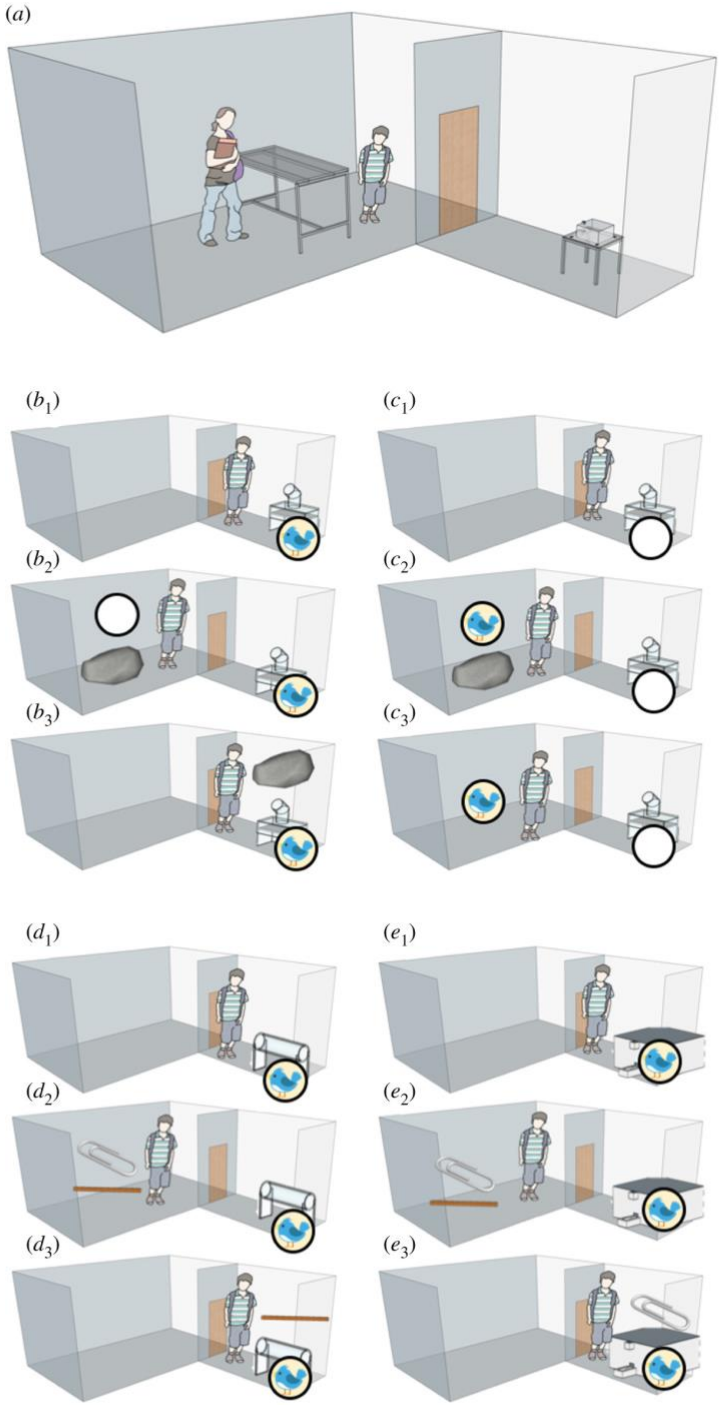

Figure 5.2: Procedure of training and test trials for flexible planning task. A: General set-up: Experimenter and participant in room 1, apparatus out-of-sight in room 2. Step 1: In room 2, participant has visual access for 10 seconds to apparatus containing reward (training: B – most preferred reward in drop-down apparatus, C – least preferred in drop-down apparatus; testing: D – most preferred in horizontal tube apparatus, E – most preferred in feeder apparatus). Step 2: After a delay, participant makes choice of tool or tool/sticker in room 1 (training: B – choice = stone vs least preferred reward, C – stone vs most preferred reward; testing: D and E – stick vs paperclip. Step 3: After a delay, participant has access to baited apparatus in room 2 – can bring their chosen item to use with apparatus (tool/ sticker) (Miller et al., 2020c).

equally familiar with these apparatuses and their respective tools from session 1 pre-experience (Fig.5.2). They therefore had comparable experience of obtaining a reward using each tool with each apparatus. In the test conditions, the same two tools were presented in each trial (pencil and paperclip); therefore, one tool was correct in one condition and the other tool was correct in the other condition. In all conditions, two delays of different length were incorporated between steps 1-2 and steps 2-3 (2 and 5 minutes; Fig.5.2). Participants were split into two subgroups with half of the participants per age in each one: subgroup A received a 2 then 5-minute delay; subgroup B received a 5 then 2-minute delay, with the delay order consistent across conditions within participant. The order of conditions within training and testing conditions was counterbalanced across participants.

Executive function and language tasks

A battery of tasks was administered to measure the different components of children's executive function ability. Specifically, Day-Night task (Gerstadt et al., 1994) measured cognitive inhibition and Knock-Tap task (Luria, 1966) tested motor inhibition. Children's working memory was assessed using the Forward Digit Span (FDS, Davis & Pratt, 1996) and Backward Digit Span (BDS, Davis & Pratt, 1996) and cognitive flexibility was tested with Dimensional Change Card Sort task (DCCS, Zelazo, 2006). Children's general language ability was measured using the British Picture Vocabulary Scale (BPVS-3, Dunn & Dunn, 2009). Brief task descriptions are summarized in Table 5.2 and detailed administration protocols are included in Appendix F. These tasks were run within the delays in the flexible planning task, in a set order within subgroup A and B.

Table 5.2. Task descriptions for executive function and language ability

Task		Description
Inhibition	Knock-Tap (Luria, 1966)	Child was asked to perform the opposite hand movement from the experimenter, for example to tap the table with flat palm when the experimenter knock on the table.
	Day-Night (Gerstadt et al., 1994)	Child was instructed to say "Day" when presented with a picture of Moon and to say "Night" when presented with a picture of Sun.
Working memory	Forward Digit Span (Davis & Pratt, 1996)	Participants were asked to repeat a series of single digits *in order* after they were read out by the experimenter.

	Backward Digit Span (Davis & Pratt, 1996)	Participants were asked to repeat a series of single digits *in reverse order* after they were read out by the experimenter.
Cognitive flexibility	Dimensional Change Card Sort (DCCS) (Zelazo, 2006)	Child was instructed to sort cards by one rule (colour) and then was asked to sort cards by a different dimension (shape).
Receptive language	British Picture Vocabulary Scale – 3rd edition (Dunn & Dunn, 2009)	Child was asked to identify pictures corresponding to spoken words from the experimenter. Each child received a number of vocabulary sets depending on their language ability.

5.3.5. Analytical plan for the flexible planning, executive function and language tasks

For the flexible planning task, the choice per trial was recorded for each participant as '1-correct' or '0-incorrect'. All test sessions were coded live as well as being video-recorded unless parental consent requested otherwise. 10% of trials were coded from video and compared to the live coding, finding 100% agreement with the data.

Generalized Linear Mixed Model (GLMM) was adopted using R version 3.6.1 to assess which factors influenced success rate in the flexible planning task in children. Success was a binary variable indicating whether the participant correctly solved the trial (1) or not (0), and was entered as a dependent variable in the models. The random effect included participant ID and fixed effects included age in years (continuous: ages 3-5 in individual years), condition (1–2 training, 3-4 for testing), gender (male/female), delay order (short-long delay/ long-short delay) and training performance (correct – 1, incorrect – 0, for model 1 only). Two separate models were run: 1. Test trials 2. Training trials. Likelihood ratio tests were used to compare the full model (all predictor variables, random effects, and control variables) firstly with a null model, and then with reduced models to test each of the effects of interest (Forstmeier & Schielzeth, 2011). The null model consisted of random effects, control variables and no predictor variables. The reduced model comprised of all effects present in the full model, except the effect of interest (Göckeritz, Schmidt, & Tomasello, 2014). Notably, I did not test effect of interaction because first none of the variables of interest in the study were expected to interact with each other to influence children's task performance, and second to avoid the poor practice of p hacking (Head et al., 2015). Additionally, post-hoc analysis was conducted using exact Mann-Whitney U-tests and Wilcoxon signed ranks tests (Sheskin, 2003).

The analysis used Kruskal-Wallis tests to assess whether age had an effect on each executive function task and language test since the data violated assumptions of normality. Post-hoc tests for the Kruskal-Wallis tests were run to examine how the age groups differed and Bonferroni corrections were adopted for multiple pairwise comparisons (Lee & Lee, 2018; Rodger & Roberts, 2013; Sheskin, 2003). Furthermore, correlational analysis was conducted to test whether individuals' success on the flexible planning task correlate with their scores in each of the executive function and language ability tasks using Spearman correlations. Inter-task correlations within the executive function task battery and language test were examined using Pearson's correlation[8].

5.4 Results

5.4.1 Children's performance in the flexible planning task

In the test trials, the full model differed significantly from the null model (X^2 = 11.46, df = 5, *p* = .04). There was a significant main effect of age (X^2 = 4.85, df = 1, *p* = .027) on success rate in the two test trials, with success increasing with age (Table 5.3). Specifically, 3-year-olds performed significantly more poorly than 4- and 5-year-olds: 3 vs 4 years: *z* = -2.24, *p* = .032; 3 vs 5 years: *z* = -2.16, *p* = .035), with no significant difference in success rate between 4- and 5-year-olds (*z* = -0.105, *p* > 0.999). Frequency analysis showed that percentages of correct choices across the two test trials were 55% for the 3-year-olds, 75% for the 4-year-olds and 75 % for the 5-year-olds. Furthermore, binomial test suggested that in the test trials, 3-year-old children did not significantly select correctly above chance (*p* = .519), while children aged 4 and 5 years selected the correct tool significantly above chance level (*p* <.001).

Table 5.3. Generalized linear mixed models on factors affecting the number of correct **test** trials in the flexible planning task. N = 87. Significant p-values in bold.

Fixed term	Estimate	z-value	p-value
Age in years	**0.489**	**2.176**	**0.030**
Condition	-0.707	-1.998	0.051
Gender	-0.473	-1.308	0.191
Delay order	-0.500	-1.407	0.160
Training	0.140	0.337	0.736

In the training trials, the full model differed significantly from the null model (X^2 = 36.59,

[8] In Miller et al. (2020c), the Spearman's rank order correlation was adopted to test the relationship between executive function and language ability with separate analysis conducted for within and across age groups. Having considered the measurement scale of these tasks (interval level) and in line with majority of executive function literature, I decided to use and report Pearson's correlations and controlled for age (in years with two decimal places).

df = 2, p <.001). There was a significant main effect of condition (X^2 = 6.44, df = 1, p = .011) on success rate (correct vs. incorrect choice) in the two training trials (Table 5.4). Specifically, in condition 1, the least preferred reward was inside the apparatus, and the choice was between the most preferred reward and the functional tool with the correct choice being the immediately available reward. In condition 2, the most preferred reward was inside the apparatus, and the choice was between the least preferred reward and functional tool, with the correct choice being the immediately available tool. Across all ages, children showed significantly higher success in condition 2 than 1 (Wilcoxon signed ranks test: z = -2.33, p = .029). Across the two training trials, 68 % of 3-year-olds, 80% of 4-year-olds and 79% of 5-year-olds made the correct choice. Binomial test revealed that children in each age group significantly selected correctly above chance level (3-year-olds: p = .006; 4-year-olds: p <.001; 5-year-olds: p <.001).

Table 5.4. Generalized linear mixed models on factors affecting the number of correct **training** trials in the flexible planning task. N = 87. Significant p-values in bold.

Fixed term	**Estimate**	**z-value**	**p-value**
Age in years	0.305	1.395	0.163
Condition	**0.906**	**2.441**	**0.015**
Gender	0.607	1.674	0.094
Delay order	-0.348	-0.975	0.329

5.4.2 Children's performance in the executive function and language ability tasks

The descriptive statistics are presented in Table 5.5. Importantly, Age had significant effects on all executive function task scores and language ability test, except for the Knock-Tap task (Table 5.5). Multiple comparisons have been conducted against a Bonferroni-adjust alpha level of 0.008 (0.05/6). Notably, 3-year-olds were outperformed by 4-year-olds on the Forward Digit Span and Backward Digit Span tasks (all p <.008). Additionally, 5-year-olds scored significantly higher on all tasks except the Knock-Tap task than 3-year-olds (all p <.008). 4-year-olds were outperformed by 5-year-olds on the Backward Digit Span and language task (all p <.008).

Table 5.5. Descriptive statistics and effects of age on executive function tasks and language ability test.

Task	3-year-olds	4-year-olds	5-year-olds	Age effects
Day-Night (range = 4-16)	10.95(4.90)	12.61(4.16)	13.82(2.55)	$\chi2$ (2, n = 85) = 7.140*
Knock-Tap (range = 3-15)	10.79(5.66)	13.07(3.54)	13.45(2.65)	$\chi2$ (2, n = 84) = 2.183
FDS (range 1-5)	3.96(0.87)	4.39(0.69)	4.38(0.86)	$\chi2$ (2, n = 86) = 6.292*
BDS (range = 1-5)	1.28(0.59)	1.73(0.83)	2.41(0.95)	$\chi2$ (2, n = 84) = 24.944***
DCCS (range = 0-6)	3.62(1.76)	4.50(1.77)	5.03(1.12)	$\chi2$ (2, n = 86) = 7.592*
BPVS-3 (range = 13-99)	56.96(14.58)	62.96(13.07)	77.14(14.38)	$\chi2$ (2, n = 86) = 25.376***

Note. Kruskal-Wallis tests were conducted for executive function tasks and language tasks. Standard deviations are in parentheses. *** indicates p <.001, ** indicates p <.01, * indicates p <.05.

5.4.3 Relationship between the flexible planning task, executive function and language ability tests

With regards to the relationship between children's performance on the flexible planning task, executive function competency and language ability, Spearman's rank-order correlations shown that across age groups children's total test score in the flexible planning task was unrelated to any of the executive function tasks or language test (Table 5.6). Nevertheless, when controlling for age, there were significant inter-task correlations within the executive function task battery and language test (Table 5.6). Notably, children's language ability was correlated with all executive function tests (all p <.05). Performance on the Day-Night task correlated with all tasks (all p <.01) except for the Backward Digit Span task (p >.05). Knock-Tap task was related to all tasks (all p <.05) except for the DCCS (p >.05), Forward Digit Span scores were associated with all tasks (all p <.05) except for DCCS (p >.05). In addition, Backward Digit Span scores were only associated with Knock-Tap, Forward Digit Span and language test (all p <.05). DCCS was correlated with Day-Night and language test (all p <.01).

Table 5.6. Correlations between flexible planning, executive function and language tasks across all ages.

Task	1	2	3	4	5	6	7
1. Flexible planning	-	.147	.107	-.039	.114	.132	.037
2. Day-Night		-	.479***	.400***	.133	.334**	.304**
3. Knock-Tap			-	.571***	.244*	.199	.401***
4. FDS				-	.282*	.197	.329**
5. BDS					-	.205	.271*
6. DCCS						-	.241*
7. BPVS-3							-

Note *** indicates p <.001, ** indicates p <.01, * indicates p <.05. Sample size vary as not all children took part in all the tasks.

5.5. Discussion

The preceding chapters have measured different components of future-oriented cognition, such as the ability to anticipate future physiological states and understanding changes in future preferences. Therefore, findings of developmental patterns can be drawn from a wide range of reasoning and behaviours. Chapter 5 further extends the research scope by investigating the cognitive correlates of future-oriented cognition in a future tool use context. In the current study, a novel behavioural paradigm featuring different types of tools, rewards and apparatuses was used to examine young children’s ability to use past information to guide current actions for solving anticipated future problems. From a methodological perspective, the novel task in Chapter 5 was first used in animal research and the current study modified it by taking consideration of existing methodological critiques. In Chapter 3 standard developmental patterns were reported with a task originally designed for primates. Similarly, in Chapter 5 children also demonstrated typical and standard age-related performance with the novel paradigm. Specifically, children aged 4 and 5 successfully linked past events to deferred future episodes and made future-directed decision in a tool-use context, while 3-year-olds were unable to do so. Moreover, the cognitive correlates of children’s future-oriented cognition were examined by testing the relationship between performance on the flexible planning task and standardised executive function and language ability tests. There was no significant correlation between any executive function task and the flexible planning task, or between language test and the flexible planning task.

Findings from the current study were consistent with most previous research which reported similar developmental trajectory of future-oriented cognition using typical spoon paradigms (Atance et al., 2015; McCormack & Hoerl, 2021; Suddendorf et al., 2011; Redshaw & Suddendorf, 2013). Notably, unlike other paradigms, the flexible planning task incorporated two delays. Half of the participants waited 2 minutes and the other half waited 5 minutes in the first delay. The results indicate that performance on the flexible planning task was not influenced by the different delay lengths. It is worthy highlighting that existing spoon tasks usually incorporate delays ranging from 5 minutes to 24 hours between the problem and item selection with no delay between item selection and use (Atance et al., 2015; Atance & Sommerville, 2014; Suddendorf et al., 2011). In comparison, non-human studies typically include a delay after the selection phase, though not before (Scarf et al., 2014). There are two reasons why the current study's design with the two delays was necessary: first, to reflect real-life situations where future-oriented scenarios often entail delays both prior and following the critical decision and selection stage; and second, to meet the aim for this paradigm to be suitable for comparative work.

Atance and Sommerville (2014) explored the influence of delay between item selection and use in spoon paradigm and found no effect on performance in 4-year olds, though they did not test 3-year olds. However, findings from the current study suggest that a delay as short as 2 minutes between encountering a problem and selecting a tool, or between tool selection and use, could pose adequate difficulty for 3-year-olds. Our results add to the substantial body of literature which suggests that 3-year-olds were only able to solve problems that were of immediate concern, and the failure in the spoon paradigm could be explained by young children's difficulty in linking past events to deferred future episodes and using memory of the past to flexibly plan for the future (Prabhakar & Ghetti, 2020; Redshaw & Suddendorf, 2013; Suddendorf et al., 2011). That said, growing evidence suggests that 3- and 4-year-olds could engage in retrieval and planning processes in memory guided planning tasks. But 3-year-olds were only able to retrieve the past for the future with direct reinstatement (Blankenship & Kibbe, 2019; Prabhakar & Hudson, 2019).

Most research indicates that 4-year-olds pass flexible planning tests, including the present study (Atance, 2015). However, Dickinson and colleagues (2018) found that, when presenting participants with a choice of two high-value objects after seeing a specific problem, 4-year-olds failed to pass the test. Similarly, in the current study, the choice in the test trials was between 2 objects of equal value, only one of which was functional in a particular condition. The findings demonstrate that 4-year-olds were able to link specific tools with specific apparatus when both tools have been previously associated with positive reward history, though with a considerably short delay. Future investigation could further manipulate delay length and include other possible options within the choices that have similar value, like tools that are rewarded in other contexts or immediately available rewards.

A major aim of the current study was to test future-oriented cognition in young children using a novel paradigm that addressed some of the key critiques of non-human animal studies. The current study therefore has several methodological advantages. As recommended by previous research, a single trial for each condition was used, and novel problems in the test sessions compared to the training sessions helped to precludes learning (Suddendoef et al., 2011; Tulving, 2005). Specifically, the design of single trials avoided repeated reward-stimulus relationships. Children received one test trial for each apparatus to assess their tool choice specific to that condition. Importantly, before the critical tool selection, the task design ensured that children had equal experience with both tools being functional as the paperclip and pencil had been equally associated with reward in the pre-experience phase. Thus, there was no difference in desirability of tools and the correct choice in test trials depended on the apparatus presented. Therefore, the task effectively tapped into children's ability of linking past information (type of apparatuses) to future-directed decisions (type of tools). Furthermore, the use of training trials established the experience of predictable return of future reward, which allowed us to attribute children's performance on tool selection to future-directed cognitive processes. Also, the future-oriented context in the flexible planning task is more similar to real-life circumstances where current actions are associated with predicted future outcomes. Additionally, unlike most developmental research, verbal cues were not used during testing which makes the current paradigm potentially suitable for comparative studies.

In training trials for the flexible planning task, children of all ages were able to inhibit the selection of an immediately available low-value reward for a tool in order to obtain a higher value reward inside the apparatus. They could also correctly select the high-value reward when it was immediately available. However, they did perform better when the high-value reward was inside the apparatus and the correct choice was the tool, indicating that children of all ages showed a general interest in tool use. Therefore, it is likely that tool use itself was rewarding for the participants, indicating that step 3 in session 1 and the training steps in session 2 may not have measured delay of gratification, but rather the participants' ability to make a correct choice when presented with two options.

The current study adopted a battery of tasks to measure children's general language ability and the different components of executive function competency (Hughes et al., 2009; Miyake et al. 2000, Wiebe et al., 2008). As expected and consistent with previous research, children's language, cognitive inhibition, working memory and cognitive flexibility was significantly influenced by age, except for their motor inhibition measured by the Knock-Tap task (Carlson, 2005). The non-significant age effect in the Knock-Tap task was likely to be attributed to its task protocol. Specifically, in the current study, simplified version of Knock-Tap task was adopted and children were only asked to perform the opposite hand movements (Pollak et al., 2010). This procedure has been suggested to be less difficult and require less inhibitory control ability than the more widely used format in which children were first asked to imitate the experimenter then required to perform the opposite hand movements (Klenberg, Korkman, & Lahti-Nuuttila, 2001; Monette, Bigras, & Guay, 2015). To address this issue, the other empirical studies (Chapter 2, 3, and 4) in this thesis have used the modified procedure and found significant age-related performance in Chinese and British pre-schoolers.

One of the central aims in the current study was to examine the relationship between children's flexible planning, executive function competency and language ability to elucidate the cognitive correlates of future-oriented cognition, especially in a spoon test context. After controlling for age, there were significant correlations in performance between children's language ability and all executive function tasks apart from the Knock-Tap task, which was the only task that rarely reliant on language. The inter-task correlations within the executive fucntion test battery largely replicated previous literature (Carlson and Moses, 2001). More importantly, there was no relationship between children's performance on the flexible planning task and their general language ability. That said, previous research which reported correlations between future-oriented cognition and language ability partly relied on children's understanding of more complex instructions, compared to ours. For instance, Ünal and Hohenberger (2017) tested pre-schoolers' ability to select items for future use from a different spatial perspective. Children's performance on the "Blow Football" task was related to temporal language ability. Although both tasks tested future-oriented cognition with spoon paradigm, the current study differed in the way that the flexible planning task minimised the verbal input and provided children with opportunities to subjectively experience the context. Moreover, unlike Ünal and Hohenberger (2017), the current study measured general language not understanding of temporal terms. On the other hand, the lack of relationship between children's performance on the flexible planning task and language ability indicates that our novel paradigm may be suitable with non-verbal species as well, making it even possible for cross-species comparison, for example with tool-using New Caledonian crows and primates.

Different lines of studies have proposed the link between future-oriented cognition and executive function with relatively few empirical investigations using the spoon paradigm (Addis et al., 2007; Atance & Metcalf, 2013; Buckner & Carroll, 2007; Ford et al., 2014; Suddendorf & Corballis, 2007). In the current study, there was no significant correlation between children's ability to select items to address anticipated problems and their executive function competency. To be noted, the lack of association is in line with previous literature which reported no relationship between pre-schoolers' future-oriented cognition and executive function using a different set of tasks (Hanson et al., 2014). Researcher have proposed the possibility that the association between these two different cognitive domains may only exist in tasks featuring conflicts between present and future states. This argument is supported by results in Chapter 4, which shown that children's inhibition control and cognitive flexibility was related to their ability to understand future preference changes when conflicting perspectives were involved. Furthermore, when measured with a delay choice task (Chapter 3), children's capacity to postpone gratification was associated with their motor inhibition ability. These tasks, including the novel flexible planning task, were specifically developed with different theoretical backgrounds and focus on certain aspects of future-oriented cognition. Therefore, it is possible that the differences of task demand and structure have contributed the mixed findings across studies and tasks. A preliminary proposal is that the cognitive correlates of future-oriented cognition may be context specific and varies between different future-oriented scenarios.

The disparity between task selection and scoring method of executive functioin may also contribute to the inconsistent literature on cognitive correlates of future-oriented cognition. A very recent investigation used the composite inhibition scores (calculated from a Day-Night variant task and DCCS test) and found that they were related to children's performance in a similar spoon task (Atance et al., 2021). However, there is a fundamental difference between Atance et al. (2021) and the current study, which is the associated value of the items or tools presented at selection stage. Notably, both tools in the flexible future planning task have been equally associated with positive reward history. But each tool would be only functional in a specific future episode with the corresponding apparatus. Therefore, it is highly likely that the ability to link past episodes to deferred future problem underlie children's success in the current study, rather than the ability to inhibit one tool over the other tool since both are functional with predictable future rewards. This might explain why there is a lack of relationship between inhibition and future-oriented cognition in the current study. Inhibition may be more implicated in training trials when children forego the immediately available low-value reward and select the tool in order to obtain a higher value reward inside the apparatus.

Although not placed to answer for potential cultural contrast between Western and Eastern children, the current study makes critical methodological contributions to this thesis and the field of future-oriented cognition research. Notably, the flexible planning task has addressed methodological critiques in relation to developmental studies as well as animal research. Importantly, children demonstrate significant age-related performance and typical developmental trajectory with the novel task, echoing those from standard developmental studies. What is worthy exploring in future studies is to compare children and animals' performance across different spoon tasks which will provide a better understanding of the evolution and convergence of cognition across species. Within this thesis, Chapter 5 provides further evidence on the cognitive correlates of future-oriented cognition. Specifically, children's ability to mentally link past events to deferred future and to make future-directed decisions was unrelated to their executive function competency and general language ability. Considering findings from preceding chapters and the current study, it seems that the cognitive correlates of future-oriented cognition may be context specific. Future research should take task structure and cognitive demand into considerations.

Chapter 6: General Discussion

The central aim of this thesis was to investigate the developmental and cognitive profile of future-oriented cognition in young children, and whether there are cultural differences between Western and Eastern populations. Specifically, I studied cognitive correlates that have been linked with future-oriented cognition in theoretical accounts and neuroimaging studies. The cross-cultural approach was directed to fill the literature gap of Eastern children's development of future-oriented cognition. In Chapter 1, I argued that future-oriented cognition is an umbrella term that encompasses the cognitive processes involved in understanding, constructing, imagining and planning for the future (McCormack & Hoerl, 2020). To elucidate the cognitive correlates of these different abilities and gain insight into the potential cross-cultural difference, this thesis tested British and Chinese children on a broad range of tasks that tap into different aspects of future-oriented cognition. The studies described in the preceding chapters reveal that there were standard and universal developmental trajectories among British and Chinese pre-schoolers, as well as some fascinating differences. Taken the emerging evidence on animals' success in planning for the future together, it suggests that future-oriented cognition may have been convergently evolved among different species and is a universally fundamental cognitive ability (Horik, Clayton, & Emery, 2012). Research on cognitive correlates of future-oriented cognition in young children is still in the early stage and this thesis further adds to the growing literature by testing two culturally diverse samples. Overall, children's executive function was related to specific components of future-oriented cognition whereas there was no evidence to support its link with theory of mind.

I will begin the general discussion with a summary to briefly synthesise the main results in the four empirical chapters. Subsequently, I will analyse this thesis' strengths and limitations. Finally, I will address the main themes of cognitive correlates and cultural contrast with conclusions drawn from the preceding chapters and previous literature, while leaving open questions for future investigation.

6.1 Summary of empirical findings

Chapter 2 provides the first systematic investigation of Chinese pre-schoolers' development of future-oriented cognition. A comprehensive test battery was administered to assess the different aspects of future-oriented cognition, specifically children's ability to a) anticipate future physiological states (Picture Book task, Atance & Meltzoff, 2005), b) select tools for future use (Spoon paradigm, Redshaw & Suddendorf, 2013), c) construct future event sequences (Prabhakar & Hudson, 2014) and d) prospectively remember to perform future actions (prospective memory, Kvavilashivili et al., 2001). Another important aim of Chapter 2 was to elucidate the cognitive correlates of Chinese children's future-oriented cognition. It included measures of executive function and theory of mind which were the two cognitive abilities that have been investigated in previous literature with Western children. When tested on tasks that were developed by Western psychologists and predominantly used with Western children, Chinese pre-schoolers showed standard and typical age-related performance on these tasks with a similar developmental trajectory to that found for Western children. Specifically, the age of 4 was the critical age for Chinese children and the youngest 3-year-olds were consistently outperformed by the 4- and 5-year-olds. Overall, Chinese children's performance across the four different future-oriented cognition tasks was related to their overall executive function competency. More specifically, the cognitive correlates appear to be different from task to task. For example, both the Picture Book task and prospective memory task were associated with working memory and cognitive flexibility whereas only the prospective memory task was related to cognitive inhibition. Moreover, across the test battery of future-oriented cognition, theory of mind ability appears unrelated to children's capacity to make future-oriented decisions. This finding is in accordance with Hanson et al. (2014) who used a different set of tasks and found no inter-task relationship between theory of mind and future-oriented cognition. Together, these studies challenge Buckner & Carroll's (2007) theoretical account of the link between these two cognitive domains, suggesting that at least in the preschool years future-oriented cognition are independent of mental state attribution.

While Chapter 2 fills the literature gap of Eastern children's future-oriented cognition by testing Chinese pre-schoolers, the findings could not address the questions of cultural contrast. The subsequent Chapter 3, therefore, has the specific rationale of testing Eastern and Western children on the same task of future-oriented cognition. Notably, the two experiments in Chapter 3 directly compared British and Chinese children's delay of gratification ability with a delay choice paradigm modified from animal research (Bramlett et al., 2012). The rotating tray task involved manipulations of reward types and visibility, allowing the influence of contextual factors to be examined in different cultures. Both Chinese and British pre-schoolers exhibited greater delayed gratification capacity when tested with qualitatively different rewards compared to quantitatively different rewards. Although reward visibility did not influence children's ability to postpone gratification, Chinese children outperformed their British peers in making more future-oriented decisions when reward visibility was manipulated. Also, in Chinese children, there were significant associations between performance on the rotating tray task, a standard delay choice test and a motor inhibition task.

The tasks adopted in Chapter 2 and 3 measured pre-schoolers' ability to make future-oriented decisions in short term future with the first-person perspective. However, decisions pertaining to the long-term future and of another person are equally important and prevalent in daily life. Hence, Chapter 4 focused on children's understanding of preference changes when they grow up to be adults in the future, while additionally testing its cognitive correlates and potential cross-cultural differences. Across British and Chinese children, when asked to envision future preferences, their predictions were more accurate for a peer than for themselves. Such other-over-self advantage has been documented across different types of future-oriented cognition (Bélanger et al., 2014; Mazachowsky et al., 2019; Russell et al., 2010). Furthermore, performance improved when they were first asked to identify their current preference before anticipating the future. To be noted, Chinese pre-schoolers outperformed their British counterparts in cognitive inhibition and cognitive flexibility tasks, but there was no country related difference in their performance on the future preference task. The ability to understand one's own, but not of peers', future preferences was related to children's inhibition control and cognitive flexibility over and above age-related improvement, highlighting the role of executive function in long-term future-oriented decisions.

Despite the methodological advances in the past decades, there is still no agreement on the "gold standard" task to measure future-oriented cognition. However, Tulving's spoon paradigm (2005) is one of the most influential tests and it has been adapted in developmental and comparative research. Chapter 5 took a different approach by focusing on the methodological issues and aimed to elucidate children's cognitive correlates in a task where existing critiques could be addressed (with no cross-cultural design). Specifically, the flexible planning task measured children's ability to use past information to solve anticipated problems in tool-use context. In the modified task, children were not verbally cued during testing and the use of single trials minimised influence of stimulus-reward relationships. Furthermore, children had experience of a predictable return of reward and delays were incorporated both before and after tool choice, allowing children's performance to be attributed to future-directed cognitive process rather than alternative learning explanations. British children were tested on the flexible planning task and they demonstrated critical and standard age-related performance. 4 and 5-year-olds consistently pass the test above chance and outperformed the 3-year-olds. The developmental patterns were similar to those using standard developmental tasks. Additionally, British children were tested for their general language ability and executive function competency, none of which were related to the ability to make decisions of future tool use. The findings are significant for research on cognitive correlates of future-oriented cognition and highlighted the role of task structure and cognitive demand. Even tasks with similar context (Spoon task in Chapter 2 and Spoon task in Chapter 5) could be associated with different cognitive correlates.

6.2 Strengths and limitations

Research on future-oriented cognition has flourished in the past two decades and it has offered unique insight into some fundamental psychological processes, such as memory and consciousness. In some cases, it even reshaped our long-standing views of cognition. For example, the study of mental time travel suggest that the memory is bi-directional; it could be projected to pre-experience the future as well as traced back to re-live the past (Tulving, 2005). Nevertheless, research on the developmental trajectory of future oriented cognition and its cognitive correlates remain heavily skewed towards Western populations, with little evidence from children growing up outside of Western societies. The main strength and novel contributions of this thesis therefore are the inclusion of Eastern participants from mainland China and the use of the cross-cultural approach, which has broadened the existing research scope of children's future-oriented cognition.

To be noted, the suite of tasks that I chose have been extensively validated with Western samples and certain component of future-oriented cognition, such as delay of gratification, has been associated with important real-life implications (Atance, 2015; Ayduk et al., 2000; Moffitt et al., 2011; Prabhakar et al., 2016). Findings from Chapter 2 to 4 where Chinese children were tested with different tasks are particularly useful in establishing an initial yet comprehensive developmental profile of Eastern children's future-oriented cognition. With very limited cross-cultural research existing in the field (Lamm et al., 2018; Redshaw et al., 2019), Chapter 3 and 4 contribute to the field both conceptually and methodologically. Crucially, the studies revealed that the existing tasks were developmentally sensitive measures for children from different cultures. The similar and comparable patterns across Chinese and British children indicated a universal developmental trajectory of children's future-oriented cognition.

Another strength of this thesis is the use of broad range of future-oriented cognition tasks, of which the importance has been increasingly recognised in the recent developmental literature (Burns et al., 2021). Notably, the breadth of task selection has not only helped to gain a comprehensive understanding of Chinese children's capacity in different aspects of future-oriented cognition, but more importantly, it ensured the findings of cognitive correlates were not tied to specific components of future-oriented cognition but covers a wide range of scenarios and contexts. For example, when there were conflicting perspectives between the future and the present, young children's cognitive flexibility and inhibitory control were related to their ability to make future-oriented cognition (Chapter 4). In context which success rely on the ability to remember demands and mentally maintain future goals, eg., prospective memory task, children's working memory appear more relevant than inhibitory control (Chapter 2).

Nevertheless, this thesis has several limitations which point to fruitful directions for future research. First, the main weakness was the issue of non-matching samples and limited demographic data. Guillaume and Funder (2016) highlighted theoretical and methodological challenges in making cross-cultural comparisons, including measurement, construct and sampling biases. Notably, sample differences existed across cultural groups could influence results by introducing confounding variables (Van de Vijver & Leung, 1997). If variables known to relate to task performance were not similar across the two samples, differences and similarities observed cannot be completely attributed to cultural factors. Importantly, matched sampling has been suggested to control for demographic variations across different cultures. This strategy involves recruiting participants of different groups as similar as possible in their relevant background characteristics (Schwartz, 1992).

While the evidence on the influence of environmental factors on future-oriented thinking is limited, research on early development of executive function and theory of mind could shed light on the issue of sample comparability for future investigation. Individual differences in theory of mind show moderate associations with language ability and family factors (Hughes, Devine, & Wang, 2018; Leece & Hughes, 2010; for a meta-analytic review, see Devine & Hughes, 2018). Specifically, family socioeconomic status (SES), family size, parental mindedness and mental-state talk were moderately related to theory of mind performance in 3-7 years old. Similarly, the development of executive function has been shown to be susceptible to a range of environmental factors, such as child language ability, family SES, parenting behaviours and exposure to parental depression (Gooch et al., 2016; Hughes, Roman, Hart, & Ensor, 2013; Ribner et al., 2022; Ursache & Noble, 2016; for a review, see Fay-Stammbach, Hawes, & Meredith, 2014). With a closely matched sample, Fujita, Devine and Hughes (2022) reported that Japanese children were delayed in their theory of mind performance but outperformed the British children on executive function measures.

In the thesis, I recruited participants in both countries from relatively educated, middle class and urban areas, but no detailed demographic information was collected due to feasibility problems. Therefore, it was impossible to conduct cross-cultural comparisons with matched samples or to statistically control for sample differences. Relatedly, samples in this thesis were not socially diverse and this raises questions about the generalisability of findings. The social diversity issue is particularly relevant in China where researchers have documented an urban-rural childhood cognitive divide in which children from rural areas are substantially left behind in cognitive development and attainment compared to peers living in urban areas (Taji, Mandell, & Liu, 2019; Yue et al., 2017; Zhang, Behrman, Fan, Wei, & Zhang, 2014). For future research, it would be very beneficial to recruit children from different cultures that are matched for verbal ability, gender, family size and type and SES, parental education attainment and degree of urbanisation and deprivation. Alternatively, if matched samples are hard to recruit, detailed demographic information on these environmental factors would allow more flexibility and power in statistical analysis to systematically account for sample differences (Schwartz, 1992).

Second, this thesis did not include any measures of socialization goals, parenting style and behaviours. These societal factors have been shown to relate to children's delay of gratification behaviours and account for the observed cross-cultural differences in a range of cognitive abilities, such as executive function and theory of mind (Hughes et al., 2018; Lamm et al., 2018, Xu et al., 2020). Research that links parental behaviours and attitudes to children's future-oriented cognition is extremely rare yet critical with educational implications, leaving an open field for future investigation. It is worth mentioning that I originally planned to conduct a cross-cultural study of parent-child dyadic conversations of future events, which was disrupted by the pandemic. Given the extensive evidence on West-East contrast of autobiographical memory and maternal reminiscence and elaboration style (Wang, 2019, 2021), it is possible that parents from different cultures would also show culturally specific traits when discussing future events. Specifically, East Asian parents may focus more on the social expectations and obligations, such as career choice and academic achievement while future-oriented conversations in Western societies may include more content of personal growth and changes in feelings and attitudes.

Third, it should be noted that this thesis used cross-sectional design which only allowed the investigation of concurrent relationships between different domains of cognitive abilities. While the thesis has revealed executive function as an important cognitive correlate, it is unclear whether it plays a predictive role in the development of children's future-oriented cognition. To the best of my knowledge, there has been no research attempt to longitudinally document the developmental trajectory of future-oriented cognition of the same individuals. That said, adopting cross-lagged designs with longitudinal approach would be beneficial to examine the predictive power of different cognitive correlates and capture a holistic picture of young children's development of future-oriented cognition. In addition, training studies would be particularly informative in identifying strategies that can be used to scaffold and improve children's capacity to make future-oriented decisions.

6.3 Main themes

6.3.1 Cognitive correlates of future-oriented cognition

Cumulative evidence from the past two decades points to a unified picture of young children's development of future-oriented cognition (Atance, 2015; McCormack & Hoerl, 2020). Notably, during the preschool years, they develop a suite of behaviour and reasoning skills for different future-oriented contexts. However, considerably less effort has been directed to elucidate the cognitive correlates and underlying mechanism that support children's ability to understand and plan for the future. This thesis adds to this research by further investigating the role of executive function, theory of mind and language in various future-oriented cognition tasks. From a broad theoretical perspective, it is worth considering Carlson and Moses's (2001) notion of "emergence" account which suggests that a certain level of executive function may be a crucial enabling factor for the development of theory of mind ability. It is reasonable to believe that a certain level of executive function competency may also be necessary for the development of future-oriented cognition. Empirically, this thesis has tested the role of executive function in different future-oriented contexts.

First and foremost, Chapter 4 provides the compelling evidence from two distinctive cultures that inhibition and cognitive flexibility were related to children's prediction of their own future preferences. This finding is in accordance with the proposal that the link between executive function and future-oriented cognition would be mostly salient in contexts when there are conflicts between future states and current states (Hanson et al., 2014). In future-oriented context, mental representations of the future and of the present coexist at the same time and inhibition is employed to de-activate and suppress the irrelevant content from the current state to interfere with reasoning of the future (Bar, 2011). That said, I suggest that stronger support of this proposal would come from research that examining the role of inhibition with the pretzel task (Atance & Meltzoff, 2006). Emerging evidence show that when physiological states were involved, even older children and adults struggled to overcome the salient and conflicting physiological states they felt at the present and the their prediction of future states were impaired (Cheke & Clayton, 2019; Kramer et al., 2017; Mahy et al., 2014, 2020; Mahy, 2016). Hence, continuing the work to understand the role of inhibition in induced-state future-oriented contexts would be a fruitful future direction.

The tasks described in Chapter 2 and Chapter 3 measured different aspects of future-oriented cognition and taken together the results suggested that cognitive-correlates may be task specific and context dependent. The inconsistent findings of cognitive correlates across different tasks fit well with the account of graded representation (Munakata, 2001). Task dependent behaviours often occur in children with graded knowledge and mental representations. Notably, dissociations in behaviour could be explained by the different levels of representations required in different tasks. Indeed, evidence suggests that there was weak to none relationship between different measures of future-oriented cognition (Jackson& Atance, 2009; Mahy et al., 2014). Considering that tasks adopted in this thesis were specifically designed to measure certain aspects of future-oriented cognition, it is very likely that they tap into different mental representations and require different cognitive correlates. For example, in scenarios where task success partially relied on the ability to inhibit motor responses, as in the delay of gratification task (Chapter 3), children's motor inhibitory control was related to their ability to make future-oriented decisions. By contrast, in tasks that dependent more on the ability to shift between current and future perspectives and to maintain future goals, for example in the Picture Book task and the prospective memory task (Chapter 2), working memory and cognitive flexibility appeared more relevant.

Furthermore, cognitive corelates of future-oriented cognition may even be different between similar contexts. Both Chapter 2 and Chapter 5 adopted the typical spoon paradigm where children were tested for their ability to link past experience to guide current tool selection for solving anticipated future problems. What was different between the two studies was the associated value of the items presented at tool selection. Inhibition seems to be involved when there was an association between correct tool and anticipated problems (Atance et al., 2021), but not when both tools have been equally associated with positive reward history. There is also the possibility that the cognitive correlates of future-oriented cognition may only be detectable in specific age groups. In Chinese children, 3-year-olds's performance on the future event sequence task was related to their inhibition ability and there was association between their spoon task performance and cognitive flexibility (Chapter 2). What should be noted is that 3-year-olds show overall difficulty with future-oriented cognition tasks and the cognitive correlates detected at this specific age may only apply to an underdeveloped mindset of future-oriented cognition.

On a different but related note, the developmental scope measured with the existing tasks was limited. Numerous research including this thesis has convergently show that from the fourth year of life children consistently pass future-oriented cognition tasks (Atance et al., 2015, Atance & Metcalf, 2013; Hudson et al,, 2011; McCormack & Hoerl, 2020). In contrast, very few studies have documented considerable differences between 4 and 5-year-olds (Caza & Atance, 2020; Dickinson et al., 2018; Payne et al., 2014). Across the vast majority of future-oriented cognition tasks, children's performance is scored with a binary scale: they either pass or fail the test. Hence, this dichotomous measure may have missed important and subtle developmental gains. Furthermore, it raises the questions of limited amount of task variability, narrow range of performance and concerns about ceiling effects. Therefore, continuous measure of future-oriented behaviours may be needed to detect subtle developmental gains and to elucidate cognitive correlates and underlying mechanism (Kopp et al., 2021).

Findings across the four empirical chapters in this thesis contrasted with the recent proposal which links theory of mind with future-oriented cognition (Atance & Metcalf, 2013; Buckner & Carroll, 2007). Yet, the results are in accordance with Hanson et. (2014) who adopted a different set of future-oriented cognition tasks and also reported no relationship between these two cognitive domains. That said, a small number of studies have shown that theory of mind was associated with prospective memory (Ford et al., 2012). However, research using other measures of future-oriented cognition, such as spoon paradigm, has failed to detect the association between these two cognitive domains. Although both theory of mind and future-oriented cognition involve a change of perspectives, it is possible that the contrast between different people's mental states (i.e. self versus other) is somewhat different to the contrast between current and future perspective (i.e. present self versus future self). It should also be pointed out that neuroimaging studies which have found the "default mode network" and overlapping neural structures between future-oriented cognition and theory of mind exclusively tested adults (Spreng et al., 2009). Hence, the link between future-oriented cognition and theory of mind may be more salient and detectable later in life and future investigation could expand the research scope to test older children and adolescents.

A substantial body of literature has used language as a marker of future-oriented cognition and early research suggest that the acquisition of temporal terms underlies the development of temporal knowledge (Busby & Suddendorf, 2005; Grant & Suddendrof, 2010; Hudson, 2001; Suddendorf, 2011). However, the role of language in children's ability to make future-oriented decision remains poorly understood. The study in Chapter 5 demonstrated that children's flexible planning ability was unrelated to their general language ability. That said, the task was designed to involve minimal verbal input, hence the null finding from a single study does not rule out that language may play a role in certain future-oriented cognition tasks. Future studies should consider narrowing the focus to specific type of language, for example temporal language (Ünal and Hohenberger, 2017), and to adopt longitudinal design to examine the causal role of language in the development of future-oriented cognition.

6.3.2 East-West contrast of future-oriented cognition

A noteworthy characteristic of the existing literature on future-oriented cognition is that research has predominantly focused on children growing up in Western societies. Very few attempts have been made to study non-Western children or compare children from different cultures (Lamm et al., 2019; Redshaw & Suddendorf, 2018). This might be taken to suggest that the observed developmental patterns may not be universal and are specific to certain cultural groups (Nielsen et al., 2017; Nielsen & Haun, 2016). By testing Chinese pre-schoolers and by comparing British and Chinese children directly on the same tasks, this thesis makes important and novel contributions to the growing body of research on future-oriented cognition. Overall, the results suggest that future-oriented cognition is a cognitive domain that is universally developed in children from different cultures with similar age-related performance and developmental trajectories. Despite cultural differences in related cognition (autobiographical memory, executive function, understanding of temporality) and parental socialization goals and practice, the development of pre-schoolers' future-oriented cognition, at least measured in thesis, seems independent of cultural influences (Gao et al., 2016; Hong et al., 2017; Sabbagh et al., 2006; Wang, 2021).

Chapter 2 represents an important first step into the investigation of future-oriented cognition in East Asian cultures. Importantly, Chinese children's developmental trajectory was similar to those found with Western peers (though not directly compared). Further evidence on the universality of future-oriented cognition come from Chapter 4. Specifically, there was no cross-cultural difference of British and Chinese children's ability to understand changes of future preference. Likewise, Redshaw et al. (2019) tested a different aspect of future-oriented cognition, the ability to prepare for alternative future possibilities, and found comparable performance between Australia, Indigenous Australian and South Bushman children. Together, these results indicate that the ability to understand and plan for the future is universal and it emerges around the same time for children from different cultures.

At the same time, this thesis also found evidence of cross-cultural differences between British and Chinese children. In line with prior reports of East Asian children's advantage in executive function (Ellefson et al., 2017; Lan et al., 2011; Oh & Lewis, 2008; Sabbagh et al., 2006; Xu et al., 2020), Chinese children outperformed their British counterparts in inhibitory control and cognitive flexibility (Chapter 4). Moreover, Chinese children exhibited greater capacity to delay gratification than British counterparts in a more challenging version of delay choice paradigm when reward visibility was manipulated (Experiment 2 in Chapter 3). By contrast, when tested with the same paradigm but without the additional contextual manipulations, British children performed at similar levels to their Chinese peers (Experiment

1 in Chapter 3). One possibility is that in context where demand of working memory and inhibition was high (when reward visibility was manipulated), Chinese children's task performance was enhanced by their greater executive function competency, which led to their overall better performance than British peers.

With only a handful of cross-cultural studies on children's development of future-oriented cognition, it is too early to suggest that the developmental and cognitive profile is identical for children from different cultures. Here I discuss three different directions that future research may wish to consider. First, the field needs more direct cross-cultural comparison between different cultures and ideally with continuous measure of future-oriented reasoning and behaviour. Lessons taken from the well-documented West-East gap of children's executive function are that individual differences are subtle to detect and could be missed with dichotomous measures that have been primarily used in future-oriented cognition research. Second, an area worth exploring is to examine the sequential steps and order in which children acquire different future-oriented cognition. One intriguing finding from theory of mind research is that Chinese and Iranian children first pass the task of diverse knowledge while it is the task of diverse beliefs for Western children (Shahaeian et al., 2011; Wellman et al., 2006). Recently, Gautam and colleagues (2019) analyzed the taxonomy of future-oriented cognition and unpacked its developmental course into three sequential stages. It is possible that children from different cultural backgrounds acquire different aspects of future-oriented cognition at different times with different orders. Third, future studies could investigate parent-child dyadic conversations of future events and compare the conversation style and content between Eastern and Western populations. Notably, culturally specific reminiscence style has been concurrently and longitudinally linked to children's autobiographical memory (Wang, 2013, 2021; Wang & Fivush, 2005). What remains unknown is that whether parents from different cultures focus on distinctive aspects of future and whether dyadic conversations predict children's own reports of future events.

6.4 Concluding remarks

The past two decades have witnessed a burst of research interest in future-oriented cognition, along with the greater recognition of its link with memory and the development of age-appropriate measures for young children. Capitalising on data from two culturally diverse samples (British and Chinese), this thesis sought to investigate the cognitive correlates of future-oriented cognition and look for potential cultural contrast between children from Western and Eastern countries. For the first time, this thesis has documented the emergence and developmental patterns of Chinese per-schoolers' ability to understand and plan for the future.

The investigations of cognitive correlates across a range of future-oriented contexts not only highlighted the role of executive function but also revealed the influence of task structure and demand. While the overall findings were indicative of universal developmental trajectory between Eastern and Western children, there were observed country-related differences in future-oriented decisions when additional executive resources were required. The insights gained into the developmental, cognitive as well as cultural perspective of future-oriented cognition pave the way for future enquiries. This thesis therefore takes us one step further in understanding "youthful short-sightedness" (temporal myopia) and making strategies to aid future-oriented decisions for the next hour, the next day, the next year and the long term future which has yet to arrive.

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Appendices

Appendix A

Letter of ethical approval

Karen Douglas
Secretary

Professor N Clayton
Department of Psychology
University of Cambridge

UNIVERSITY OF CAMBRIDGE

CAMBRIDGE
PSYCHOLOGY RESEARCH
ETHICS COMMITTEE

28 January 2019

Application No: PRE.2017.108

Dear Professor Clayton

Cognitive development and individual differences in episodic future thinking

The Cambridge Psychology Research Ethics Committee has given ethical approval to your research project: 'Cognitive development and individual differences in episodic future thinking' as set out in your application submitted on 18 December 2017.

The Committee attaches certain standard conditions to all ethical approvals. These are:

(a) that if the staff conducting the research should change, any new staff should read the application submitted to the Committee for ethical approval and this letter (and any subsequent letter concerning this application for ethical approval);
(b) that if the procedures used in the research project should change or the project itself should be changed, you should consider whether it is necessary to submit a further application for any modified or additional procedures to be approved;
(c) that if the employment or departmental affiliation of the staff should change, you should notify us of that fact.

Members of the Committee also ask that you inform them should you encounter any unexpected ethical issues.

Ethical approval will expire on 30 September 2021. If you require an extension, please submit an amendment request before the expiry date (guidance at www.bio.cam.ac.uk/psyres/amendments).

If you would let us know that you are able to accept these conditions, we will record that you have been given ethical approval.

Please note that there have been changes to the procedures regarding amendments. Full details are given on the REC website.

Yours sincerely

[Signature redacted]

K S Douglas

cc Ning Ding

Appendix B

Ethics application form

UNIVERSITY OF CAMBRIDGE

COUNCIL OF THE SCHOOL OF THE BIOLOGICAL SCIENCES
Cambridge Psychology Research Ethics Committee

Question 1: Title of the study

Notes: The title should be a single sentence

Cognitive Development and Individual Differences in Episodic Future Thinking

Question 2: Primary applicant

Notes: The primary applicant is the name of the person who has overall responsibility for the study. Include their appointment or position held and their qualifications. Primary applicants cannot be research students or junior research assistants. For studies where students and/or research assistants will undertake the research, the primary applicant would normally be their supervisor.

Professor Nicola Clayton, FRS, Department of Psychology

Question 3: Co-applicants

Notes: List the names of all researchers involved in the study. Include their appointment or position held and their qualifications

Miss Ning Ding, PhD student, Department of Psychology

Question 4: Corresponding applicant

Notes: Give the name of the person to whom correspondence regarding this application is to be addressed. This person should be the primary applicant or one of the co-applicants. An email address for correspondence must be provided.

Miss Ning Ding (information redacted)

Question 5: In which Department(s) or Research Unit(s) will the study take place?

Notes: Indicate where the study procedures will take place as well as the location for the storage and analysis of data. If the study will use National Health Service facilities, give a contact name and address of the Trust R&D office.

Department of Psychology, University of Cambridge.

Question 6: What are the start and end dates of the study?

Notes: If exact dates are unavailable, explain why and give approximate dates.

Data collection will take place between March 2019 and September 2021.

Question 7: Briefly describe the purpose and rationale of the research

Notes: Attach any detailed research proposals, if they have been submitted or will be submitted to a funding body. Make the objectives of the study clear.

The overarching aim of this project is to investigate episodic future thinking (EFT) in British and Chinese populations. EFT is a key developmental milestone and it refers to the ability to imagine oneself at a specific time in the future (Atance, 2015). The second aim of the research is to understand what cognitive mechanisms underline EFT development and what factors account for children's individual differences in future thinking skills.

Thinking about the future is an important aspect of human cognition; it pertains to our abilities to anticipate possibilities, plan ahead and prepare for uncertainties. Using behavioural and verbal paradigms, studies have shown that the ability to imagine future scenarios and use such imagination to guide current action is developed in children between 3 and 5 years old (Atance & Meltzoff, 2005, 2006; Atance, Louw & Clayton, 2015; Russell, Alexis & Clayton, 2010). However, the bulk of this research used predominately Western sample and little is known about EFT in non-Western cultures. As a result, evidence concerning the universality of EFT development is scarce and we intend to bridge the gap by assessing EFT in Chinese preschoolers.

Secondly, cognitive development does not happen in vacuum and children's cognition often involves multiple mechanisms working together. Although researchers have documented the phenomenological characteristics and age-related improvements in children's future thinking skills, there is no clear answer to what cognitive abilities underline the development of EFT and what factors account for children's individual differences. Potential candidates include executive function (EF, a set of cognitive processes to control, coordinate information and assist goal-directed behaviour) and theory of mind (ToM, the ability to understand the mental states and desire of others), which children develop around the same time as EFT (Hanson, Atance, && Paluck, 2014). Therefore, we intend to expand previous research by employing different measures of EFT and other cognitive abilities to provide a more comprehensive picture of EFT development in preschoolers.

Thus, the current project will examine episodic future thinking in children aged between 3 to 5 in the UK and China. The project has two key aims:

1. To investigate the culturally-fairness of a battery of EFT tasks among Chinese preschoolers and examine the developmental trajectory of EFT with a non-western sample
2. To enhance our understanding of the underlying cognitive mechanisms of EFT by examining the link between EFT, general intelligence, executive function and theory of mind

Question 8: Who is funding the costs of the study?

Notes: Give the name and address of funding bodies or other sponsorship (other than the University of Cambridge) involved in providing resources for the study.

This project has not received any internal or external scholarship or funding. As a self-funding student, Miss Ning Ding receives £900 research allowance per year from the Department of Psychology and this will be spent on materials, experimental apparatus, etc.

Question 9: Describe the methods and procedures of the study

Notes: Attach any relevant material (questionnaires, supporting information etc.) as appendices and summarise them briefly here (e.g. Cognitive Failures Questionnaire: a standardised self-report measure on the frequency of everyday cognitive slips). Do not merely list the names of measures and/or their acronyms. Include information about any interventions, interview schedules, duration, order and frequency of assessments. It should be clear exactly what will happen to participants. If you are collecting any human tissue samples (for example, saliva, urine, blood, breast milk), please confirm that they will be stored at a location that has an appropriate licence from the Human Tissue Authority.

Measures of Episodic Future Thinking
We will use a range of tasks to investigate episodic future thinking (EFT) in preschoolers between 3 to 5 years old. There will be broadly 3 types of EFT experiments.

1. Verbal Paradigms
   The verbal methods often involve children answering questions and making predictions for future scenarios. For example, in the Picture Book Task (Atance & Meltzoff, 2005), Participants will first view a series of pictures depicting pictorial scenes which are specifically designed to evoke thought about future states such thirst, cold and hunger. Then children will be asked to verbally predict and explain future states, and to made an adaptive decision to address their own future need. They can also be asked to predict the future states/needs of another person, e.g. same-aged peer or an adult. The verbal test of EFT takes 15-20 minutes to complete.

2. Behaviour Paradigms
   Often referred as the "item choice" test, the behavioural methods often require children to select items for future use (based on a specific past experience). For example, Atance et al., (2015) adapted a task from comparative literature to assess children's capacity to draw on a past experience that entailed the lack of a particular resources and to make subsequent adaptive choice. Children visits two rooms, one with toys and one without toys. Participants is asked to decide to place toys in one of the rooms visited for either immediate future or when they are 1 year older. Another example of children's EFT measure is the Blow Football Task (Russell et al., 2010). Specifically, children need to imagine a future event from a different visual/spatial perspective and use the envision to make an adaptive choice. The typical behavioural EFT task takes 30 minutes to complete.

3. Conflicting Current and Future States Paradigms
   This type of experiment involves the experimental manipulation of children's current desire or physiological state. The purpose of such design is to create a conflict between children's current and future desire. For instance, Atance & Meltzoff (2006) designed the "pretzel task" and it involves children eating salty pretzels to elicit the feeling of thirst. Then participants are asked whether he/she would choose for tomorrow, water or pretzel. This type of experiment is designed to test the Bishof-Köhler hypothesis and it investigates whether children can overcome their current state/desire (in conflict with their future desire) to choose something that is usually preferred in a future context. This type of experiment task usually takes 30 minutes to complete.

In our research, we might adapt and modify some features of the experimental designs. For instance, change the objects that children are presented to or vary the delay between the specific past event children experience and the future scenario when they are asked to make future-oriented choice. We might also change the temporal distance of future episodes that children are asked about (15 mins, next day, 5 years later, etc.).

Measures of Executive Function, Theory of Mind and Intelligence
We will employ commonly used tests from the developmental literature or verbal tests adapted for children from the comparative cognition literature (as in Miller et al., 2016). We will use a battery of tests to collect data on executive function, theory of mind and intelligence. For example, Marshmallow Test to measure delay of gratification (Mischel, 1972), Backward Digit Span to assess working memory (Carlson, 2005) and Black/White Task to test inhibition (Simpson & Riggs, 2005), etc. In terms of ToM tasks, there are different versions of tests available in the developmental literature which tap into similar cognitive abilities (e.g., Carlson & Moses, 2001; Wellman & Liu).

Question 9a: Does the study involve any pharmaceutical or other compounds with physiological effects?

Notes: This includes all compounds licensed under the Medicines Act. However, some compounds may be considered as Investigational Medical Products and studies of them, therefore, as clinical trials (CTIMPs). If there is any ambiguity, investigators should contact the Medicines and Healthcare Products Regulatory Agency (MHRA) for guidance. Include any response from the MHRA in your application. CTIMPs must seek NRES approval.

The project does not include any use of pharmaceutical or compounds with physiological effects.

Question 10: What ethical issues does this study raise and what measures have been taken to address them?

Notes: Describe any discomfort or inconvenience that participants may experience. Include information about procedures that for some people could be physically stressful or might impinge on the safety of participants, e.g. noise levels, visual stimuli, equipment; or that for some people could be psychologically stressful, e.g. mood induction procedures, tasks with high failure rate. Indicate what procedures are in place if clinically relevant information arises from the study (e.g. from brain scans or questionnaire responses that might indicate that a participant is at risk).

The study does not raise any known ethical issues. Parental consent will be obtained for child participants before taking part in the study and it is extremely unlikely that they will be in any distress situation. If there is any sign of distress, testing will cease immediately. Miss Ning Ding will be responsible for visiting children in nurseries/schools in the UK and China. She has obtained annually subscribed updated DBS Enhanced check and passed training of Safeguarding Children.

A specific task of EFT (the pretzel task, Atance & Meltzoff, 2006) will involve children consuming up to 30 small salty pretzels to elicit the feeling of thirst. Before testing, researcher will check with school teachers about food allergy and make sure that children who are allergic to any ingredients of pretzel (e.g., gluten) will not participate. During the testing, children will not be forced to eat any pretzel and can stop any time during the process.

Question 11: Who will the participants be?

Notes: Describe the groups of participants that will be recruited and the principal eligibility criteria and ineligibility criteria. Make clear how many participants you plan to recruit into the study in total.

We will recruit 150 -180 children (50 – 60 children per age group) aged between 3 and 5 years in each country (China and the UK). In total, the number of participants for the whole study is between 300 to 360. Participants included in the project shall be typically developing children without cognitive deficits.

Question 12: Describe the recruitment procedures for the study

Notes: Gives details of how potential participants will be identified or recruited. Include all advertising materials (posters, emails, letters etc.) as appendices and refer to them as appropriate. Describe any screening examinations. If it serves to explain the procedures better, include as an appendix a flow chart and refer to it.

In China, we will initially contact head teachers of local schools and nurseries by letter (Appendix B) providing information about the research team and opportunities to take part in the study. This will then be followed up one week later with a phone call to the head teacher of relevant gatekeeper to seek permission to recruit participants. After obtaining the school/nursery's permission, we will send parents information sheet (Appendix D) and consent form (Appendix F) by school arrangement. Only children with signed consent forms will take part in the study.

In the UK, same recruitment procedures will be used. Firstly, local schools and nurseries will be contacted enquiring whether they would be willing for research to take place (Appendix A). Then letters containing participant information sheet (Appendix C) and parental consent form (appendix E) will be sent to the parents by school arrangement and it allows them to contact the research team for further questions. Only children with signed consent forms will participate in the study.

Please see below a summary chart of the recruitment procedure

To ensure the accuracy of translations, standard translation and back translation procedures have been applied to all documents in Mandarin Chinese. The process was completed by the corresponding applicant and an independent person who is fluent in English and a native Chinese speaker.

Question 13: Describe the procedures to obtain informed consent

Notes: Describe when consent will be obtained. If consent is from ***adult participants****, give details of who will take consent and how it will be done. If you plan to seek informed consent from* ***vulnerable groups*** *(e.g. people with learning difficulties, victims of crime), say how you will ensure that consent is voluntary and fully informed.*

If you are recruiting ***children or young adults*** *(aged under 18 years) specify the age-range of participants and describe the arrangements for seeking informed consent from a person with parental responsibility. If you intend to provide children under 16 with information about the study and seek agreement, outline how this process will vary according to their age and level of understanding.*

How long will you allow potential participants to decide whether or not to take part? What arrangements have been made for people who might not adequately understand verbal explanations or written information given in English, or who have special communication needs?

If you are not obtaining consent, explain why not.

We will send out participant information sheets (English version see Appendix C; Chinese version see Appendix D) and parental consent forms (English version see Appendix E; Chinese version see Appendix F) by school arrangement to obtain parental permission. Children will not participate in the study unless we have received the signed parental consent form. Content of the form include information about the study, use of data and researcher's contact details for parents to ask further questions. Additionally, we will verbally seek the child's assent to participate at the beginning of each session (audio or video-recorded).

Question 14: Will consent be written?

Yes

*Notes: If **yes**, include a consent form as an appendix. If **no**, describe and justify an alternative procedure (verbal, electronic etc.) in the space below.*

Guidance on how to draft Participant Information sheet and Consent form can be found on the Psychology Research Ethics Committee website.

Written parental consent form need to be obtained for each participant to take part in the study. We have prepared separate consent forms for both languages (English version see Appendix E; Chinese version see Appendix F).

Question 15: What will participants be told about the study? Will any information on procedures or the purpose of study be withheld?

Notes: Include an Information Sheet that sets out the purpose of the study and what will be required of the participant as appendices and refer to it as appropriate. If any information is to be withheld, justify this decision. More than one Information Sheet may be necessary.

At the beginning of each session, child participant will be told that he/she is going to play games with the researcher. Then researcher will explain the rules tailored for child's age-appropriate understanding level.

Question 16: Will personally identifiable information be made available beyond the research team?

Notes: If so. indicate to whom and describe how consent will be obtained.

Personally identifiable information will NOT be made available beyond the research team. All hard copy data (e.g. consent forms) will be securely stored in locked cabinets at the Department of Psychology. Each participant will have a unique ID number but no other identifiable information. Collected data will be stored in password-protected electrical files which is only accessible to members of the research team. Some participants' contact details will be stored on laptop for scheduling study sessions, which will also be password-protected and not accessible beyond the research team.

Question 17: What payments, expenses or other benefits and inducements will participants receive?

Notes: Give details. If it is monetary say how much, how it will be paid and on what basis is the amount determined.

Children from schools and nurseries will receive prizes (e.g. stickers) after each session or they can "win" through the course of the study, depending on different experimental design. Children will receive the prizes, regardless of their task performance.

Question 18: At the end of the study, what will participants be told about the investigation?

Notes: Give details of debriefings, ways of alleviating any distress that might be caused by the study and ways of dealing with any clinical problem that may arise relating to the focus of the study.

Parents (and the schools/nurseries where appropriate) will be fully informed at the beginning of the research period. Children tested in person will be verbally informed about the purpose of the study afterwards if they are interested and we will use age-appropriate language.

Question 19: Has the person carrying out the study had previous experience of the procedures? If not, who will supervise that person?

Notes: Say who will be undertaking the procedures involved and what training and/or experience they have. If supervision is necessary, indicate who will provide it.

Professor Nicola Clayton, FRS has extensive experience of psychology research in school and nursery settings and has previously supervised a number of studies of children's future thinking skills (Atance et.al., 2010; Russell et. al., 2015). Miss Ning Ding is a current PhD student from the Department of Psychology and has received extensive training on experimental design, research ethics and data analysis. The whole project is under the supervision of Professor Clayton.

Question 20: What arrangements are there for insurance and/or indemnity to meet the potential legal liability for harm to participants arising from the conduct of the study?

Notes: Insurance would normally be provided by the University's or Medical Research Council's insurance for persons employed by them or working in their institutions. Please contact the appropriate Insurance Office to arrange for insurance. If you do not have an appropriate institutional affiliation, say how you will provide public indemnity insurance, including insurance against non-negligent injury to participants. Evidence of insurance is required before a Letter of Approval can be issued.

There is no potential harm to participants and we have received the insurance cover for human volunteer studies issued by the University of Cambridge (Insurance Ref: HVS/2017/2144).

Question 21: What arrangements are there for data security during and after the study?

Notes: Digital data stored on a computer requires compliance with the Data Protection Act; indicate if you have discussed this with your Departmental Data Protection Officer and describe any special circumstances that have been identified from that discussion. Say who will have access to participants' personal data during the study and for how long personal data will be stored or accessed after the study has ended.

Data storage will comply with the requirements of the Data Protection Act. We will use unique ID numbers so that data cannot be linked back to the participants. These unique ID numbers will be used for both raw data and data stored on electronic files for data analysis. Specifically, only members of the research team will have access to the data. These data will be stored securely for a minimum of 10 years and possibly indefinitely in data archives in accordance with good research practice. Hard copy data will be kept in locked cabinets in secure office at the Department of Psychology.

Signatures of the study team (including date)

Notes: The primary applicant and all co-applicants must sign and date the form. Scanned signatures are acceptable.

The Principal Investigator and anyone on the research team with direct contact with participants during the administration of the active compounds should have a current certificate of Good Clinical Practice (GCP). Please include the certificates with the application.

[Signature redacted]	[Signature redacted]
Professor Nicky Clayton 15.12.17	Ning Ding 15.12.17

Appendix C

Letter to nursery and school

UNIVERSITY OF CAMBRIDGE
Department of Psychology

Comparative Cognition Lab
Web: https://www.psychol.cam.ac.uk/ccl/
Principal Investigator: Professor Nicky Clayton
Email: [information redacted]
Phone: [information redacted]

Dear Head Teacher,

We are a team of researchers in the Department of Psychology at the University of Cambridge, working in Professor Nicky Clayton's (Fellow of Royal Society) research group on developmental cognition. Our current research project explores the development of children's future thinking skills. The study has been reviewed and approved by the Cambridge Psychology Research Ethics Committee (PRE.2017.108).

This research is important because we want to understand how future-oriented cognition is developed in children. Prospection is the hallmark to human species and the ability seems to develop in children between 3 and 5 years old. However, there are many remaining questions about the cognitive mechanisms underlying its development and the factors accounting for individual differences in future thinking skills. Our project has a special focus on British and Chinese children since there has been no systematic investigation on how children from different cultures develop the ability to think and plan for future.

We are currently looking for children aged 3-5 years to participate in our research and we would like to conduct the study in nurseries during normal nursery hours. Children will be taken out of class for 2 non-consecutive sessions each lasting 30-45 minutes. Our researcher (who passed DBS enhanced check and children's safeguarding training) will see the children on a one-to-one basis. The study involves engaging behavioural tasks, like playing games of future planning and selecting items for future use. We will also measure children's ability to process information and regulate behaviours. Children will receive stickers at the end of study.

We would greatly appreciate if you could agree taking part. We plan to start the research in March 2019. If you decide to participate, please do not hesitate to email me, Ning Ding, on the address given below. We will provide you with printed consent forms for parents to sign and envelopes for returning them. Should you have any questions, we would also be very happy to call you or visit your nursery to discuss it further.

Please do let us know if you require any more information and feel free to contact us on [information redacted] or phone [information redacted].

We look forward to hearing from you.
Thank you.
All the best,

Professor Nicky Clayton, Miss Ning Ding and the team
Tel: [information redacted]
Email (Ning Ding): [information redacted]

Appendix D

Participant information sheet

UNIVERSITY OF CAMBRIDGE
Department of Psychology

Comparative Cognition Lab
Web: https://www.psychol.cam.ac.uk/ccl/
Principal Investigator: Professor Nicky Clayton
Email: [information redacted]
Phone: [information redacted]

Dear Parent or Guardian,

The Head Teacher at [nursery/school name], has kindly given me permission to contact you about a research project currently being carried out by the Comparative Cognition Lab at the University of Cambridge, led by Professor Nicky Clayton. This project aims to provide insight into the cognitive development in preschoolers aged 3 to 5 years. It will investigate how children develop different future thinking skills. (The following sentence will be added after receiving ethics approval: The study has received ethical approval from the Cambridge Psychology Research Ethics Committee (PRE.2017.108). If your child is within this age range (3-5 years), having him or her take part would be a great help to the project!

What does the study involve?
Your child will be given a series of fun tasks assessing their future thinking skills. The research phase will take place during nursery/school hours. Children will be taken out of class for two non-consecutive sessions (each lasting 30 - 45 minutes) to take part in the study and return to classroom afterwards. These activities are specifically designed for preschoolers and children enjoy participating. For example, children will engage in future planning activities, play games of future planning and select items for future use. There will be no direct physical contact between the researcher and the child and the study does not involve touching the child. Your child will receive stickers for their participation.

How will the data be used?
The study data are for research purposes only. Your child will not be individually identifiable. The overall data will be reported at a group level at professional conferences, in academic books or articles, and in short reports to the schools/nurseries taking part.

Will my results be kept confidential?
The data collected will remain anonymous and any personal information will stay confidential. We will store data using random ID numbers so that the data cannot be linked back to you or your child. The data will be stored on secured electronic files or in a locked cabinet in the Department of Psychology, and will be accessible only by researchers in the Comparative Cognition Lab. Information about how the University uses personal information can be found at: https://www.information-compliance.admin.cam.ac.uk/data-protection/research-participant-data.

How to participate in this research?
If you are willing for you and your child to take part in this study, please complete and sign the following consent form and return it to the nursery/school. Your child will be asked if they want to take part at the beginning of each session (audio or video-recorded). We will also ask your consent for video recording the sessions in the enclosed consent form. Children who do not want to participate will return to their classroom. You and your child may withdraw at any time without explanation. If you have any question about the study, please do not hesitate to contact me.

Thank you for your time,

Ning Ding
Comparative Cognition Lab
Email: [information redacted]
Phone: [information redacted]

Appendix E

Consent form

UNIVERSITY OF CAMBRIDGE
Department of Psychology

CONSENT FORM PSYCHOLOGY STUDY – TO BE RETURNED TO THE NURSERY

I confirm that I have read the information provided and give permission for me:

___________________________ (parent's name) and my child: _____________________________ (child's name) to take part in this study.

Child's Date of Birth: ______________

Child's Gender: ___________________

Year Group: _________________________

Signed _________________________________ Date: _____________________________________

Relationship to child: ________________________________

OPTIONAL: VIDEO PERMISSION

Do you consent to your child being video recorded for **research purpose?** Only researchers from the Comparative Cognition Lab will have access to the videos:

YES ☐ NO ☐

Do you consent to your child being recorded and the video being used for **academic conferences?** Only researchers from the Comparative Cognition Lab will have access to the videos. All videos presented at conferences will be anonymous. Children's faces will be pixelated and they would not be identifiable.

YES ☐ NO ☐

Please see below for the contact details of the contact researcher and I am happy to answer any questions you may have.

Miss Ning Ding
Comparative Cognition Lab
Department of Psychology
Email: [information redacted]
Phone: [information redacted]

For Researcher Only

Has the child participant give consent at the beginning of each session?

Session one ❑ YES ❑ NO

Session two ❑ YES ❑ NO

Appendix F

Task protocol

Measures of Executive Function

Day-Night (Gerstadt, Young, Diamond, 1994): This task is a classic stroop-like verbal cognitive inhibition task. The experimenter firstly showed the child the "day" card (picture of the sun) and the "night" card (picture of the moon) and they were asked to identify the objects on the cards. The experimenter then explained the rules and children were instructed to say "day" for the night card and "night" for the day card. A total of 16 cards were shown one at a time in a pre-fixed pseudo-random order. There were 2 practical trials with one trial of each picture card to ensure that the children understand the rules. If they failed, the experimenter would repeat the instructions followed by 2 additional practice trials. Accuracy out of 16 trials were recorded.

Grass-Snow (Carlson & Moses, 2001): This was a variant version of the Day-Night task. Children were firstly asked to name the colour of grass and snow. Then the experimenter introduced one green paper and one white paper and asked children to point to the green paper when they heard the word "Snow" and to the white paper when "Grass" was spoken. Children received two practice trials and repeated instructions if necessary. Accuracy out of 16 trials was recorded.

Knock-Tap (Luria, 1966): This motor inhibition task taps into children's ability to inhibit established motor movement and prepotent responses evoked by visual stimuli. In the first part of the study, children were asked to mimic the experimenter's hand movement. After passing 8 consecutive trials, children were asked to perform the opposite hand movement from the experimenter. Specifically, to tap on the table with an open palm when the experimenter knocks on the table with a fist, and vice versa. The motor inhibition score was recorded as the total number of correct trials out of 15 trials.

Dimensional Change Card Sort (DCCS, Zelazo. 2006): This task measured cognitive flexibility and children were asked to sort 12 cards in two sets based on a rule of colour or shape of the pictures. After the first set of six cards, the rule switched and children were required to sort the second set of cards by a different rule. The order of sorting rule was counterbalanced; half the children started with colour and switched to shape whereas the other half started with shape and switched to colour. The number of correct responses in the post-switch phase (out of 6 trials) was recorded.

Spin the Pots (Hughes & Ensor, 2005): This task assessed children's working memory. The experimenter first introduced 8 visually distinct pots differing in colour and placed them on a lazy Susan rotating tray. Children were shown that there were 6 stickers, each was hidden under one pot with two pots remaining empty. The experimenter then covered the whole display with a cloth and spun it around and children were asked to retrieve the stickers one by one. In each trial, children must choose one pot after the spinning has stopped and cloth removed. The task ended when all six stickers have been found or the children have reached a maximum of 12 attempts. Children's working memory was calculated as 12 minus the number of errors made.

Forward Digit Span (Davis & Pratt,1996): This test was conducted as an assessment of short-term memory and as a warm-up for the following backward digit span task. Participants were asked to repeat a series of single digit in the exact same order after they were read out loud by the experimenter. For example, 6-9, 5-8-2, 5-2-8-3, 1-3-6-2-9. The highest number of digits remembered and recalled was recorded.

Backward Digit Span (Davis & Pratt,1996): Participants were presented with a random string of single digits and were instructed to repeat the string of digits in reverse order. The strings began with two digits and a correct response led to the next string being one digit longer, for example, 3-5, 4-9-5, 1-9-6-2, 7-3-5-1-9. Participants received two practice trials with feedback prior to test trials to make sure they understand the rules. The test stopped when participants errored on two consecutive trials and the highest level of success (number of digits recalled) were recorded.

Measures of Theory of Mind

Diverse Desire (Wellman & Liu 2004): The experimenter first introduced a toy figure "Mr Bear" and children were shown a picture of orange juice and a picture of milk. They then answered a question of their own desire "which drink do you like best, orange juice or milk?". Whichever drink the children chose, the experimenter told the children "Mr Bear doesn't like [drink the child chose] and Mr Bear really likes [other drink]. Mr Bear is thirsty, which drink will Mr Bear choose?". The order in which the drinks were named was counterbalanced and children received a score of 1 if they correctly responded to the question with the opposite drink from their own desire (total score range: 0-1).

Diverse Belief (Wellman & Liu 2004): Children were shown a toy figure and pictures of a bed and a basket. The experimenter said "Here is Thomas and he wants to find his bunny. His bunny might be hiding under the bed or it might be hiding in the basket." The children were then asked "Where do you think Thomas's bunny is hiding, under the bed or in the basket?".

Whichever location the children chose, the experimenter told them that Thomas thinks the bunny is hiding in the opposite location and asked the target question: “So where will Thomas look for his bunny, in the basket or under the bed?” The order in which the locations were named was counterbalanced and children received a score of 1 if they answered correctly to the target question with the opposite location given to their own belief (total score range: 0-1).

Knowledge Access (Pratt &. Bryant, 1990): Children were shown a miniature wooden box containing a small plastic toy. The experimenter asked the children: “what do you think is inside the box” (the child could give any answer they like or say I don’t know). Next, children were invited to open the box and see what was inside and play with it. The experimenter then closed the box and asked: “Okay, what is in the box?” A toy figure named “Polly” was introduced and the experimenter asked children the target question: “Polly has never ever seen inside the box. Now comes Polly. So, does Polly know what is in the box?”, followed by a memory question: “Did Polly see inside the drawer?”. Children need to correctly answer both the target and memory questions to be given a score of 1 (total score range: 0-1).

False Belief Change of Content (Flavell, Green & Flavell, 1989): The experimenter showed the children a closed egg box with a label and a clear image of chicken eggs on the surface, however box contained bouncy balls instead. After asking the children: “What’s inside the box?”, the experimenter opened the box, revealed the bouncy balls and encouraged them to play with the toys. Next, the box was closed with the bouncy balls inside, and the experimenter asked the representational change question: “Before you looked inside, what did you think was inside the box?”, followed by the reality control question “what’s in the box really?”. The children were then asked the false belief question: “your friend hasn’t seen what’s inside this box, if they see this box all closed up, what will they think is inside it, eggs or balls?”. To receive a score of 1, children need to correctly answer all three questions (total score range 0-1).

False Belief Change of Location (Baron-Cohen, Leslie & Frith, 1985): Children were told a story that was demonstrated by the experimenter with two playmobile characters (“Su” and “Shaun”), a little box, a basket with a blanket and a little ball. Shaun first played with the little ball and put the ball in the box before going play outside. Su entered the room and took out the ball from the box to play then put it in the basket and covered it with cloth, then went outside. At this point, the children were asked three forced-choice control questions to assess their memory of the story. If the children failed to answer all three questions correctly, the experimenter would repeat the process to ensure that they understand the story. The task would terminate after the children’s failure to pass the memory control questions after the second attempt. Next, the experimenter continued the task by saying that Shaun has returned to the room and he wanted to play with the ball. Children were then asked the false belief prediction question: "Where will Shaun look for his ball?". The experimenter then demonstrated that Shaun went to the box and opened it, but it was empty. Lastly, the children were asked the false belief explanation question: "why did Shuan look for his ball in the box?". A score of 1 was given if the children correctly responded to both the false belief prediction and false belief explanation question (total score range 0-1).

Measures of Language Ability

British Picture Vocabulary Scale (BPVS 3rd edition, Dunn & Dunn, 2009): This test measured the breadth of participants' vocabulary knowledge. In each trial, participants were asked to select one out of four pictures that best corresponded the meaning of a word read out loud by the experimenter. Each participant received a number of vocabulary sets depending on their language ability and the test stopped when participants errored on eight out of the 12 trials within a set. The test was administered and raw and standardised scores were calculated based on the guidelines in the BPVS manual.