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Inhibition and cognitive flexibility are related to prediction of one's own future preferences in young British and Chinese children

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ABSTRACT

The ability to shift from current to future perspective is pivotal to future-oriented cognition. With two distinct cultural groups, UK ($N = 92$) and China ($N = 90$), we investigated 3 to 5-year-olds' understanding of preference changes occurring within themselves and their peers (another child). We administered a battery of representative tasks of executive function and theory of mind to examine their underlying relationships with children's ability to predict future preferences. British 3-year-olds outperformed Chinese children in predicting future preferences, while no country differences were observed between the 4- and 5-year-olds. Across the UK and China, children were more accurate when predicting for their peers than for themselves. They were also more accurate when their current preferences were identified first, i.e. before answering questions about the future. Chinese children outperformed their British counterparts on inhibition and cognitive flexibility tasks whereas there were no Eastern and Western differences in their theory of mind abilities. After controlling for age and children's knowledge of generic adult preferences, children's performance in the inhibition and cognitive flexibility tasks were significantly correlated with the prediction of their own future preferences, but they were not significantly correlated when predicting for a peer. These results are discussed in relation to the conflicts between multiple perspectives and the cognitive correlates of future-oriented cognition.

1. Introduction

Thoughts about the future have an important place in human life and anticipation of how the future will unfold can influence behaviour in various ways (D'Argembeau, Renaud, & Van der Linden, 2011). The preschool years have been found to be a critical period for children's development of many cognitive milestones, including future-oriented cognition. Over the past two decades, research has indicated that young children are able to delay immediate gratification for a better reward in the future (Prencipe & Zelazo, 2005), select tools or save resources for a future need (Atance, Metcalf, & Thiessen, 2017; Russell, Alexis, & Clayton, 2010; Suddendorf, Nielsen, & Von Gehlen, 2011), anticipate physiological states (Atance & Meltzoff, 2006), understand knowledge growth (Atance & Caza, 2018) and talk about future events (Hudson, 2006; Zhang & Hudson, 2018).

A recent line of research has focused on children's reasoning of changes in preferences, specifically the contrast between current and future preferences. Decision making is impaired by inaccurate predictions about the way in which preferences, values and feelings change over time (Gilbert & Wilson, 2007). Among adults, there was a tendency to underestimate the extent of changes that often lead to projection bias and regrettable choices (Loewenstein & Angner, 2003; Quoidbach, Gilbert, & Wilson, 2013). In pre-schoolers, Bélanger, Atance, Varghese, Nguyen, and Vendetti (2014) designed a task to assess young children's prediction of changes in future preferences. This task involved showing pre-schoolers child-preferable and adult-preferable items then asking them to choose which they preferred at present and in the future. Older children were increasingly better at predicting that they would hold different preferences when they grow up, whereas 3-year-olds' decisions on future preferences were largely restricted by their current ones.

Children's ability to understand preference changes for another individual (e.g. a same-aged peer) has also been shown to improve with age (Bélanger et al., 2014). More importantly, there was an 'other-over-self-advantage' in which pre-schoolers were more accurate in predicting

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the future preferences for their peers compared to themselves. Notably, such an effect has been found in subsequent studies adopting the same paradigm (Lee & Atance, 2016), as well as tasks assessing different components of children's future-oriented cognition. For example, when choosing the correct items for future use from a different spatial perspective, 4-year-olds, but not 3- or 5-year-olds, were better at selecting for a peer than for themselves (Russell et al., 2010). Similarly, children aged between 3 and 7 had difficulty in overcoming the salient state of thirst and predicting their own future physiological states, but they had more success when predicting for another person, namely the experimenter in the "pretzel task" (Mazachowsky, Koktavy, & Mahy, 2019). This pretzel task involves first inducing the feeling of being thirsty when children were given salty pretzels to eat, then they were asked whether they would like pretzels or water for tomorrow (Atance & Meltzoff, 2006). Research indicates that both children's and adults' predictions were heavily influenced by their current physiological state (Kramer, Goldfarb, Tashjian, & Lagattuta, 2017; Martin-Ordas & Atance, 2021). The other-over-self-effect has also been reported using a delay of gratification paradigm (Prencipe & Zelazo, 2005). Specifically, pre-schoolers who adopted a third-person perspective made more future-oriented decisions, i.e., selecting the delayed and better reward, whereas children adopting the self and first-person perspective made more impulsive decisions.

Despite the growing body of literature on pre-schoolers' development of future-oriented cognition, two areas remain largely under investigated. First, data has primarily come from Europe or America. To our knowledge, only two studies have examined and contrasted future-oriented cognition between different cultures. In comparing children from an Australian urban area and two rural communities, the Indigenous Australian and the South African Bushman, the overall developmental trajectory of children's ability to understand and prepare for alternative future possibilities did not differ (Redshaw et al., 2019). On the contrary, 4-year-old Rural Cameroonian Nso pre-schoolers demonstrated greater capacity of delay of gratification than their German peers from urban areas in the classic Marshmallow test (Lamm et al., 2018; Mischel & Ebbesen, 1970).

Cognitive development is a malleable and context-specific process, which is sensitive to social and cultural influences (Henrich, Heine, & Norenzayan, 2010; Wang, 2016). Few studies have tested children's future-oriented cognition from other cultures. Therefore, the existing body of knowledge of its developmental trajectory and cognitive correlates could be culturally skewed and biased, hence more effort is needed to examine cognitive development outside of Western societies (Nielsen & Haun, 2016).

Notably, cross-cultural research has tended to focus on the comparisons between children from collectivistic cultures, i.e. Chinese backgrounds, and children from individualistic countries, i.e. European American societies (Sabbagh, Xu, Carlson, Moses, & Lee, 2006; Wang, 2018). 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, 2010). The contrast between "I" versus "We" culture has been supported by cross-cultural variations in memory, attention and perception (Cohen & Kitayama, 2007; Greenfield, Keller, Fuligni, & Maynard, 2003). Furthermore, Chinese adults have shown other-oriented bias in contrast to Western counterparts who typically demonstrated greater egocentric bias in a visual perspective-taking task (Kessler, Cao, O'Shea, & Wang, 2014; Wu & Keysar, 2007). Therefore, testing the future preference task - a perspective-taking task of future mental states - with Chinese and British pre-schoolers makes a unique contribution to the field by studying future-oriented cognition through the developmental as well as the cultural lens.

Less is known about the cognitive correlates of future-oriented cognition and its underlying mechanism compared with the rich literature on age-related increase in performance during the pre-school years (Atance, 2015; Clayton, 2014). Theory of mind and executive function have both been proposed to be related to children's future-oriented cognition (Buckner & Carroll, 2007; Suddendorf & Corballis, 2007). Given the well-established East versus West differences in executive function and theory of mind, cross-cultural research offers the ideal testing ground to explore the cognitive domains underlying children's ability to understand and plan for the future.

The first account, proposed by Buckner and Carroll (2007), suggests that episodic memory, episodic future thinking, theory of mind and spatial navigation rely on a common cognitive mechanism of self-projection. This self-projection account proposes that the ability to disengage from the immediate present and to shift perspective to alternative temporal, mental and spatial situations is supported by these different yet overlapping cognitive capacities. Theory of mind refers to the ability to perceive and attribute different internal mental states in oneself and others, which includes an understanding of desires, beliefs, emotions, knowledge and intentions (Wellman, Cross, & Watson, 2001). Intuitively, the centrality of future-oriented cognition and theory of mind both involve a shift in perspective. 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 to facilitate the ability to anticipate mental states changes within the same person at different temporal points. Indirect evidence on the self-projection account and relationship between theory of mind and future-oriented cognition comes from studies highlighting their parallel developmental timing (Atance & O'Neill, 2005; Perner, Kloo, & Gornik, 2007; Suddendorf et al., 2011; Wellman & Liu, 2004), as well as their common neural networks and structures (Addis, Wong, & Schacter, 2007; Spreng, Mar, & Kim, 2009).

Several studies have directly tested the relationship between theory of mind and future-oriented cognition in children. 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 capacity to remember and act upon future events (Ford, Driscoll, Shum, & Macaulay, 2012). However, Hanson, Atance, and Paluck (2014) failed to find an association between performance on standardised theory of mind tasks and children's ability to anticipate future physiological states, plan for future needs and judge temporal distance of future events. Further, a recent study, using a latent analytic approach, did not find support of a common multidimensional latent factor underlying the various abilities of episodic memory, episodic future thinking, theory of mind and spatial navigation (Immel, Altgassen, Meyer, Endedijk, & Hunnius, 2022).

Children growing up in Western societies generally outperform their peers in Eastern countries on theory of mind tasks (Hughes, Devine, & Wang, 2018; Oh & Lewis, 2008), or have cultural-specific developmental sequences (Duh et al., 2016; Shahaeian, Peterson, Slaughter, & Wellman, 2011; Wellman, Fang, Liu, Zhu, & Liu, 2006; Wellman & Liu, 2004). Additionally, a large-scale meta-analysis reported parallel developmental trajectories among children from Mainland China, Canada and United States (Liu, Wellman, Tardif, & Sabbagh, 2008). However, there were substantial variations in the timing of passing false belief tests in different countries, particularly among pre-schoolers from Hong Kong. If the self-projection account holds, specifically that future-oriented cognition is linked with theory of mind, one might expect that children's performance on the future preference task would be associated with theory of mind ability, given that predicting changes in future preferences involves attributing mental states across different people. Furthermore, if any cultural differences in future prediction ability were supplemented by corresponding cultural differences in theory of mind, this would provide evidence to support the self-projection account and the link between mental states attribution and future-oriented cognition. For example, British children outperforming Chinese counterparts on both future preference task and theory of mind measures.

The second account of cognitive correlates in future-oriented cognition suggests that executive function, especially inhibitory control, scaffolds children's ability to make future-oriented decisions (Atance & Jackson, 2009; Suddendorf & Corballis, 2007). Executive function refers to a set of higher-order cognitive abilities and is considered to be a unitary construct in children comprising of three key components: working memory, cognitive flexibility and inhibition (also referred as inhibitory control) (Hughes, 2011; Miyake et al., 2000). In particular, inhibition enables control of attention and behaviours and suppression of prepotent responses in order to select the most appropriate responses for different circumstances (Diamond, 2013). This is a highly relevant ability in future-oriented scenarios when both the current and future perspectives are involved, as people need to put aside their current feelings and desires to make adaptive decisions (Atance & Jackson, 2009). Furthermore, when thinking about the future, it is important to keep track of multiple perspectives (i.e. working memory) while being able to flexibly shift and coordinate the different demands (i.e. cognitive flexibility).

This second account emphasizes the role of conflicts in future-oriented cognition. Several researchers have argued that the conflicts experienced by children between their current states and future states underlie the difficulty with accurate future-oriented reasoning (Atance & Meltzoff, 2006; Atance, Rutt, Cassidy, & Mahy, 2021; Bélanger et al., 2014; Mahy et al., 2020; Mahy, Masson, Krause, & Mazachowsky, 2020). 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. This would help to reduce the cognitive resources for coordinating different perspectives and benefits children's predictions of future psychological and physiological needs (Lee & Atance, 2016; Mazachowsky et al., 2019). Based on this account, a possible means of reducing conflicts between future and current perspectives would be to satiate children's current needs. For instance, preschoolers 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). Similarly, children who were asked to indicate their current preferences before predicting future preferences outperformed their peers who were first asked to select the items they would like in the future (Bélanger et al., 2014).

Although neuroimaging studies have found executive function and future-oriented cognition share overlapping cortical areas (Stuss & Alexander, 2000; Szpunar, Spreng, & Schacter, 2014), findings from developmental literature were mixed. Children's ability to select items from a different spatial perspective for future use was related to inhibition and spatial working memory after controlling for age (Ünal & Hohenberger, 2017). Moreover, prospective memory was positively predicted by school-aged children's inhibition (Ford et al., 2012). Contrarily, children's executive function competency and ability to plan future tool use was unrelated (Miller et al., 2020). With a battery of standardised tasks measuring future-oriented cognition and executive function, Hanson et al. (2014) did not find significant inter-task correlations among pre-schoolers.

In cross-cultural research, one clear and consistent finding is that pre-schoolers from Chinese cultural backgrounds typically outperform their Western peers on measures of executive function, especially on inhibition tasks (Lan, Legare, Ponitz, Li, & Morrison, 2011; Lewis et al., 2009; Sabbagh et al., 2006, Xu, Ellefson, Ng, Wang, & Hughes, 2020; for a review, see Schirmbeck, Rao, & Maehler, 2020). To this end, testing executive function and future preference task using a cross-cultural design provides a unique position that facilitates elucidating the cognitive correlates of future-oriented cognition. First, if conflicts between multiple perspectives underline the difficulty in future anticipation, children's executive function ability, particularly conflict inhibition and cognitive flexibility, would be related to their performance in the future preference task when conflicting perspectives are involved. Research indicates that executive function was most relevant when one's own perspective was involved (Fizke, Barthel, Peters, & Rakoczy, 2014). Moreover, if children with better executive function ability, i.e., Chinese pre-schoolers, also consistently outperform their peers on the future preference task, this could be interpreted as evidence to support the role of executive function in future-oriented cognition.

In light of the need to identify the cognitive correlates of future-oriented cognition and understand whether children develop comparable future prediction ability in different cultures, the current study adopted the future preference task (Bélanger et al., 2014). This task involved attribution of future mental states (potentially linking to theory of mind ability) as well as conflicting perspectives between current and future states (potentially linking to executive function ability). Specifically, this task consisted of two baseline conditions focusing on current preferences ('self-now', 'peer-now') as well as three experimental conditions with two test conditions focusing on future preferences ('self-future', 'peer-future') and one control condition assessing children's general knowledge of adults' preferences ('adult-now'). The order of testing was counterbalanced so that 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 more stringent within-subjects design for conditions, reducing any potential participant variations between groups.

Based on previous literature using the future preference task, pre-schoolers were predicted to perform better when predicting future preferences for a same-aged 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 taking 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 on inhibitory control tasks (Lan et al., 2011; Sabbagh et al., 2006). Finally, we expected that the children from both countries would show age-related increase in performance reflecting their understanding of preference changes within themselves and a peer of the same age. Given the lack of research and exploratory nature of the current study, we made no specific predictions regarding country-related differences on the future preference task.

2. Methods

2.1. Participants

The participants were 182 children aged between three and five-years-old. In the UK, 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. The British participants were recruited at nurseries and schools in Northeast Somerset and central London, which served predominantly white, middle-class backgrounds. All children that participated in the British site were from non-Asian backgrounds. 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 from a university-affiliated public nursery in Kunming, Yunnan Province - a typical regional and new first tier city based on its population, economy and urbanisation (Wu, Cheng, Liu, Han, & Yang, 2015). All Chinese participants belonged to the Han group, the most dominant ethic group in China. The UK data collection took place from March to July 2019, and the Chinese data collection took place from October to December 2019. All participants were typically developing children.

2.2. Ethics

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). Information sheets and consent forms were provided to parents and written parental consent was obtained prior to participation of the children. We also obtained written consent from parents to video-record the experimental sessions.

2.3. Procedure

The study included a single experimental session of 45 mins 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 task, Gerstadt, Hong, & Diamond, 1994; Knock-Tap task, Luria, 1966), working memory (Spin the Pots task, 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, Green, & Flavell, 1989) and False Belief Location (Baron-Cohen, Leslie, & Frith, 1985). The brief task descriptions were outlined in Table 1 and detailed protocol was included in the Appendices. 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 1).

Table 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.
Dimensional Change Card Sort (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 was 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.

2.4. 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 previously 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 items that they liked for themselves or for a peer. The task consisted of baseline conditions and experimental conditions, and children were given specific verbal instructions accordingly. There were two baseline conditions involving questions of current preferences. Specifically, in the self-now baseline conditions, 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 adult-now condition. 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 the 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?". 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. 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 studies on children's future-oriented cognition have also predominately adopted verbal instructions (McCormack & Hoerl, 2020).

Each condition consisted of five trials and children completed all five 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. Notably, we used actual items, not pictures of items, in all trials. A within-subject 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 experimental 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. 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 fifteen pairings of items that created across three different categories with six pairs in the Drink & Snack category, five pairs in the Reading & Watching category, and four 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 fifteen pairings were then evenly grouped into three sets with five pairings in each group, ensuring that each group covered all three categories of items. Across the three 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 current and future 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 understood that their future preferences would be different by selecting the corresponding adult-typical items in the test trials. The three groups of item parings across conditions were counterbalanced so that 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 was conducted to ensure the selected items were suitable and representative. A full list of item pairings is presented in the Appendices (Table B.1).

2.5. Analysis plan for the future preference, executive function and theory of mind tasks

In the future preference task, there were five 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. This represents a standard scoring approach in previous studies using the future preference task (Atance et al., 2021; Bélanger et al., 2014; Kopp, Hamwi, & Atance, 2021; Lee & Atance, 2016). Moreover, in the current study, 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 four or five child-preferable items correctly. It is also worth noting that these percentages were not dropout rates, but rather indicated the proportions of children who correctly selected four or five trials in the baseline conditions. No children failed all baseline trials. Also, the percentages from the current study were comparable, if not higher overall, than the 85% reported in Bélanger et al. (2014) original study. All experimental sessions were live coded as well as video recorded unless parents requested no recording. A random selection of 10% ($N = 20$) of videos was coded for inter-rater reliability and Cohen's Kappa test shown excellent inter-observer rating agreement, $\kappa = 0.902$, $p < .001$.

Two scoring methods were adopted to analyse children's performance in the future preference task. Firstly, 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 are statistically robust in analysing binary data with unequal trials for each participant (Ibrahim, Chen, & Lipsitz, 2001; Ng, Carpenter, Goldstein, & Rasbash, 2006), so particularly suitable for the future preference task as the number of test trials for each child depended on their performance in the baseline conditions. Secondly, as the standard method and consistent with prior related 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 five). The proportional scoring method resulted in a single score ranging from 0 to 1 per experimental condition per participant. This approach allowed correlational analysis between performance in the future preference task, executive function and theory of mind tasks (Atance et al., 2021; Hanson et al., 2014), whereas dichotomous responses were less commonly used and less robust for correlational analysis.

GLMM analysis was conducted (using R version 3.4.3) to assess which factors influenced children's success rate in the future preference 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 included age (continuous: age in years with two decimal places), condition (self-now, peer-now, self-future, peer-future, adult-now), country (China, UK), sex (male, female), order (baseline then test, test then baseline), interaction effect of country and condition, interaction effect of condition and age, interaction effect of country and age, trial type (baseline, test) and trial number (1–25). Two separate models were run: 1. all trials; 2. test trials only. 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, Kliegl, Vasishth, & Baayen, 2015). We ran further analyses for the significant variables identified in the GLMMs where applicable, using Tukey contrasts for pairwise comparisons, and to compare performance against chance using binomial tests. 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 included all trials were reported in the Appendices (Table C.1).

Generalized Linear Models (GLM) were adopted to investigate age (continuous: age in years with two decimal places) and country's influence on children's performance on the executive function tasks as well as the composite score of theory of mind tasks. Also, we adopted Tukey contrasts for pairwise comparisons for significant variables identified in the GLM where applicable. For individual theory of mind task that measured with binary outcomes, Chi-square tests were conducted to examine which factors affected children's performance. 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. We conducted both zero-order correlations, as well as Pearson product-moment correlations controlled for children's age and performance on the adult-now trials.

3. Results

3.1. Children's performance in the future preference task

In the experimental trials only, the full model differed significantly from the null model ($X^2 = 345.85$, df $= 5$, $p < .001$). There were

Table 2
Output from generalized linear mixed models.

Fixed term	Chi-square	df	*p*-value
Age	79.584	1	**< .001**
Country	4.612	1	**.032**
Condition	220.38	2	**<.001**
Order	44.604	1	**<.001**
Sex	1.7006	1	.192

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

significant main effects of age, country, condition and order on success rate (Table 2). There were no significant main effect of sex on success rate. The full models with the interaction terms (added separately) of Country: Condition ($X^2 = 0.73$, df = 2, $p = .692$) and Age: Condition ($X^2 = 2.887$, df = 2, $p = .236$) were not significantly different to the model with main effects only. Additionally, the full model with the interaction term (Age: Country) encountered an issue of non-convergence so model estimates were considered to be untrustworthy (Bates et al., 2015; Bolker et al., 2009). Therefore, none of these interaction effects significantly improve the model and the final model reported (full model of main effects only) was the best fit (Table 2). The dataset and analysis script are available at https://doi.org/10.6084/m9.figshare.22044404.v1.

Across all experimental trials, children's performance improved with age (Tukey contrasts: age 4 vs age 3: $z = 1.066$, $p < .001$; age 5 vs age 3:

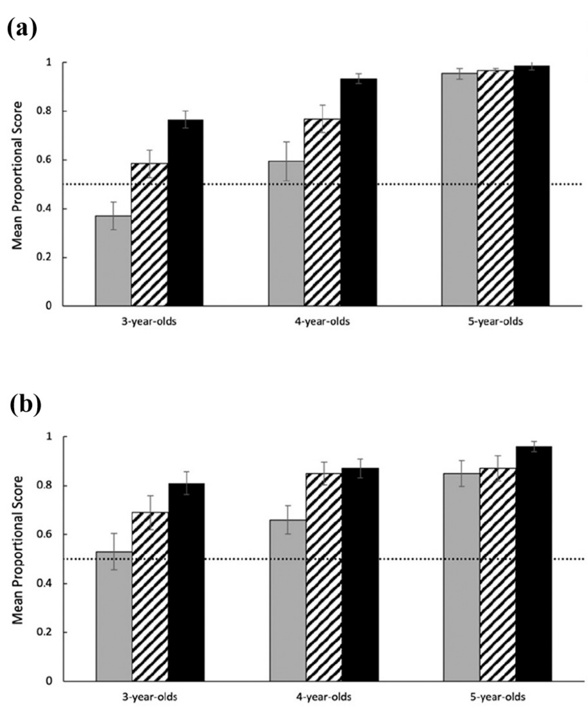

Fig. 1. a: Children's proportional scores for each age group by experimental conditions in China. Error bars represent standard errors of the mean proportional scores. Reference line corresponds to chance responding (i.e. mean proportional score of 0.5). b: Children's proportional scores for each age group by experimental conditions in the UK. Error bars represent standard errors of the mean proportional scores. Reference line corresponds to chance responding (i.e. mean proportional score of 0.5).

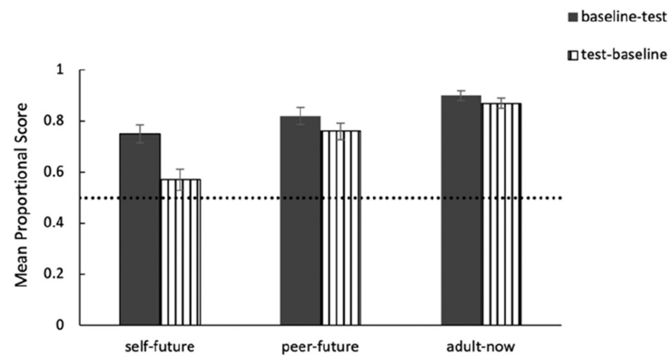

Fig. 2. Children's proportional scores for testing order 1 (baseline-experimental) and order 2 (experimental-baseline) by conditions. Error bars represent standard errors of the mean proportional scores. Reference line corresponds to chance responding (i.e., mean proportional score of 0.5).

$z = 2.935$, $p < .001$; age 5 vs age 4: $z = 1.868$, $p < .001$). Overall, taken across all age groups, British children outperformed Chinese children (China vs UK: $z = -2.162$, $p = .031$). Specifically, within age groups, there was a significant difference between the 3-year-olds (Tukey contrasts: China age 3 vs UK age 3: $z = -3.41$, $p < .001$, Fig. 1 a and b), but not the 4- and 5-year-olds (China age 4 vs UK age 4: $z = 0.425$, $p = .671$; China age 5 vs UK age 5: $z = 0.771$, $p = .441$, Fig. 1 a and b).

Performance was poorer when children answered questions of future preferences first before the baseline conditions (order 2), compared with children who were asked about their current preferences first then followed by the experimental conditions (order 1) ($z = -6.537$, $p < .001$, Fig. 2). Between the experimental conditions, children's performance was highest in the adult-now trials, then in peer-future trials and lowest in the self-future trials (adult-now vs self-future: $z = 13.737$, $p < .001$; adult-now vs peer-future: $z = 7.612$, $p < .001$; peer-future vs self-future: $z = 7.075$, $p < .001$, Fig. 1 a and b). Furthermore, binomial tests were conducted to compare children's performance against chance level (set at 0.5). All age groups' success rate were above chance level (all $p < .001$), except for the 3-year-olds who performed at chance level in order 2 (experimental-baseline) ($p = .056$). Percentages of correct choices in the future preference task at trial level were presented in Table 3. Results using baseline and experimental trials combined dataset were presented in the Appendices (Table C.1).

3.2. *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 tasks were presented in Table 4. GLM analysis found that age was a significant predictor for children's performance for all executive function tasks and the composite score of theory of mind tasks, with older children showing increasingly higher performance in all tests (Table 5). Specifically, across countries, pairwise comparisons suggested that 5-year-olds significantly outperformed 4-year-olds and 3-year-olds respectively on all executive function tasks as well as in the composite score of theory of mind tasks (all $ps < .001$). For individual theory of mind tasks, Chi-square tests indicated that children's performance only varied as a function of age (Diverse Desire: $X^2 = 30.84$, $n = 182$, $p < .001$; Diverse Belief: $X^2 = 25.89$, n = 182, $p < .001$; Knowledge Access: $X^2 = 73.02$, n = 182, $p < .001$; False Belief Content: $X^2 = 83.09$, n = 182, $p < .001$; False Belief Location: Knowledge Access: $X^2 = 68.06$, n = 182, $p < .001$).

Table 3
Percentages of correct choices in future preference task separated by age group, country and condition.

	UK			China		
	self-future	peer-future	adult-now	self-future	peer-future	adult-now
3-year-olds	47.2	62.8	77.3	35.5	56.6	78.7
4-year-olds	58.8	83.4	91.3	56.2	74.0	93.3
5-year-olds	86.1	87.1	98.7	94.6	97.3	98.5

Table 4
Descriptive statistics of executive function and theory of mind tasks.

Task	3-year-olds	4-year-olds	5-year-olds
Executive function			
Day-Night (range = 4–16)	9.32(2.78)	11.61(2.67)	13.82(1.92)
Knock-Tap (range = 4–15)	10.15(2.66)	12.27(2.17)	13.80(1.46)
Spin Pots (range = 4–12)	7.02(2.18)	8.76(2.45)	10.32(1.73)
DCCS (range = 0–6)	3.40(1.28)	4.92(1.46)	5.58(0.96)
Theory of mind			
Diverse Desire (range = 0–1)	0.77(0.43)	1(0)	1(0)
Diverse Belief (range = 0–1)	0.63(0.49)	0.77(0.42)	1(0)
Knowledge Access (range = 0–1)	0.27(0.47)	0.73(0.45)	1(0)
False Belief Content (range = 0–1)	0 (0)	0.32(0.47)	0.80(0.40)
False Belief Location (range = 0–1)	0.12(0.32)	0.55(0.50)	0.87(0.34)

Table 5
Output from Generalized linear models.

Task	Predictor	Estimates	t-value	p-value
	Age	1.908	8.553	**< .001**
Day-Night (N = 182)	**Country**	1.029	2.740	**0.008**
	Age × Country	0.132	0.297	0.769
	Age	1.708	8.937	**< .001**
Knock-Tap (N = 181)	Country	0.440	1.367	0.173
	Age × Country	0.265	0.688	0.492
	Age	1.904	7.596	**< .001**
SpinPots (N = 182)	Country	0.239	0.734	0.464
	Age × Country	0.148	0.378	0.705
	Age	1.035	9.677	**< .001**
DCCS (N = 182)	**Country**	0.537	2.985	**0.003**
	Age × Country	0.219	1.023	0.308
	Age	1.386	14.967	**< .001**
ToM (N = 182)	Country	0.079	0.509	0.111
	Age × Country	0.256	1.382	0.169

Generalized linear models on factors affecting children's performance on executive function and composite score of theory of mind (ToM) tasks. P-values <.05 are highlighted in bold.

Notably, there were significant **country** effects (Table 5), as Chinese pre-schoolers outperformed their British peers on the Day-Night task (China vs UK: $z = 2.74$, $p = .006$) and DCCS task (China vs UK: $z = 2.985$, $p = .003$). In contrast, there was no significant difference between Chinese children and British children in performance on the Knock-Tap task (z = 1.368, $p = .172$), Spin the Pots task (z = 0.734, $p = .463$) and composite score of theory of mind tasks (z = 0.509, $p = .610$). The Age × Country interaction was non-significant for all tasks (all *ps* > .05, Table 5).

3.3. Relationship between future preference task, executive function and theory of mind tasks

The inter-task correlations within the batteries 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 (Table D.1 in the Appendices). 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 D.1 in the Appendices). 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, $r = 0.635$, $p < .001$; self-future and adult-now, $r = 0.417$, $p < .001$; peer-future and adult-now, $r = 0.376$, $p < .001$).

Children's scores in the self-future condition and peer-future conditions were used to examine the relationship between children's reasoning of preference changes and their executive function and theory of mind task performance. The Day-Night task and Knock-Tap test measured inhibition ability and children's performance between these tasks were significantly correlated ($r = -0.333$, $p = .002$). Therefore, we computed an inhibition composite score for each participant by dividing the raw sum score across both tasks by the maximum possible sum score (final score range = 0–1). The same method was used to create the composite score for executive function. The composite score of theory of mind was created by dividing children's sum score across the five tasks by the maximum possible score that they could obtain on this task battery.

We first tested zero-order correlations among children's performance on the future preference task, executive function tasks and theory of mind tasks (Table 6). Then, we controlled for age and children's performance on the adult-now trials for partial correlations (Table 6). Notably, overall across UK and China, we found significant relationships between children's performance in the **self-future** condition and their executive function competency. Specifically, with executive function composite score ($r = 0.150$, $p = .045$), inhibition composite score ($r = 0.171$, $p = .022$), Knock-Tap ($r = 0.193$, $p = .010$) and DCCS ($r = 0.155$, $p = .039$). In contrast, Day-Night ($r = 0.099$, $p = .187$) and Spin the Pots ($r = -0.025$, $p = .739$) were unrelated to performance in the self-future condition. Importantly, in the peer-future condition, children's performance was not significantly associated with any individual executive function task nor any composite scores (all $p > .05$). Furthermore, there was no significant correlation between children's theory of mind ability and performance in the self-future condition ($r = -0.046$, $p = .537$) and peer-future condition of the future preference task ($r = -0.004$, $p = .958$, Table 6). Results showing correlational analysis by each country were included in the Appendices (Table E.1).

Table 6
Zero-order and partial correlations (controlling for age and adult-now performance) between children's performance on the future preference task with executive function (EF) tasks and theory of mind (ToM) tasks, separated by test conditions.

	Zero-order		Partial	
	Self-future	Peer-future	Self-future	Peer-future
EF composite	0.358***	0.248**	0.150*	0.015
Inhibition composite	0.366***	0.248**	0.171*	0.031
Day-Night	0.322***	0.209**	0.099	-0.035
Knock-Tap	0.343***	0.250**	0.193**	0.092
Spin Pots	0.160*	0.176*	-0.025	0.020
DCCS	0.338***	0.199**	0.155*	-0.025
ToM composite	0.221**	0.218**	-0.046	-0.004

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

4. Discussion

We investigated British and Chinese pre-schoolers' future-oriented reasoning, specifically the ability to understand that their future preferences would be different from the current ones for themselves and for a peer (i.e. another child of the same age). Using a within-subject design, the current study adapted 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 current study made unique contributions to the field of developmental cognition in general and cultural similarities and differences in developmental cognition in particular, by demonstrating that British 3-year-olds outperformed their 3-year-olds Chinese peers on the future preference task, while no cross-cultural differences were found among the older age groups. To investigate the cognitive correlates of future-oriented cognition, we administered a battery of standardised tasks of executive function and theory of mind and found evidence to support the role of executive function. After controlling for age and children's knowledge of generic adult preferences, pre-schoolers' inhibition and cognitive flexibility were significantly related to the prediction of children's own future preferences, though not correlated with their predictions for a peer.

The current study also replicated a few important findings in the developmental literature. First, in line with previous research, we reported an age-related increase in performance in young children's understanding of changes in preference, revealing a developmental trajectory comparable to other aspects of future-oriented cognition during the preschool years (Atance & Meltzoff, 2005; Bélanger et al., 2014; Kopp et al., 2021; Russell et al., 2010; Prencipe & Zelazo, 2005; Suddendorf et al., 2011). The increased ability to predict changes of preference was likely to be the combined results of several underlying cognitive abilities developing around the same time, including understanding of the link and distinction between past, present and future as well as more advanced mental attribution ability and temporal cognition (Lagattuta, 2014; Lagattuta, Tashjian, & Kramer, 2018; Repacholi & Gopnik, 1997). In comparison, imagining that another item and activity could be desirable while also imagining a future perspective was particularly difficult for the 3-year-olds (Wright Cassidy et al., 2005). It is important to highlight that 3-year-olds' failure in the future preference task was unlikely to be due to their linguistic incompetency, since the ability to understand the auxiliary "will" in English and the future temporal adverbs in Chinese were already present in 3-year-olds (Harner, 1975; Liang, Wu, & Li, 2019).

Second, children made more accurate predictions of future preferences for their peers than for themselves. The condition effect suggests that future-oriented cognition differed as a matter of perspective (Atance et al., 2021; Mahy et al., 2020; Mahy, Moses, et al., 2020). Notably, in the present study, the comparisons between different test conditions were conducted within the *same* individuals (rather than between-subjects), thus reducing any potential participant variations between groups andfurther highlighting the effect of perspective. Taking another person's perspective creates "psychological distance", which helps to mentally separate oneself from the immediate situation and environment, and in turn allows greater flexibility in thoughts and actions (Lee & Atance, 2016; Liberman, Trope, & Rim, 2011; Mazachowsky et al., 2019). Importantly, Russell et al. (2010) revealed that only 4-year-olds, though not 3- or 5 years-olds, displayed the other-over-self-advantage when they were asked to select a tool for future use. It is very likely that taking the *visual* and *spatial* perspective of another person (as in Russell et al., 2010) is different from taking the *psychological* perspective of another person in the future preference task.

Finally, the significant order effect in the current study highlights that children's difficulty in future-oriented cognition could partially arise from conflicting perspectives (Atance et al., 2021). Specifically, 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 research (Atance et al., 2010; Bélanger et al., 2014). When multiple perspectives are in conflict, recognising and fulfilling one perspective would free up cognitive resources, and in turn reduce the cognitive demand while facilitating the quality of decision-making for another perspective. To this end, our findings may have practical and 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 abiity. We found cross-cultural variations in British and Chinese per-schoolers' performance on the future preference task, but only among the youngest age group (3-year-olds). Although studies of adults' visual perspective-taking revealed Western population's egocentric bias (Kessler et al., 2014; Wu & Keysar, 2007), in our study, British 3-year-olds outperformed Chinese counterparts on a future prediction task involving multiple psychological perspectives. This is important because it suggests that culture may have different influence or manifest age specific patterns on various types of perspective-taking abilities.

It is worth noting that there were no country-related differences in the 4- and 5-year-olds, suggesting that the overall developmental trajectory and timing for consistently passing the future preference task did not vary between Eastern and Western countries for these age groups. A contrasting age pattern in different cultures was observed among children from Australia Brisbane area and the Aboriginal Bushman community (Redshaw et al., 2019). Specifically, cross-cultural differences in preparing for alterative future possibilities were reported in 4- and 5-year-old groups with no differences in 3-and 6-year-olds (Redshaw et al., 2019). It is possible that developmental trajectories of different types of future-oriented cognition may be culturally specific, considering there is no evidence to support a common latent factor underlying various tasks (Immel et al., 2022).

Notably, the age of 4 has been suggested as the critical point when children pass different tasks measuring varying aspects of future-oriented cognition, such as the ability to select a tool for future use and understand knowledge growth (Atance & Caza, 2018; Russell et al., 2010; Suddendorf et al., 2011). Taken together, conclusions drawn from the current study are that the capacity to understand and envision future emerges around the same time in children from Western and Eastern cultures. Additionally, its development is less impacted by culture and may rather indicate normal cognitive maturation. However, we cannot completely rule out the possibility of cross-cultural differences of children's future-oriented cognition, as the variations may be subtle to detect and sensitive to the type of measure. For example, despite the universal developmental trajectories among children from Iran, Australia, China and US, there were still significant differences of cultural-specific developmental sequences of theory of mind ability (Shahaeian et al., 2011; Wellman et al., 2006). Therefore, a potentially fruitful path for future research is to incorporate continuous measures and examine whether children acquire various future-oriented cognition in different steps and orders (Kopp et al., 2021).

Our findings have largely replicated the well-documented East-versus-West contrast on children's inhibitory control and cognitive flexibility (Lan et al., 2011; Oh & Lewis, 2008; Sabbagh et al., 2006; Schirmbeck et al., 2020; Xu et al., 2020). The non-significant differences between Chinese and British children's working memory and motor inhibition were in line with previous studies, which could be attributed to the level of difficulty and children's familiarity with task demand (Lan et al., 2011; Sabbagh et al., 2006; Thorell, Veleiro, Siu, & Mohammadi, 2013). Similarly, we did not find any influence of culture on children's theory of mind ability - a finding corroborated by a recent large study and a meta-analysis (Duh et al., 2016; Liu et al., 2008).

The current study tests the relationship between children's executive function competency, theory of mind ability and understanding of preference changes with two culturally diverse groups. These findings are critical in light of the two accounts, namely the self-projection account and the executive function and conflict account, on the cognitive correlates of future-oriented cognition (Buckner & Carroll, 2007; Suddendorf & Corballis, 2007). Consistent with Hanson et al. (2014) and Immel et al. (2022), our results show no relationship between children's theory of mind and future prediction ability, directly challenging the self-projection account. One possibility is that these two domains of cognition develop separately during the preschool years. Furthermore, 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 differences within the same individual and between people at different temporal points. Furthermore, 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.

To the best of our knowledge, this is the first study providing evidence of the role of inhibition and cognitive flexibility in future prediction ability. Importantly, we found that children's cognitive flexibility (DCCS task) and inhibition control (composite score of Day-Night and Knock-Tap task) were associated with the prediction of children's own future preferences, even after controlling for age and children's knowledge of generic adult preferences. This suggests that future prediction ability partly depended on children's ability to switch between contrasting perspectives and to inhibit interferences from the current perspective (Atance & Jackson, 2009). Better inhibition and cognitive flexibility are advantageous in future-oriented contexts when children need to suppress interferences from conflicting perspectives and to select the most appropriate responses for the future. Our results, therefore, were in favour of the executive function and conflict account of the cognitive correlates in future-oriented cognition. Having said that, the significant relationship between executive function and future prediction ability did not hold when we analysed the UK and China separately (Table E.1 in the Appendices). This was likely due to relatively small samples, therefore future studies should consider recruiting larger samples to further investigate cognitive correlates in each country.

Motor inhibition (Knock-Tap task) was significantly related to children's performance on the future preference task, because children had to indicate their choice of items by naming it or pointing to it. Spatial working memory (Spin-the-Pots task) was unrelated to children's prediction ability. This finding may arise as children were reminded on each trial, therefore it required minimal demand on working memory. It is possible that there may be a link with verbal working memory tasks, such as word span or digit span. Furthermore, working memory may be more involved in future-oriented tasks 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, Messer, & Ebdon, 2001) and in the future planning task of tool use (Suddendorf et al., 2011).

At first glance, our findings may seem in contrast with Hanson et al. (2014) who reported no significant interrelations between these cognitive abilities. However, Hanson et al. (2014) used a different battery of tasks and the researchers suggested that using a task involving conflicting perspectives, such as the future preference task in the current study, was more suitable to test the potential role of executive function in future-oriented cognition. Using the same future preference task, Atance et al. (2021) did not find significant correlations between executive function and children's prediction of future preferences. It is likely that the manipulation of conflicts between different perspectives and potentially using a very general scoring method of executive function led to the null findings (Carlson & Moses, 2001).

Executive function task performance was not associated with prediction of a peer's future preferences, with several possible explanations. First, executive function has been shown to be strongly related to preschoolers' coordination of different perspectives in mental states ascription, particularly when children's own perspectives were involved (Fizke et al., 2014). Second, the current study used no pictures but relied on verbal instructions only when the peer was introduced, resulting in children not feeling as socially close and familiar with the peer. 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.

In our studies, across age groups inhibition and cognitive flexibility were associated with children's future prediction ability for themselves. Although Chinese 3-year-olds outperformed their British peers on executive function, they were worse on the future preference task. This finding may suggest that British children's better understanding of future preferences may not be fully attributed to executive function competency, as shown in Atance et al. (2021). Potential explanations may include different socialization goals, parenting attitudes and family structures in China and UK ((Lamm et al., 2018)). For instance, British children may be more likely to come from families with siblings, providing direct experience in observing their older siblings' desires and preferences. Furthermore, nursery life involves complex social environments and interactions with children from different ages, which may facilitate future-oriented cognition. Therefore, when Chinese children first go to nursery (3-year-olds), they may have difficulty in understanding future preferences. With increasing time spent in these type of childcare settings, their future prediction abilities become indistinguishable from their British peers (there were no country difference between 4- and 5-year-olds' performance on the future preference task).

At a broader level, across age groups, Chinese children's advantage on executive function ability did not transfer to the future preference task. It suggests that inhibition and cognitive flexibility may be one of the several scaffolding abilities that support children's reasoning with conflicting perspectives. It is also possible that disassociations in behaviours and task dependent performance reflect the graded knowledge and mental representations in different tasks - a phenomenon often reported in the developing stage of cognitive development (Munakata, 2001). Future studies could test older children with a broader range of tasks to elucidate the cognitive correlates of future-oriented cognition.

The current study has several limitations. First, we used non-matching samples and collected limited demographic data, potentially introducing confounding variables to the cross-cultural differences. For future research, it would be very beneficial to recruit children from different cultures that are matched for important demographical factors, such as family socioeconomic status (SES) and degree of urbanisation and deprivation (Fujita, Devine, & Hughes, 2022). Second, we did not include any measure of children's verbal ability. It is possible and likely that the associations between executive function and future prediction would be attenuated if verbal ability were controlled (Ünal & Hohenberger, 2017) - a point to address in future research. Lastly, many of the executive function measures had ceiling or near-ceiling effects among the 5-year-olds; using a battery of tasks with greater difficulty may help reveal further evidence on children's cognitive correlates.

To summarize our findings, we present the first East versus West comparison of pre-schoolers' future-oriented cognition. We assessed their ability to understand changes of preference occurring within oneself and within a peer, and related these findings to executive function and theory of mind performance. Both British and Chinese children showed age-related developmental trajectory in their future prediction ability. British 3-year-olds outperformed their Chinese counterparts while no country-related differences were found among 4- and 5-year-olds. Furthermore, in both UK and China, children predicted more accurately for peers than for themselves, and their performance improved when they had the opportunity to identify their current preferences before anticipating the future. Importantly, we demonstrated that children's prediction of their own future preferences (though not of others) was significantly related to their inhibition and cognitive flexibility abilities, providing direct evidence on the role of executive function in children's future prediction ability. Taken together, the current study paves the way for future research on the cognitive correlates and underlying mechanisms of future-oriented cognition. Such findings advocate for a diverse and integrated approach to investigate cognitive development in children with regards to cross-cultural research.

Authors' contributions

N·D. R.M., and N.S·C conceived and designed the experiments. N·D. ran the experiments, R.M and N·D analysed the data, and N.S.C. was responsible for the overall direction and production of the research. N.D prepared the manuscript, which was reviewed, discussed and edited by R.M. and N.S.C.

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Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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Appendix A

A.1. Task protocol for the executive function and theory of mind tasks

Day-Night (Gerstadt et al., 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.

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.

A.2. 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 et al., 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 et al., 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 Shaun 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).

Appendix B

Table B.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

Appendix C

C.1. Children's performance in the future preference task (both test and baseline trials)

Across all trials, the full model differed significantly from the null model ($X^2 = 475.84$, df = 6, $p \leq .001$). There were main effects of age, country, condition, order and trial type on success rate, with no main effect of sex or trial number (Table C.1). Across all trials, children's performance improved with age (Tukey contrasts: age 5 vs age 3: $z = 8.092$, $p < .001$; age 5 vs age 4: $z = 4.208$, $p < .001$; age 4 vs age 3: $z = 4.208$, $p < .001$). Performance was lower when children completed the task in order 2 (test-baseline) than in order 1 (baseline-test), $z = 3.392$, $p < .001$). Furthermore, across age groups Chinese children were outperformed by their British counterparts (China vs UK: $z = -3.258$, $p = .001$). Among all trials, children's performance was lower in the experimental conditions than in the baseline conditions (self-future vs self-now: $z = 3.140$, $p = .001$; peer-future vs peer-now: $z = -2.985$, $p = .001$).

Table C.1
Outputs from generalized linear mixed models.

Fixed term	Chi-square	df	p-value
Age	58.652	1	**<.001**
Country	10.605	1	**.001**
Condition	28.217	3	**<.001**
Order	11.552	1	**<.001**
Trial type	63.23	1	**<.001**
Trial number	27.314	23	.239
Sex	3.239	1	.490

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.

Appendix D

Table D.1
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	0.888***	0.817***	0.766***	0.764***	0.821***	0.528***	0.205**	0.207**	0.502***	0.533***	0.393***
2. Inhibition Composite	–	0.909***	0.876***	0.530***	0.581***	0.446***	0.201**	0.217**	0.419***	0.431***	0.307***
3. Day-Night		–	0.596***	0.493***	0.558***	0.445***	0.209**	0.200**	0.459***	0.402***	0.301***
4. Knock-Tap			–	0.451**	0.479**	0.344***	0.142	0.182*	0.269***	0.368***	0.248**
5. Spin the Pots				–	0.466**	0.417***	0.153*	0.180*	0.375***	0.414***	0.326***
6. DCCS					–	0.451***	0.145	0.102	0.443***	0.490***	0.362***
7. ToM Composite						–	0.538***	0.642***	0.794***	0.778***	0.831***
8. Diverse Desire							–	0.374***	0.363***	0.223***	0.295***
9. Diverse Belief								–	0.407***	0.298***	0.342***
10. Knowledge Access									–	0.476***	0.563***
11. False Belief Content										–	0.665***
12. False Belief Location											–

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

Appendix E

Table E.1
Partial correlations between children's performance on the future preference task with executive function (EF) tasks and theory of mind (ToM) tasks (controlling for age and performance on adult-now trials). Results were presented for each country and separated by test conditions.

	Overall ($N = 182$)		UK ($N = 92$)		China ($N = 90$)	
	Self-future	Peer-future	Self-future	Peer-future	Self-future	Peer-future
EF composite	**0.150***	0.015	0.159	−0.077	0.071	0.109
Inhibition composite	**0.171***	0.031	0.157	−0.072	0.157	0.155
Day-Night	0.099	−0.035	0.128	−0.119	0.002	0.036
Knock-Tap	**0.193****	0.092	0.142	−0.005	**0.272****	**0.229****
Spin Pots	−0.025	0.020	−0.022	−0.015	−0.032	−0.054
DCCS	**0.155***	−0.025	0.186	−0.078	−0.003	−0.003
ToM composite	−0.046	−0.004	−0.115	−0.102	0.060	0.109

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

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