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Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 46(0)

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Publication Date
2024

Peer reviewed

Asymmetry in Language, Asymmetry in Mind: The Effect of Sagittal Time-space Metaphors on Children's Understanding of Time

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Abstract

Although space helps children to grasp time, comprehending temporal metaphors remains challenging. Particularly, Mandarin has different degree of ambiguity in sagittal time-space metaphors, where 'qian' (front/past) expresses both future-in-front and past-in-front mappings but 'hou' (back/future) predominately expresses future-at-back mappings. Temporal metaphors with a longer duration unit (e.g., year vs. hour) also increase this challenge. We investigated: 1) when children understand sagittal time-space metaphors; 2) whether different degree of ambiguity leads children to having an asymmetric understanding of the past and future; 3) how the unit of temporal duration affects time understanding. 138 Mandarin-speaking children (3-5 years) undertook an 8-item sagittal time-space metaphors test. The results showed that age 5 is a milestone to understand sagittal time-space metaphors, and a longer unit of time duration and more ambiguous space-time metaphors hinder children's time comprehension. This study reveals the development of time cognition in non-western children and demonstrates how language impacts cognition.

Keywords: Language and thought; Mandarin metaphors; Chinese children; Time

Introduction

Life is nothing but time. To comprehend this abstract concept, people frequently use spatial metaphors to think of time. In the process of conceptualizing how one traverses through time, many languages and cultures depict the future as in front of the observer and the past as behind them (Boroditsky, 2000; Clark, 1973; Gentner, Imai, & Boroditsky, 2002; Lakoff & Johnson, 2003; Moore, 2006; Torralbo, Santiago, & Lupiáñez, 2006; Ulrich et al., 2012). Such experience of spatialization time can help individuals learn and understand abstract time metaphors. Children are known to utilize space to understand time early in life (Burns et al., 2019; Iossifova & Marmolejo-Ramos, 2013; Starr & Srinivasan, 2021; Tversky, Kugelmass, & Winter, 1991). By the age of five, English-speaking children start forming mental timelines and perceptions of time distance (Coull, Johnson, & Droit-Volet, 2018; Tillman et al., 2018; Tillman, Fukuda, & Barner, 2022). This time-space mapping can emerge even earlier, around the age of four, facilitated by visual-spatial priming (Tillman et al., 2018). Furthermore, the learning of spatial language also promotes the development of temporal concepts (Bowerman & Levinson, 2001; Choi et al., 1999; Srinivasan & Carey, 2010). For instance, the use of distance-related terms (e.g., The movie was *long*) with temporal words makes abstract time more tangible, aiding children in forming an understanding of time.

Interestingly, several studies have shown that English children's comprehension of time is not symmetric, such that it is easier for them to understand the past than the future. In Clark's (1971) study, forty children aged between three and five were asked to use terms involving the temporal conjunctions "before" and "after". This study revealed a process for understanding temporal words in early childhood: initially, children comprehended neither term; then they understood "before" but not "after"; followed by a stage where they confused "after" with "before"; and finally, they grasped both concepts accurately. Similarly, Zhang and Hudson (2018) employed a picture-sentence matching task to investigate children's understanding of "yesterday" and "tomorrow". In this study, children aged 3 to 5 were shown two pictures depicting different states of an object and were asked to match these with sentences referring to past or future actions. The results showed a clear preference for selecting correct matches in past-tense sentences over future-tense ones, indicating a more robust understanding of past-related concepts. These studies suggest that for English-speaking children, comprehension of past events tends to be easier.

However, it is unknown whether such an asymmetric understanding of the past and future can be generalised across languages and cultures. Particularly unlike English, Mandarin's temporal metaphors have unique sagittal spatial metaphors, where there is a different degree of ambiguity for the spatial metaphors for the past and future. For example, the sagittal space-time word 'qian' (front or before) presents an ambiguity, as it can represent both future-in-front and past-in-front mappings (Gu, Zheng, & Swerts, 2019; Yu, 2012), in contrast to 'hou' (back, future), which mainly express future-at-back mappings (Table 1b). Interestingly, Mandarin adults not only use such sagittal space-time metaphors to talk about time but also gesture forward to indicate past events (Gu, Zheng, & Swerts, 2019).

However, this seems to go against our embodied walking experiences. In many cultures, the concept of "front" is associated with places yet to be reached, symbolizing the

In L. K. Samuelson, S. L. Frank, M. Toneva, A. Mackey, & E. Hazeltine (Eds.), *Proceedings of the 46th Annual Conference of the Cognitive Science Society.*

future, while "back" is linked to places already passed, representing the past (Burns et al., 2019; Casasanto & Jasmin, 2012; Miles, Nind, & Macrae, 2010). If the Mandarin sagittal linguistic ambiguity is reflected in the speech, gestures, and thoughts of Mandarin-speaking adults (Gu, Zheng, & Swerts, 2019; Gu, 2022), the somewhat 'confusing' multimodal behaviours may hinder children's understanding of sagittal temporal terms, especially the concept of the past. Thus, the unique ambiguity in Mandarin sagittal space-time words, where 'qian' can refer to both past and future but 'hou' can hardly introduces an unexplored intriguing question: does it lead Chinese children to developing a different asymmetric understanding of the past and the future compared to what has been reported for children from other languages?

Table 1: Different degrees of ambiguity in Mandarin sagittal space-time metaphors.

	Future-in-front mappings	Past-in-front/future-at-back mappings
(a)	前 途 (qian-tu, *front path*) meaning: future	前天(qian-tian, *front day* the day before yesterday
(b)	Hardly any '后' for past	后天 (hou-tian, *back day*) the day after tomorrow

Note: While 'qian' can express the meaning of the 'future', the majority of 'qian' is used for the meaning of temporal 'past' or 'sequential earlier'.

At the same time, the duration of time presents another layer of complexity in children's understanding of time. The complexity of temporal concepts in language often involves sequencing and numeracy, with longer temporal units posing greater challenges to children's understanding of time. For instance, terms like "one season" or "one year" are more perplexing for children than shorter durations such as "one day." Research shows that 5-year-old English-speaking children have lower accuracy in time-space matching tasks with longer temporal terms like "last year" compared to "yesterday" (Marghetis et al., 2014). However, this study has not sufficiently focused on how children younger than five years old comprehend time, nor have they further analyzed the impact of time duration on understanding.

In short, so far, most studies have predominantly examined English-speaking children, with few focusing on speakers of other languages or from non-Western backgrounds. However, we know that spatial language and spatial language for time vary widely across cultures and languages (e.g., Le Guen & Pool Balam, 2012; Levinson, 2003; Majid et al., 2004), and their speakers also conceptualise space and time differently (Núñez & Sweetser, 2006; Sullivan & Bui, 2016). For example, Mandarin speakers conceptualise time differently than English speakers (Boroditsky, 2001; Gu, Zheng, & Swerts, 2019). How children with a different linguistic or cultural background understand time is largely underexplored.

In this study, we investigated 3-6-year-old Chinese children and asked three research questions: 1) At what age do they begin to grasp sagittal time-space metaphors; 2) Will the linguistic ambiguity in sagittal temporal words result in an asymmetric understanding of the past and future; and 3) How do temporal units of different durations affect children understanding of time? These inquiries help reveal not only how children understand time but also how linguistic structure shapes young children's time cognition.

Methods

Participants

Of a total of 148 Mandarin-speaking children (3-6 years, mean = 4.86), including 3 3-4-year-olds (mean = 3.84, 5 girls), 58 4-5-year-olds (mean = 4.46, 28 girls), and 67 5-6-year-olds (mean = 5.43, 31 girls). 10 participants were excluded because they were outside the target age range (n = 3) and withdrew partway through the task (n = 7). All children and their parents spoke Mandarin as their primary language. Informed consent was obtained from the guardians of all participants.

Procedure

Participants undertook 8-item sagittal time-space metaphors (STM). The STM covered four temporal units in ascending time duration: hour, day, season, and year. Each unit had two questions, using two sagittal temporal types: 'qian' ("*before*," refers to the *past*), and 'hou' ("*after*," refers to the *future*), with a balanced sequence. For instance, when the unit was the "hour" and the space-time word was 'qian', children were asked, "Which meal is *before* lunch? Breakfast or dinner?" Further details are provided in Table 2. The experimenter deliberately did not produce any gestures in the task to avoid any potential priming. The questions were arranged in the following order: year, day, hour, and season. Participants also completed other studies not related to the current experiment.

Coding and Analysis

Scoring STM Responses In assessing STM comprehension, a binary scoring system was employed: a correct response received a score of 1, while an incorrect response was given a score of 0. For example, when the temporal unit was the "hour" and the temporal direction was "qian," the correct response is 'breakfast'. In total, there were 1104 data points.

Temporal Type (Different Degree of Ambiguity) Building on prior research discussed in the introduction, the temporal word 'qian' (past) was presumed to carry higher ambiguity than 'hou' (future). The tested questions were coded as two temporal types (past or future), corresponding to higher and lower degrees of ambiguity accordingly. While 'qian' can sometimes imply future concepts in certain spatial-temporal mappings (Gu, Zheng, & Swerts, 2019; Yu, 2012), in our stimuli, the term 'qian' was coded as 'past/before' for all items, as native Mandarin adults will unambiguously interpretate it as past according to conventional Mandarin discourse to denote past events.

Unit Type Four temporal units of different durations (hour, day, season, and year) were coded as four categorical data.

Statistical Analysis Firstly, to analyze how age, the ambiguity of temporal terms, and temporal duration affect children's understanding of STM, we used the glmer model in R, with the dependent variable being children's binary responses in 8-item STM tests. Our analysis included four models with increasing levels of complexity. The reduced model included only the intercept and participants as random effects. The age model (model 1) was built upon the reduced model. It only added age as a continuous variable. Model 2 increased two extra categorical variables, unit type (baseline = "hour") and temporal type (baseline = "future"), as fixed effects. The interaction model (model 3) expanded further by introducing interaction effects between age and unit type, as well as between age and temporal type. To further analyze the interactions between age and temporal types in Model 3, we employed marginal means and trend analyses. Utilizing the emmeans package in R, we calculated the average predicted effects of temporal types across different age levels and assessed how these effects evolve with age. Secondly, to investigate when children emerge with an understanding of different types of STM, we used the bio-test to explore whether the accuracy of STM in different groups was significantly higher than the chance level (50%).

Table 2: The space-time words used in the experiment and the corresponding questions.

Unit Type	Questions	Temporal Type
Hour	Which meal is *before* lunch? Breakfast or dinner?	Past ('qian')
	Which meal is *after* lunch? Breakfast or dinner?	Future ('hou')
Day	Which day is *before* Wednesday? Tuesday or Thursday? [1]	Past ('qian')
	Which day is *after* Wednesday? Tuesday or Thursday?	Future ('hou')
Seas on	Which season comes *before* summer? Spring or fall?	Past ('qian')
	Which season comes *after* summer? Spring or fall?	Future ('hou')
Year	How old is one year *before* four years old? Is it three years old or five years old? [2]	Past ('qian')
	How old is one year *after* four years old? Is it three years old or five years old?	Future ('hou')

Note: 1. Days of weeks are talked as "week+number" in Mandarin, e.g., "Week one" is Monday and "Week 4" is Thursday, etc. 2. As three or five years old may be considered as 'past' by older children, the age in the question was determined by a prior query: After asking the child's age, we modified the question based on their answer. For instance, if they were five years old, we would ask, 'How old is one year before five years old? Is it four years old or six years old?'.

Results

The Emergence of Understanding Mandarin Sagittal time-space Metaphors

Figure 1 shows that the accuracy of STM tests in children at ages three, four, and five is 49%, 48%, and 64%, respectively. The age model (model 1) showed there was an age-related improvement in children's acquisition of STM (β = 0.45, p = .002). Comparison of this model (AIC: 1466) with the reduced model excluding age (AIC: 1473) indicated a substantial improvement in model fit ($\chi^2(1) = 9.13$, $p = .003$). Additionally, the bio-test showed that the accuracy of STM tests in 5-year-old children (64%, $p < .001$) was significantly higher than the chance level (50%), but it was not shown in 3-year-olds (49%, $p = .616$) or 4-year-olds (48%, $p = .785$). It suggested that the milestone for children mastering the sagittal time-space words is age 5.

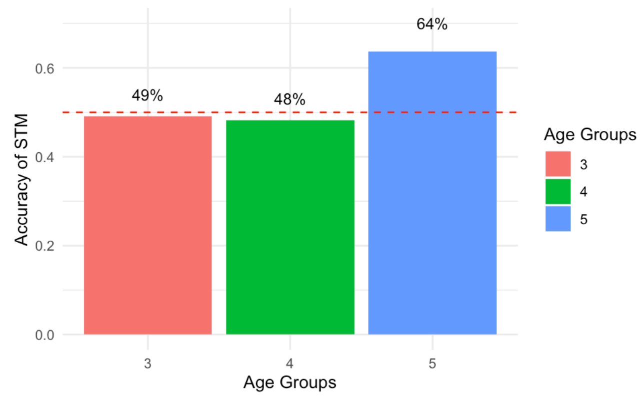

Figure 1: Accuracy of STM for children in three age groups.

Effect of Space-Time Temporal Types (Degree of Ambiguity) on Understanding of Past and Future

As shown in Figure 2, the accuracy of past among three, four, and five-year-olds was 42%, 45%, and 62%, respectively, whereas the accuracy of future for the same age groups was 56%, 51%, and 66%. The inclusion of age (model 2, AIC: 1437) indicated a substantial improvement in model fit (model 1, AIC: 1466) ($\chi^2(4) = 36.6$, $p < .001$). This model identified not only age ($\beta = 0.47$, $p = .002$) but also temporal type as a significant predictor in the STM acquisition (β = -0.28, p = .03). Although there was no interaction between age and temporal type (β = 0.33, p = .123), adding the interaction term (model 3, AIC: 1412) significantly improved model fit (model 2, AIC: 1437) ($\chi^2(4) = 33.25$, $p < .001$).

Further analysis based on model 3 revealed a significantly higher performance of the future (estimated marginal mean = 0.443) compared to the past (estimated marginal mean = 0.163) at an average age of 4.87 years (β = 0.28, SE = 0.136, z-ratio = 2.066, p = .039). Trend analysis showed a significant improvement in responses to past as age increased (β = 0.663, SE = 0.195, z-ratio = 3.394, $p < .001$), while improvements of future were not significant (β = 0.331, SE = 0.194, z-ratio = 1.706, p = .088). These findings indicated that the acquisition of the past ('qian') was harder than that of the future ('hou') for Chinese children.

Moreover, contrast analyses revealed significant positive effects of future over the past at ages 3 and 4 (age 3: β = 0.900, SE = 0.417, z-ratio = 2.158, p = .031; age 4: β = 0.569, SE = 0.225, z-ratio = 2.528, p = .014), while at age 5, there was no longer a significant difference between the past and future (β = 0.237, SE = 0.140, z-ratio = 1.694, p = .09). It indicated that although children keep learning these words, 'hou' was harder than 'qian' during the first 3–4 years of life. This asymmetry between the past and future was minimized until the age of 5 (Figure 3).

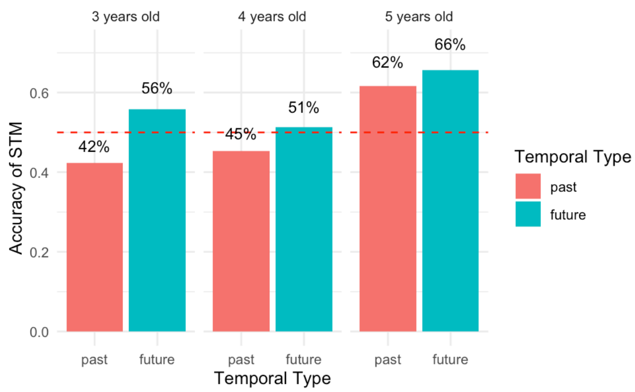

Figure 2: Accuracy of STM in two temporal types in three age groups.

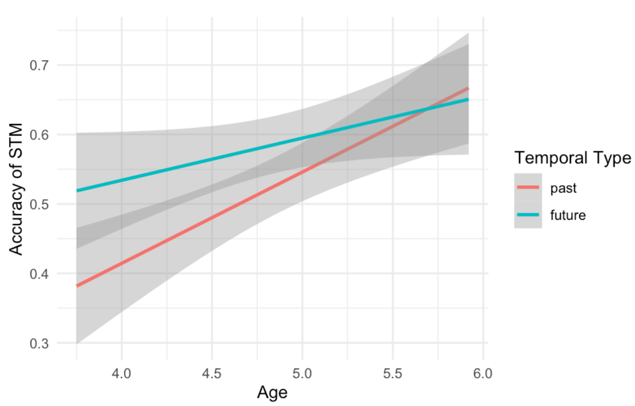

Figure 3: Interaction of temporal type and age.

Effect of Temporal Duration (Unit Type) on Children's Understanding of Time

As shown in Figure 4, the accuracy of "hour," "day," "season," and "year" was 63%, 61%, 57%, and 43%. The interaction model (model 3) revealed the fixed effect of unit type: "day" and "year" significantly predict STM understanding, with "hour" serving as the baseline ("day": β = 5.89; "year": β = 6.38, p's < .001). In contrast, "season" showed no predictive value (β = 2.12, p = .162). The post hoc test showed that the accuracy for the longest temporal unit ("year": 43%) was much lower than for other units ("hour": 63%, β = 1.05, p < .001; "day": 61%, β = 0.86, p < .001; "season": 57%, β = 0.7, p = .001). But there were no significant differences when we compare "hour vs. day" (β = 0.19, p = .754), "hour vs. season" (β = 0.35, p = .273), and "day vs. season" (β = 0.16, p = .834). It pointed to the challenge of understanding sagittal time-space metaphors caused by the longer time duration.

As shown in Figure 5, the bio-test revealed the "hour" and "season" were significantly higher than the chance level at 5 years old (hour: 81%, season: 69%, ps < .001), but it was not shown in 3-year-olds (hour: 42%, p = .837; season: 46%, p = .721) or 4-year-olds (hour: 47%, p = .798; season: 45%, p = .886). Unlike "hour" and "season," the accuracy of "day" was higher than the chance already at 4 years old (61%, p < .001), while "year" did not achieve the chance at 3, 4, and 5 years old (age 3: 54%, p = .423; age 4: 41%, p = .984; age 5: 43%, p = .965). In short, children first grasped the concept of "day" at age 4, then went on to understand "hour" and "season" by age 5, while continuing to struggle with the concept of "year" at age 5.

Notably, age significantly interacted with unit type. Specifically, the interaction between age and unit type "day" and "year" showed a significant negative effect (age×day, β = -1.25, p < .001; age×year, β = -1.53, p < .001; age×season, β = -0.51, p = .104). This indicated that the patterns of development with age for the unit types "day" or "year" differed from "hour" and "season." As age increases, "hour" and "season" appear to be gradually acquired, whereas "day" or "year" do not follow this trend (Figure 6).

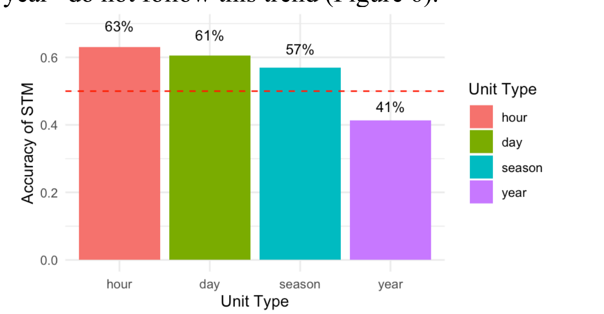

Figure 4: Accuracy of STM in four temporal units.

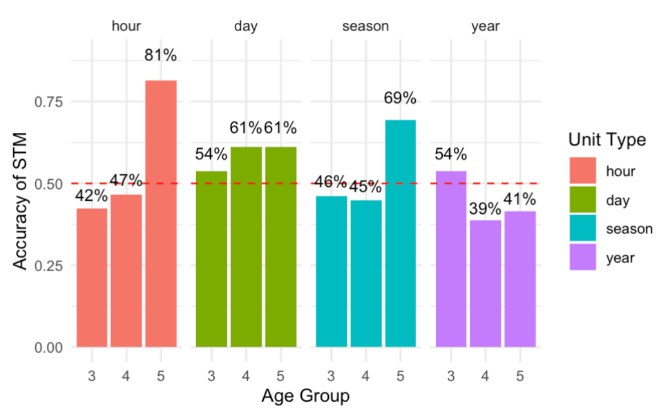

Figure 5 Accuracy of STM in four temporal units in three age groups.

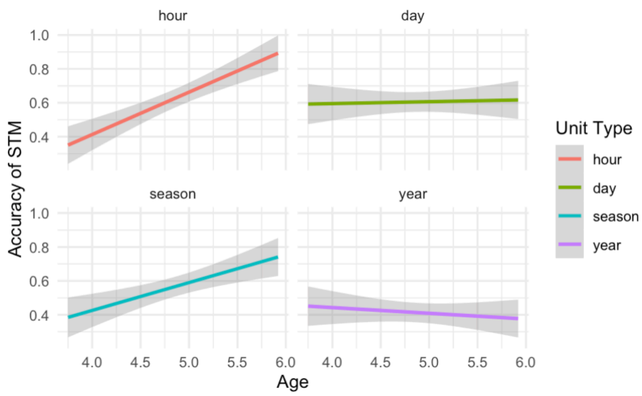

Figure 6: Interaction of unit type and age.

Discussion

In this study, we investigated how the Mandarin sagittal time-space metaphors and different time units affect Chinese children's understanding of time. We found that these children begin to acquire sagittal metaphors at age five. Notably, their understanding of different temporal directions (front/past, back/future) is asymmetrical, with the concept of the past ('qian', front) presenting a larger challenge than the concept of the future ('hou', back). Moreover, they have more difficulty understanding metaphors with longer time units.

We revealed the age of 5 as a developmental milestone in Mandarin-speaking children comprehending sagittal time-space metaphors. The fifth year of life is critical for various aspects of time understanding. At this age, children gradually develop an understanding of past and future (Busby Grant & Suddendorf, 2011; Busby & Suddendorf, 2010; McCormack & Hanley, 2011), direction preferences in time-space mappings (Tillman, Fukuda, & Barner, 2022), grasping duration (Tillman & Barner, 2015), memory for temporal connectives (Blything, Davies, & Cain, 2015), and accurate use of temporal terms (Busby Grant & Suddendorf, 2011). Our findings indicate that the age of five is a key stage for Chinese children to master highly challenging time-space words, specifically sagittal ones. It also contributes to revealing that age 5 may represent a common and generalizable milestone in time cognition across cultural contexts.

It is important to note that the children's ability to order events in this study showcases their comprehension of temporal words and primarily demonstrates how children interpret and apply temporal terms within their linguistic framework. Moreover, this capability extends beyond mere sequencing to encompass a richer cognitive understanding of how past and future events are conceptually framed within their language, reflecting inherently more complex cognitive skills. Therefore, our study highlights how the development of mastering temporal vocabulary and deeply understanding temporal concepts is asymmetric.

Interestingly, time reasoning also reflects an asymmetrical understanding of time, and the pattern of this asymmetry is reversed. Our data show that Chinese children have a better understanding of the future ('hou') than the past ('qian') from ages 3 to 4. In contrast, English children more readily grasp "yesterday" than "tomorrow" (Zhang & Hudson, 2018). Similarly, English-speaking children first acquire the meaning of "before" and then subsequently grasp the "after" (Clark, 1971). One of the reasons why the past is simpler is that past events are based on experiences that have already occurred, making them easier to understand. In contrast, future events are hypothetical and require a child to envision scenarios that have not yet happened, which is a more complex cognitive task. Supporting evidence for this challenge is found in memory and causal reasoning research across various cultures. Children perform better in tasks involving forward sequencing, such as forward digit span tasks, compared to backward sequencing tasks (Chen & Stevenson, 1988; Fuson, Richards, & Briars, 1982). It is also simpler for children to predict an outcome from known causes (forward reasoning) than to infer a cause from an observed outcome (backward reasoning) (Björkman & Nilsson, 1982; McCormack & Hanley, 2011). These studies suggests that the ease of understanding the past may be a cross-cultural phenomenon.

However, our study's contrary finding, where the past is more difficult to comprehend, could be attributed to the ambiguity of the Mandarin term for the past, 'qian,' which ambiguously refers to both "future" and "past" in temporal contexts (Xu, 2008; Yu, 2012). This ambiguity hinders Mandarin-speaking children's learning and comprehension of the term 'qian'. It also reflects the complexity of Mandarin's sagittal axis representation of time. Crucially, our contrary finding contributes to a better understanding of the effect of language on thought (e.g., Boroditsky, 2001; Gu, Zheng, & Swerts, 2017). Specifically, it shifts the emphasis from cross-linguistic comparisons to within-language temporal-spatial metaphors, providing insights into the asymmetry in children's acquisition of lexical temporal concepts within the Chinese context.

Furthermore, longer durations associated with temporal words impede children's comprehension of time concepts. Even at age 5, children have not yet mastered the concept of the longest temporal unit, "year", while the other three were understood before this age. At the same time, the accuracy for "year" is significantly lower compared to the other three units. Similarly, English-speaking children also struggle with temporal words representing longer time units, such as next year (Marghetis et al., 2014). Thus, the difficulty caused by the time durations can also hinder children's understanding of temporal concepts, a challenge that appears to be cross-cultural. It could be that the year is such a large time unit that children have not gained much experience with it.

In addition, it is worth considering that the difficulties in mastering larger temporal units are caused by children's immature numeral and spatial cognition. Through development, there is an interconnected relationship between time, space, and numbers (Pitt et al., 2021; Serrien & Spapé, 2015; Srinivasan & Carey, 2010; Winter, Marghetis, & Matlock, 2015). Distance and amount metaphors are used to describe temporal durations in various cultures (Casasanto, 2008; Casasanto et al., 2004). These experience-based information between specific distances and numbers can aid children in learning the abstract time duration (Brannon & Roitman, 2003; Casasanto, 2008; Dramkin & Odic, 2023; Emerson & Cantlon, 2009; Pitt et al., 2021; Srinivasan & Carey, 2010, 2010; Walsh, 2003). However, if the distances or numbers are too large, it will introduce the ambiguity of time for them.

There is a complex relationship between unit types and the age-related acquisition of STM understanding in early childhood. Specifically, when the unit is "hour" or "season," there is a noticeable increase in STM acquisition with age, as depicted in Figure 6. This trend is not observed for "day" and "year." It may be attributed to the qualitative differences in the vocabularies used for these units. For "hour" and "season," the instruction employs event-based vocabulary (e.g., spring and fall), which without numerical context might be more intuitively grasped by younger children. Conversely, in the cases of "day" and "year," the employed number-based vocabularies (e.g., 4 years old) could be more challenging for younger children to comprehend. This suggests that the numeric concepts in time terms might be more challenging in the developmental trajectory of STM acquisition.

This study has some limitations. While event order inherently contains sequences of earlier and later events, these may not align with the conventional 'past' and 'future' relations often described as asymmetric in the literature (e.g. Hudson & Mayhew, 2011; Busby et al. 2009; Tillman & Walker, 2022). Although Mandarin-speaking children show a different sequence in acquiring temporal words like 'before' and 'after' compared to previous findings with English-speaking children, it is important to note that language describing temporal orderings does not necessarily entail reasoning about the past or future events. Moreover, existing literature on temporal orderings reveals different kinds of asymmetries or ages of acquisition, distinct from the discussions on past vs. future concepts. Future studies can further directly investigate Chinese children's conceptions of future and past time.

In conclusion, our study presents three key findings regarding the understanding of sagittal time metaphors in Mandarin-speaking children: 1) At age five, it is a critical milestone for children to grasp sequence time. 2) Mandarin temporal words containing '前' ('qian', front/past) pose more difficulty for children than those with '后' ('hou', back/future), suggesting an asymmetric understanding of earlier and later concepts. 3) The longer temporal units (e.g., "year") hinder children's time understanding compared to shorter ones (e.g., "day"). These findings contribute to how Mandarin-speaking children develop time concepts and reveal ambiguity based on semantics and time duration, hindering time-space metaphor acquisition in the early years, with a potential implication for the relationship between language acquisition and cognition.

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