Locating past and future: The Influence of Spatial Ability on Time Representation

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Abstract

The representation of time depends heavily on spatial skills. Saj et al. (2014) demonstrated that left-hemispatial neglect patients, who lost the ability to detect objects in their left visual field, have a selective deficit in remembering items corresponding to the past, i.e., the left side of their mental timeline. The current study used the same memory task but tested neurotypical individuals (N = 76) to examine whether individual differences in spatial ability as well as learning order (chronological vs. random) predict how well participants remember items and associations between the item and time (past or future). Our results indicate that higher spatial ability and chronological learning both lead to better memory. This study is among the first to demonstrate how individual differences may impact time representation and memory that relies on a mental timeline.

Keywords: spatial memory; time perception; mental timeline; individual differences

Introduction

"I want to be a scientist when I grow up." "I should wake up at 7 am to go to work." "I've been waiting for you for more than 2 hours!" Time is an essential part of how humans think and communicate, and humans constantly use the concept of time to make decisions and plan their lives. While fundamental to many human activities, time is also an abstract concept that is not directly accessible through the senses and requires other sensory-motor processes (Grondin, 2001; Kövecses, 2017).

Metaphoric Mapping Theory suggests that abstract concepts are represented through concrete concepts with sensory features (e.g., Ulrich & Maienborn, 2010; Barsalou & Wiemer-Hastings, 2005; Lakoff & Johnson, 1980). Time is also an abstract notion that is represented using spatial concepts and comprehended through the metaphorical usage of space (Boroditsky, 2000). Starting from childhood, people associate time with space (Choy & Cheung, 2017), and their judgments about time seem to be influenced by spatial information (Boroditsky, 2000; Boroditsky & Gaby, 2010; Núñez et al., 2006). For instance, English speakers depict time as a horizontal line. When English speakers were asked to locate several events in a space, they located the early events on the left side and later events on the right side (Tversky et al., 1991). On the other hand, Aymara speakers of the Bolivian Andes associate the front with the past and ahead with future descriptions (Núñez & Sweetser, 2006). The timeline can also be vertical, and Mandarin speakers demonstrate time in the up and down array (Boroditsky et al., 2011). People also differ in how they name the duration of time. For example, English and Indonesian speakers perceive time as a distance ("short period," "long ago"), whereas Greek and Spanish speakers perceive time as a quantity ("much time," "big holiday") (Casasanto et al., 2004). Notably, even though time is represented differently across languages and cultures, all these terms are based on spatial concepts.

Spatial Ability and Time

Although the field generally agrees that time relies on space, not much research has been done to empirically examine the influence of spatial ability on how people perceive and represent time. Spatial ability, defined as "the skill for representing, generating, recalling, and transforming non-linguistic and symbolic information" (Linn & Petersen, 1985, p. 1482), vary highly across individuals (Lajoie, 2003). For example, whereas some people are experts on mentally imagining changes in the position of an object, others fail to do so (Blajenkova & Kozhevnikov, 2009). As time representation depends on the understanding of space, one can expect that better spatial ability leads to better representations and judgments about time.

To our knowledge, only one study has demonstrated that the individual's spatial ability affects their representation of time. Saj et al. (2014) tested people who experienced a right-hemisphere stroke and subsequent impairment in their ability to detect objects on the left side of their visual field. The time representations of these left hemispatial neglect patients were assessed on a memory task in which they were asked to recall and recognize items associated either with past or future. These patients struggled to remember the past items presumably because their left visual field deficits resulted in a failure to represent the left items, corresponding to the past items on their mental timelines. In other words, their ability to remember items was influenced by their ability to mentally represent items on a timeline. Whereas participants without a neglect could identify 85% of the past items, the neglect group could only identify 64% of them. The performance of the two groups did not differ for the future items.

Although Saj et al (2014) highlighted the influence of spatial skills on time representation in the hemisphere neglect patients, no study thus far asked whether individual differences in spatial ability among neurotypical individuals affect the representation of events along a mental timeline. Thus, using the same paradigm, the current study investigates whether spatial abilities of neurotypical individuals alter their

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representations of memorized past and future events on a mental timeline.

Mental Timeline

A mental timeline is a representation of time as a linear line. People mentally position the past and future. They represent time events following their writing and reading direction (Bergen & Chan Lau, 2012). As mentioned earlier, English speakers prefer to put early events to the left and later events to the right, parallel to their mental timeline. They put the past to the left because it is coming first considering the writing direction of English, and future events to the right (Santiago et al., 2007). One recent study (Martarelli et al., 2017) using the modified version of Saj et al.'s (2014) paradigm also pointed out the existence of a mental timeline. When they examined the encoding, recalling and recognition tasks of people who learnt the items auditorily, they observed that people tended to look to the left for past items while their gaze were on right for future items. Based on this study, we also expect people to benefit from a mental timeline for remembering the items.

Several findings support the existence of the mental timeline by indicating its positive influence on task performance (see von Sobbe et al., 2019 for a review). First, when the direction of mental timeline and time order of the presented items are compatible, people respond quickly (Ulrich & Maienborn, 2010). For instance, English speakers react faster to events presented earlier with their left hand, whereas Hebrew people react faster to the same events with their right hand due to their reverse timeline (Fuhrman & Boroditsky, 2010). Second, people are better at remembering objects presented in a chronological order, which means the order aligns with both their mental timeline (past-to-future) and the timeline direction (left-to-right). Further, learning in a chronologically ordered objects (left to right directioned and linear) positively influence memory performance when the participants required to indicate the temporal learning order of the objects as the first, second, and third, but not when people are only asked to identify the spatial locations of objects as left, middle, and right (Pathman et al., 2018). Therefore, the memory for the temporal order of items but not the memory for the spatial location is influenced by whether objects are represented chronologically or not. This order is critical because it is only influential for the understanding of the time concept through space, not merely for the spatial understanding. The current study examines whether learning items in a chronological order influences the representation of memorized items on a mental timeline. Given that the literature suggests that chronological ordering fosters task performance, we also expect to see the positive effect of the order.

The Present Study

The present study aimed to replicate the experiment of Saj and colleagues (2014) with neurotypical individuals. This replication has two main goals: First, it intended to investigate spatial ability as an individual difference affecting the representation of time in healthy individuals. If we are forming a mental timeline in remembering the relations between items and time points associated with the items, spatial ability should affect how well individuals can remember the item-time relations. Second, this study provides an exciting opportunity to advance our knowledge on the effects of learning order (chronological or random). Thus, when participants learn the items in a chronological order, i.e., past items followed by future items, they are expected to remember more items compared to learning the past and future items in random order. Since we recruited native speakers of Turkish, another language that represents the time from left to right (Bostan et al., 2016), we expect to observe an increase in their memory performance when participants learn past items first and then proceed to the future items.

Based on the proposed roles of spatial ability and mental timeline on the representation of time, we hypothesized that both spatial ability and chronological presentation of items positively influence people's time representation measured through a memory task. We measured several cognitive skills (e.g., object imagery, verbal and visual skills) that might be responsible for better performance.Yet, we expected that only spatial ability influences the time representation, not the other cognitive skills.

Method

Participants

Eighty-eight Turkish-speaking undergraduate students were recruited at Sabanci University located in the suburb of Istanbul, Turkey. Twelve participants were excluded from the analysis because their data were incomplete (N = 6) or they were considered as outliers since they scored at least three interquartile ranges higher than third quartile or lower than first quartile (N = 6). As a final sample, 76 participants (57 females; M_{age} = 21.5, SD_{age} = 1.41) participated in this study which required at least 68 people according to the a priori power analysis.

Materials

First, we administered the memory task created by Saj et al (2014). Then, to assess spatial ability, we used the Mental Rotation Task (MRT; Peters et al., 1995, originally by Vandenberg & Kuse, 1978) and the Number Line Estimation Task (*hereafter* NLET; Sullivan et al., 2011). In addition to these objective spatial ability tasks, we also administered two self-report scales of imagery: Vividness of Object and Spatial Imagery Scale ([VOSI]; Blazhenkova, 2016) and Verbal and Visual Style of Processing Scale (Akgün et al., 2014 originally by Childers, Houston, & Heckler, 1985).

Mental Rotations Test (MRT; Peters et al., 1995, originally by Vandenberg & Kuse, 1978) The MRT consisted of 24 questions required to be completed in six minutes. Each trial presented the target object (a block figure consisting of 10 cubes) and four options: two correct objects that were identical to the target but rotated and two distractor objects that were different from the target. Participants were asked to identify the two correct objects among the four options. If participants chose both of the correct options, they received 1 point for the question. If participants fail to identify at least one of the items, they received no points.

Number Line Estimation Task (NLET; Sullivan et al., 2011) We adapted the NLET by Sullivan and colleagues (2011). In this task, participants were presented with 20 randomly selected numbers (e.g., 13, 86) and a line. The left endpoint of the line represented 0, and the right endpoint represented 100. Participants were asked to mark a point on the line that corresponded to the each presented number. Note that the original paradigm used numbers between 0 to 1000, but we used 0 to 100 due to the technical limitation of our online interface. Participants marked the number by dragging a marker on the line and were instructed to respond as fast and correctly as possible. The initial location of the marker was randomized for each question.

Vividness of Object and Spatial Imagery (VOSI; Blazhenkova, 2016) The VOSI is a self-report questionnaire testing object imagery and spatial imagery, each scale consisting of 14 items. Participants were asked to rate the vividness of object imagery (e.g., "Shape and color of an autumn leaf") and spatial imagery (e.g., "Schema (plan) of a computer connecting to a printer") on a 5-point Likert scale (1 = no image at all; 5 = perfectly clear and vivid). The Cronbach's alpha was .85 for the spatial imagery scale and .88 for the object imagery scale.

Style of Processing Scale (Childers, Houston, & Heckler, 1985) Style of Processing Scale assesses whether individuals prefer to engage in verbal or visual processing. Verbalizers prefer to read, like to play word games, and have a great vocabulary. On the other hand, visualizers prefer to understand ideas with visual diagrams rather than reading about them and picture things when thinking. The scale consists of eight visual (e.g., "My thinking often consists of mental pictures or images.") and eight verbal questions (e.g., "I prefer to read instructions about how to do something rather than have someone show me."). Participants were requested to rate the items on a scale of 1-4 (1 = always true; 4 = always false). The Turkish version of the scale with satisfactory reliability (r = 0.94) was distributed to the participants (Akgün et al., 2014). The Cronbach's alpha was .74 for the visual scale and .72 for the verbal scale in the current data.

Memory task We used the task by Saj et al. (2014) to measure participants' ability to represent time. Participants learned four sets of items (foods, objects, clothes, activities) across four blocks. As described below, each block consisted of the encoding phase, the recall-test phase, and the recognition test phase (see below for the description of each phase). The current study only reports the results of the recognition test.

Encoding phase. In the encoding phase, participants were informed about a fictional man named *Mehmet* and some items Mehmet liked 10 years ago (past items) and other items Mehmet will like 10 years later (future items). For example, in the food block, they read the following instructions (but in Turkish):

"Today, Mehmet is 40 years old. In the first part of this study, you will learn about things that Mehmet liked to eat ten years ago (when he was 30 years old) and things that he will like to eat in 10 years (when he will be 50 years old)."

Then, participants saw the pictures of the past food items "Mehmet liked to eat ten years ago" with a white cap, and the future food items "Mehmet will like to eat in 10 years" with a black cap (Figure 1a). Half of the participants received the food pictures starting from the past ones that Mehmet used to like to the future items that Mehmet will like to eat in 10 years (*chronological order condition*), whereas the others received the pictures in mixed order regarding their time (*random order condition*). Thus, in the chronological order condition, participants encoded the items in line with their mental timeline starting with the past items and continuing with the future ones. The pictures of foods were presented one by one and centered on the screen. Participants were asked to write down the name of the food, and if the food was one of which "Mehmet liked to eat ten years ago" or "Mehmet will like to eat in 10 years" to a text box according to the hat it has. After writing the item-time pairs, participants saw the correct sentences (e.g., Apple is a food Mehmet will like to eat in 10 years) immediately after each question. In the following three experimental blocks, participants learned about objects, clothes, and activities instead of food. When participants had completed all of the ten items in the set, the recall phase started.

Recall-test phase. In this phase, participants were asked to freely recall and write down all of the items they remember and indicate the time of the items as ten years ago or ten years later. After the participant wrote down the items and times to a textbox, the study proceeded to the next phase. The results of this phase are not discussed in this report.

Recognition-test phase. In this phase, participants saw 14 food pictures one by one. In addition to the ten target pictures they studied in the encoding phase, there were four additional items they had never seen before. For each picture, they were asked to press the up (down) arrow on the keyboard if they saw the picture (or not). According to their responses, their *item recognition* performance was calculated. If they indicated that they saw the item by pressing the up arrow, they were further asked to indicate the time of the item as ten years ago by pressing the left arrow or ten years later by pressing the right arrow key (Figure 1b). Their performance for remembering the time of the items was used to calculate their *item-time recognition*.

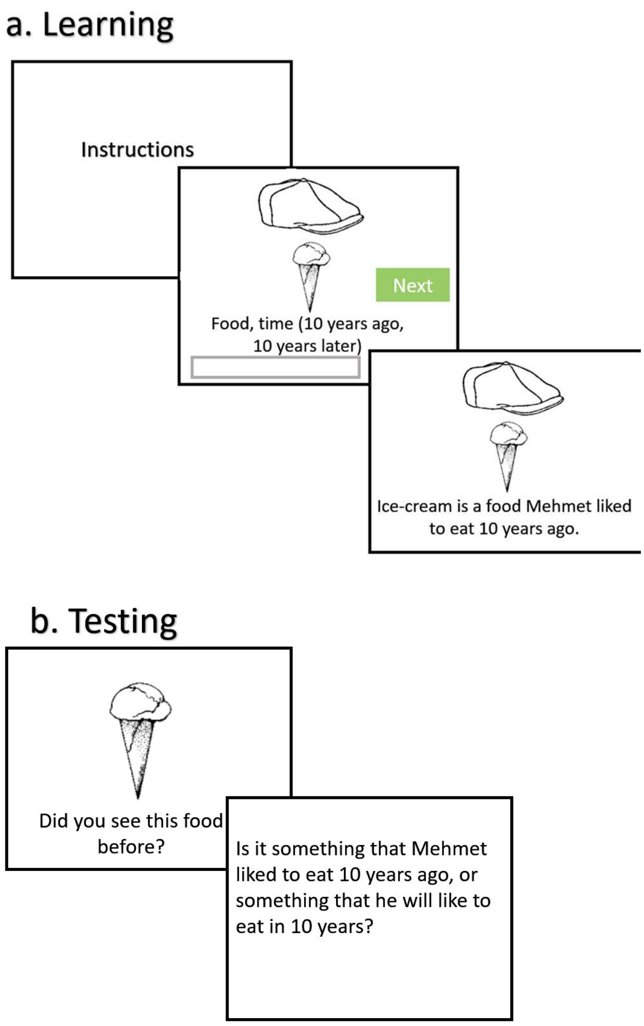

Figure 1: Questions from the memory task. a) Learning Phase: Participants learned the instruction, wrote down the item and time into the textbox, and received feedback. b) Testing Phase: In the first part (item recognition), participants pressed the up arrow key on their keyboard if they saw the item. In the second part (item-time recognition), participants pressed the left arrow key if the item was from 10 years ago, and the right arrow key if the item was for 10 years later.

Procedure

When participants signed up for the study, they were directed to *Labvanced*, a web interface for conducting online experiments (Finger et al., 2017). After consenting, participants started the memory task. All participants completed four memory sets (foods, objects, clothes, activities) in the same given order. Half of the participants were randomly assigned to the *chronological order condition* in which they learned all of the past items before the future items. The other half was assigned to the *random order condition* and learned the items in random order. After completing the memory task, they continued with spatial ability tasks and individual differences scales. These scales were represented in a random order to all participants. Lastly, they were requested to provide their age and gender.

Results

Table 1 summarizes the means, standard deviations, and 95% confidence intervals of all variables tested in the study. We hypothesized that the spatial ability scores measured with MRT and NLET would predict how well participants recognize the learned item-time associations (i.e., location of the items on a mental timeline). We used *R* (R Core Team, 2012) and the *lme4* function (Bates et al., 2014) to perform a generalized linear mixed-effects model (GLMM) analysis. We tested memory performances (*item recognition accuracy* and *item-time recognition accuracy; 0 = incorrect, 1 = correct*) as dependent variables and the accuracy in MRT, the error rate in NLET (*higher error scores corresponds to a lower performance*), learning order (*hereafter* Order, *1 = chronological, 2 = random*), as independent variables (i.e., fixed effects). Except for Order, we used *z*-scores of each predictor variable. We first tested MRT, NLET, and Order only and then compared this model with another model, including all self-report individual difference measures (Verbal-Visual, VOSI) to be able to compare the contribution of all independent variables including the ones that we do not expect to be related to memory performance. In all models, we included subjects (i.e., participants) and items in the memory task as random intercepts. We also controlled the influence of gender on recognition models, and we did not observe any effect on gender. All tested models are provided in the Appendix.

Table 1. Means, standard deviations (SDs), and 95% confidence intervals (95% CI) of all variables tested in the study in the chronological and random trials.

	Chronological		Random	
	Mean (SD)	95% CI	Mean (SD)	95% CI
MRT	8.14 (3.92)	[6.87 - 9.40]	7.95 (4.28)	[6.61 - 9.29]
NLET	75.6 (24.7)	[67.6 - 83.5]	81.6 (27.2)	[73 - 90.1]
VOSI - Spatial	2.97 (0.65)	[2.76 - 3.18]	2.72 (0.65)	[2.51 - 2.92]
VOSI - Object	3.87 (0.58)	[3.68 - 4.05]	3.75 (0.69)	[3.53 - 3.96]
Verbal	20.1 (4.24)	[18.8 - 21.5]	21.6 (4.30)	[20.3 - 23]
Visual	28.2 (3.22)	[27.2 - 29.2]	27.5 (3.53)	[26.4 - 28.6]

Item Recognition

We first examined whether participants correctly recognized the items they learned. According to our GLMMs, only MRT predicted the item recognition (Table 2). When we compared a model with Order as the sole predictor (Model 1) and a model that additionally included the interaction between Order and NLET (Model 2), no improvements were observed in the model fit ($X^2(2)= 4.12$, $p = 0.12$). However, including

MRT and a three-way interaction between MRT, NLET, and Order (Model 3; Table 1) significantly improved the model fit ($X^2(5)= 12.15$, $p = 0.03$). When we added all variables (MRT, NLET, Order, VOSI, and Visual-Verbal Scores; Model 4), none of the variables predicted the item recognition. In sum, Model 3 with MRT, NLET, Order, and their three-way interaction explained item recognition better than other models, and MRT was the only significant predictor of item recognition (See Table 2).

Table 2. A GLMM with the first impression as MRT, NLET, Order, and their two-way interactions as predictors for item recognition (Model 3).

	B	*SD*	*Z*	*P*
Intercept	3.778	0.303	12.471	< 0.001***
MRT	0.630	0.250	2.524	0.011**
NLET	-0.162	0.229	-0.708	0.479
Order	0.349	0.296	1.181	0.238
MRT*Order	-0.535	0.339	-1.581	0.114
NLET*Order	0.436	0.306	1.424	0.154
MRT*NLET	0.296	0.182	1.621	0.105

Notes: Signif. codes: ***$p < 0.001$ **$p < 0.01$, *$p < 0.05$

Item-Time Recognition

When we examined whether participants accurately recognized the time associated with the items, their performance was predicted positively by MRT and negatively by NLET (Table 3). The chronological trials resulted in a higher item-time recognition rate than the random trials ($M_{\text{chronological}} = 0.85$, $SD_{\text{chronological}} = 0.36$; $M_{\text{random}} = 0.71$, $SD_{\text{random}} = 0.46$). The interaction between Order and NLET was also found, suggesting that better performance in NLET (i.e., lower line estimation error scores) led to a higher recognition rate in the memory task especially when the items are presented in a chronological order. Interestingly, MRT positively predicted the item-time recognition rate regardless of the Order.

Table 3. A GLMM with the first impression as MRT, NLET, Order, and their two-way interactions as predictors for the item-time recognition (Model 7).

	B	*SD*	*Z*	*P*
Intercept	2.010	0.164	12.283	< 0.001***
MRT	0.435	0.164	2.653	0.008**
NLET	-0.308	0.145	-2.134	0.033*
Order	-1.031	0.182	-5.670	< 0.001***
MRT*Order	-0.347	0.210	-1.652	0.099
NLET*Order	0.453	0.185	2.444	0.015*
MRT*NLET	-0.043	0.108	-0.396	0.692

Notes: Signif. codes: ***$p < 0.001$ **$p < 0.01$, *$p < 0.05$

For the item-time recognition rate, a model with the Order and NLET (Model 6) resulted in a significantly better fit than a model without NLET (Model 5; $X^2(2) = 8.01$, $p = .02$). Although MRT significantly predicted the item-time recognition rate, adding MRT and interaction terms including MRT (Model 7) did not increase the model fit ($X^2(3) = 7.38$, $p = .06$). When we added all variables to the model (Model 8); MRT, Order, and Verbal scores predicted better performance (Table 4). This model was better than the model with Order, MRT, and NLET only (Model 9; $X^2(4) = 16.24$, $p = .002$), or the model with these three predictors and their interactions (Model 7; $X^2(1) = 5.82$, $p = .016$).

To sum up, remembering the time of the items influenced by MRT, NLET, Order. Better spatial skills and learning items chronologically increased memory for time representation. However, spatial ability was not the only factor that explained performance success, verbal ability also predicted the recognition rate.

Table 4. A GLMM with the first impression as MRT, NLET, Order, VOSI Object and Spatial, Visual and Verbal scores as predictors for the item-time recognition (Model 8).

	B	*SD*	*Z*	*P*
Intercept	2.010	0.161	12.47	< 0.001***
MRT	0.256	0.106	2.415	0.016*
NLET	-0.097	0.090	-1.071	0.284
Order	-0.984	0.184	-5.351	< 0.001***
VOSI-Obj	0.018	0.109	1.693	0.090
VOSI-Spa	0.019	0.196	0.185	0.853
Visual	0.154	0.091	1.687	0.092
Verbal	0.216	0.096	2.262	0.024*

Notes: Signif. codes: ***$p < 0.001$ **$p < 0.01$, *$p < 0.05$

Discussion

The present study followed the Metaphoric Mapping Theory (Ulrich & Maienborn, 2010) to elucidate the influence of spatial ability on the representation of time. Recognizing learned items (item recognition) was simply about remembering each individual item, and is not expected to depend on order. Indeed, our results showed that learning in a chronological order did not improve the item recognition rate, and the only significant predictor in the main model (Model 3) was MRT. This finding showed that people with better spatial skills displayed a better item memory. Some scholars suggest an overlapping system for spatial ability and memory (Hassabis & Maguire, 2007; Rubin & Umanath, 2015), and higher scores in spatial imagery predict higher memory details for personal events (Aydin, 2018). Our findings might be in favor of the common mechanism underlying for memory and spatial skills they suggest. On the other hand, another group of scholars supports that spatial ability and memory are distinct constructs (Carina et al., 2021; Clark et al., 2020; Palombo et al., 2013). If this is the case, one possible explanation for the relationship between spatial ability and memory performance can be the higher executive functions of individuals. The executive function, and working memory are not orthogonal constructs (Miyake et al., 2001), and spatial ability was found to be related with executive function in previous studies (Kubik et al., 2020). Thus, rather than the mere influence of spatial ability on memory, general executive functions might be leading to better performance on item memory.

Importantly, our main focus in this paper is time representation, which is about remembering the associations between the items and time (past or future) presumably by locating the items on a mental timeline. As we expected, both spatial ability (MRT and NLET) and Order positively affected how well participants remembered the pairs of item and time. These results suggest that the ability to estimate and manipulate the spatial relations between objects may lead to better time representation performance. In the same vein, having a better performance when the learning order of the items is chronological is consistent with the possible use of the mental timeline.

Another finding worth emphasizing is the interaction between NLET and Order in the item-time recognition rate. Although MRT, NLET, and Order were the significant predictors of item-time recognition, the only significant interaction we observed was the interaction between Order and NLET. The lower error rate in NLET predicted higher item-time recognition when the learning order was chronological not random. On the other hand, the lack of MRT x Order interaction indicates that individuals with high mental rotation ability can learn the association between item and time regardless of the presentation order of the items. These findings may suggest that the ability to work with a linear representation of items influences memory performance especially when the reorganization of item is not necessary (chronological order condition), whereas the ability to spatially manipulate mental images can help the formation of a mental timeline regardless of learning order.

At this point, our design is limited to test if the positive influence of the item order is due to learning items in a chronological order (i.e., past items followed by future items) and not due to learning them merely in two separate sets (i.e., one set of items followed by another sets of items). Future studies should test this limitation by presenting the objects in a specific order which is contrary to timeline (e.g., presenting future items first) so that we can confidently assert that the influence of item order stems from the use of mental timeline. Addedly, to prevent chunking of items just based on two groups (10 years age and 10 years later), continuous time groups (e.g., 5 months ago, 2 years later, 3 days ago) can be used in future studies.

Interestingly, in addition to MRT and Order, verbal ability also predicted item-time recognition. Since language serves as a medium between time and space (Boroditsky, 2000; Bottini & Casasanto, 2013; Lakoff & Johnson, 1999), we speculate that verbal ability plays a mediatory role in the relationship between space and time. Relatedly, spatial ability was previously found to be negatively related to verbal ability (Blazhenkova & Kozhevnikov, 2009), and we expect that some participants either had a good verbal ability or spatial ability. Perhaps some individuals with high verbal skills use language to perform the task, compensating for their lower spatial ability. Future studies should examine the understanding of time in different experimental designs, hindering participants from memorizing the content verbally and/or encouraging them to imagine a mental timeline.

Another notable limitation of the study is that, although our sample size ($N = 76$) should be sufficient to capture the effects of interest, our sample population lacked diversity, which necessarily limits the generalizability of the findings. Our sample were young adults in a university and predominantly female. To claim that spatial ability is fundamental to the representations of time, we must test more participants varying in age, gender, and other demographic variables. Further, the current study only investigates time representation in memory, and future studies should also assess the effects of spatial ability on time estimation and judgments. These individual difference studies can also make contributions to the language and thought literature by advancing the understanding of how time representations depend on spatial concepts.

To conclude, this study was the first to examine the effects of individual differences in spatial ability and verbal skills on the mental representation of time. We found that both of them are essential for representing and remembering the time, and though indirectly, our results also may support the proposition that humans use a mental timeline to remember depending on the increased performance of participants in the chronological order condition. We hope that our findings inspire more researchers to conduct experimental studies to further scrutinize the influence of individual differences on time representation with different experimental designs and sample populations.

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Appendix

Models

Model 1: Item Recognition ~ Timeline Congruency + (1 | Subject) + (1 | Item)

Model 2: Item Recognition ~ Timeline Congruency * NLET + (1 | Subject) + (1 | Item)

Model 3: Item Recognition ~ MRT * Timeline Congruency + Timeline Congruency * NLET + MRT * NLET + (1 | Subject) + (1 | Item)

Model 4: Item Recognition ~ MRT + Timeline Congruency + NLET + VOSI-Spatial + VOSI-Object + Visual + Verbal + (1 | Subject) + (1 | Item)

Model 5: Item-time Recognition ~ Timeline Congruency + (1 | Subject) + (1 | Item)

Model 6: Item-time Recognition ~ Timeline Congruency * NLET + (1 | Subject) + (1 | Item)

Model 7: Item-time Recognition ~ MRT * Timeline Congruency + Timeline Congruency * NLET + MRT * NLET +(1 | Subject) + (1 | Item)

Model 8: Item-time Recognition ~ MRT + Timeline Congruency + NLET + VOSI-Spatial + VOSI-Object + Visual + Verbal + (1 | Subject) + (1 | Item)

Model 9: Item-time Recognition ~ Timeline Congruency + NLET + MRT + (1 | Subject) + (1 | Item)