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Which way does time fly in artificial intelligence?

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Abstract

Abstract concepts are frequently mapped onto more concrete sensorimotor experiences. One such mapping concerns time and space: people who read and write from left to right tend to associate the past with the left and the future with the right, a correspondence known as the mental timeline (MTL). The present study examined whether an MTL-consistent spatial bias is also observed in ChatGPT and whether this bias can be altered by manipulating linguistic and cultural context. In four experiments, thirty-two independent chat sessions were conducted, with each session treated as an independent AI respondent and asked to place past-related and future-related words at any location on an *xy* plane (a word allocation task). When the prompt was written in English (Experiment 1), written in Arabic (Experiment 2), or written in Arabic and additionally specified that the model was a native speaker of Arabic (Experiment 3), past words were placed to the left and future words to the right. In contrast, when a Japanese prompt specified that the model was a person from a culture in which text is read from right to left (Experiment 4), this pattern was reversed. These results suggest that ChatGPT predominantly exhibits the MTL typical of English-speaking cultures, and that this mapping can be modulated by framing reading direction.

Keywords: mental timeline, conceptual metaphor, embodied cognition, large language models

Introduction

Abstract concepts are often mapped onto more concrete sensorimotor experiences. According to embodied and metaphor-based accounts of cognition (e.g., Barsalou, 1988; Lakoff & Johnson, 1980), people understand and reason about abstract domains, such as emotion or time, partly by recruiting representations derived from bodily and perceptual experience. Such conceptual mappings often bias cognitive processing (Metaphor congruency effect: e.g., Meier & Robinson, 2004; Santiago et al., 2007; Sasaki et al., 2015, 2016; Uchikawa et al., 2026).

Although conceptual metaphors are widely regarded as grounded in embodied experience, the question of what makes a metaphor an embodied metaphor remains a matter of debate (Casasanto & Gijssels, 2015; Gibbs, 1994). One reason is that metaphorical mappings are also richly expressed in language, making it difficult to separate the contribution of bodily experience from that of linguistic experience. Large language models (LLMs) possibly offer a novel perspective on this issue. LLMs are trained on large amounts of human-produced text rather than through direct sensorimotor interaction with the physical environment. A recent study reported that some metaphor congruency effects, specifically those involving spatial–emotional mappings, are reproduced in ChatGPT (Sasaki et al., 2026). Findings of this kind do not in themselves indicate that LLMs possess the same conceptual representations as humans. Nevertheless, they can provide new insights into the discussion of embodiment and conceptual metaphor, because they reveal which human-like metaphorical correspondences can be observed in a system that has learned from human-produced language data.

Among conceptual metaphors, some concern the relationship between time and space. For example, it has been proposed that people associate the past with the left and the future with the right (mental timeline: e.g., Macnamara et al., 2018; Ouellet et al., 2010; Santiago et al., 2007). This metaphorical mapping is observed in Japanese people (Sato, 2014; Uchikawa et al., 2026; but see Ikeda,

2023). Several studies have reported metaphor congruency effects related to the MTL. In a word classification task, the classification is promoted when past and future words are classified with left and right hands, respectively (e.g., Santiago et al., 2007; Sato, 2014). The MTL also biases spatial attention (Ouellet et al., 2010). Moreover, arrangement of pictures depicting temporal sequences is in line with the MTL (Fuhrman & Boroditsky, 2010). Recently, when people are asked to place past-related and future-related words at any location in a space (the word allocation task; WAT), they tend to place past words to the left and future words to the right (Uchikawa et al., 2026). Briefly, the MTL influences cognitive processing.

Previous studies have shown that the MTL is influenced by linguistic and cultural factors. Speakers of languages written and read from left to right, such as English and Japanese, typically show a left–past/right–future mapping, whereas this mapping has been suggested to be reversed (i.e., left–future/right–past) among speakers of Hebrew and Arabic, whose writing systems proceed from right to left (Fuhrman & Boroditsky, 2010; Park et al., 2024). Meanwhile, recent studies have demonstrated that the outputs of LLMs can be substantially modulated by contextual information provided in prompts. For example, assigning specific personas or cultural identities to LLMs can alter their responses and behavioral characteristics (e.g., Adilazuarda et al., 2024; Tseng et al., 2024), suggesting that prompt-based contextual framing influences how knowledge is expressed. Against this background, an important question is whether a metaphorical correspondence such as the MTL is likewise sensitive to linguistic and cultural contextual manipulations in LLMs.

The present study asked whether the metaphor congruency effect associated with the MTL is also reproduced in ChatGPT using the WAT. Experiment 1 tested whether the word allocation bias observed in humans, in which past words are placed to the left and future words to the right, is observed when ChatGPT is given an English prompt. In Experiments 2 through 4, we manipulated the linguistic and

cultural context of the prompt to examine whether this bias would be reversed, as has been suggested for speakers of right-to-left languages. Specifically, Experiment 2 used a prompt written in Arabic, Experiment 3 additionally specified that the model was a native speaker of Arabic, and Experiment 4 specified, in a Japanese prompt, that the model was a person from a culture in which text is read from right to left.

Experiment 1

Experiment 1 examined whether the allocation bias for past and future words observed in humans in the WAT is also observed in ChatGPT.

Method

AI respondents. Experiment 1 used ChatGPT-4. The aim of this study was to examine whether the *x* coordinates of past words and future words differed, and thus we planned to conduct a paired *t*-test. On the basis of the effect size reported in a previous study (Uchikawa et al., 2026), we conducted an a priori power analysis using G*Power (Faul et al., 2007) with the following parameters: Cohen's $dz = 0.725$, $\alpha = .05$, $1 - \beta = .99$, one-tailed. The analysis indicated a required sample size of $N = 32$. Accordingly, thirty-two independent chat sessions were conducted, with each session treated as an independent AI respondent.

Materials and Procedure. Each AI respondent was given a prompt written in English (Appendix A). The stimuli were 10 time-related words used in previous studies (e.g., Sato, 2014; Uchikawa et al., 2026), translated from Japanese into English. The past words were past, before, yesterday, last time, and last year; the future words were future, after, tomorrow, next time, and next year. Each AI respondent was asked to place these words at any location on an *xy* plane (*x* axis: left end = −10, right end = 10; *y* axis: bottom end = −10, top end = 10) and to output the coordinates of each word.

Data Analysis. For each AI respondent, we calculated the mean *x* coordinate of the five past words and the mean x coordinate of the five future words. These means were compared using a paired *t*-test.

Results and Discussion

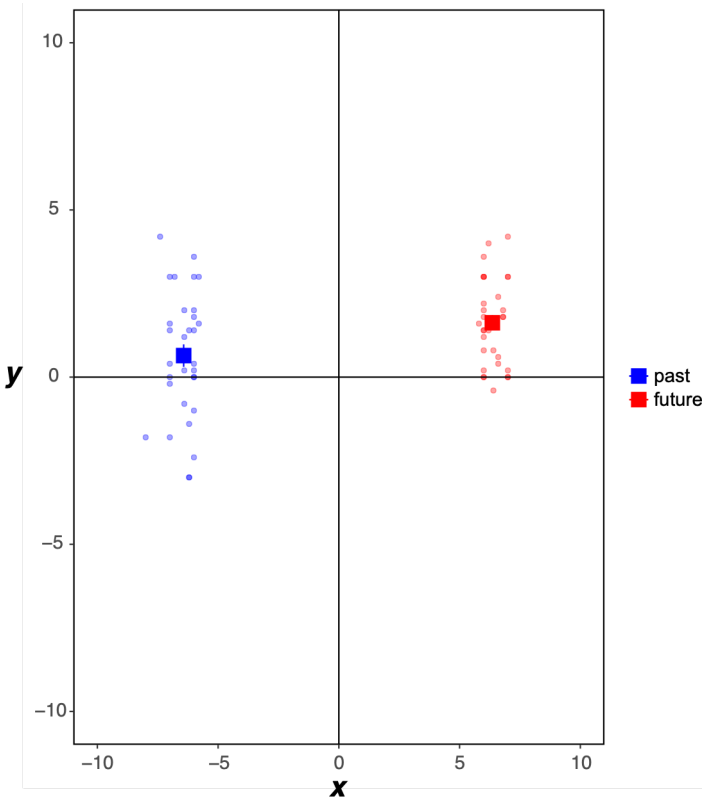
The results are shown in Figure 1. The mean *x* coordinates were $M = -6.425$ ($SD = 0.535$) for past words and $M = 6.356$ ($SD = 0.418$) for future words. A paired *t* test revealed that future words were placed significantly further to the right than past words, $t(31) = 78.187$, $p < .001$, Cohen's $dz = 13.822$. Thus, a metaphor congruency effect consistent with the MTL was observed.

Experiment 2

Experiment 1 showed that the metaphor congruency effect associated with the MTL is observed

Figure 1

Results of Experiment 1



Note. Error bars represent standard errors.

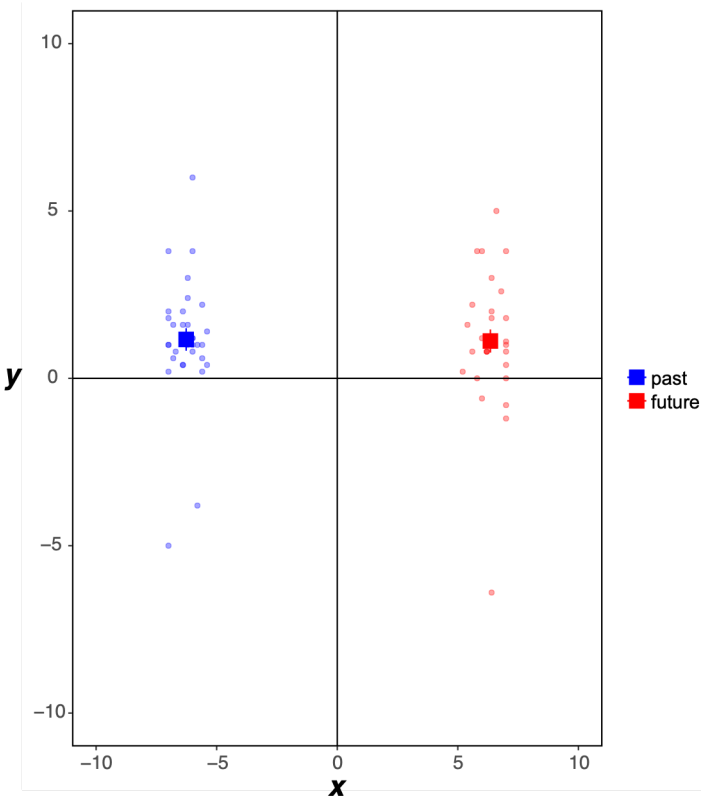
in ChatGPT. It has been suggested that the MTL may be influenced by writing and reading direction, and that the MTL is reversed (i.e., left = future, right = past) among speakers of Hebrew and Arabic (Fuhrman & Boroditsky, 2010; Park et al., 2024). To examine whether this phenomenon is reproduced in ChatGPT, Experiment 2 used a prompt written in Arabic.

Method

AI respondents, Materials, Procedure, and Data Analysis. The method was identical to that of Experiment 1, except that ChatGPT-5.2 was used and that the entire prompt was written in Arabic (Appendix B). The prompt used in Experiment 1 was translated into Arabic using the first author's ChatGPT-5.2. The translated prompt was then back-translated into Japanese by the last author's ChatGPT-5.2, and we confirmed that there were no meaningful discrepancies in content. The Arabic prompt was not checked

Figure 2

Results of Experiment 2



Note. Error bars represent standard errors.

by a native speaker of Arabic.

Results and Discussion

The results are shown in Figure 2. For each AI respondent, the mean *x* coordinates of the past and future words were calculated (past words: $M = -6.266$, $SD = 0.531$; future words: $M = 6.350$, $SD = 0.525$). A paired *t*-test revealed that future words were placed significantly further to the right than past words, $t(31) = 70.548$, $p < .001$, Cohen's $dz = 12.471$. Thus, the typical metaphor congruency effect of the MTL (left = past, right = future) was observed, rather than the reversed pattern reported for speakers of right-to-left languages.

Experiment 3

In Experiment 2, the typical metaphor congruency effect of the MTL was observed even when the prompt was written in Arabic. One possible explanation is that the training data of LLMs consist mainly of text from English-speaking cultures. Several studies have pointed out that, even when the input language is not English, the outputs of LLMs tend to follow the knowledge and values of English-speaking cultures (e.g., Aksoy, 2024; Tao et al., 2024). Thus, to make the cultural framework more explicit, Experiment 3 added a sentence stating "You are a native speaker of Arabic" to the beginning of the prompt.

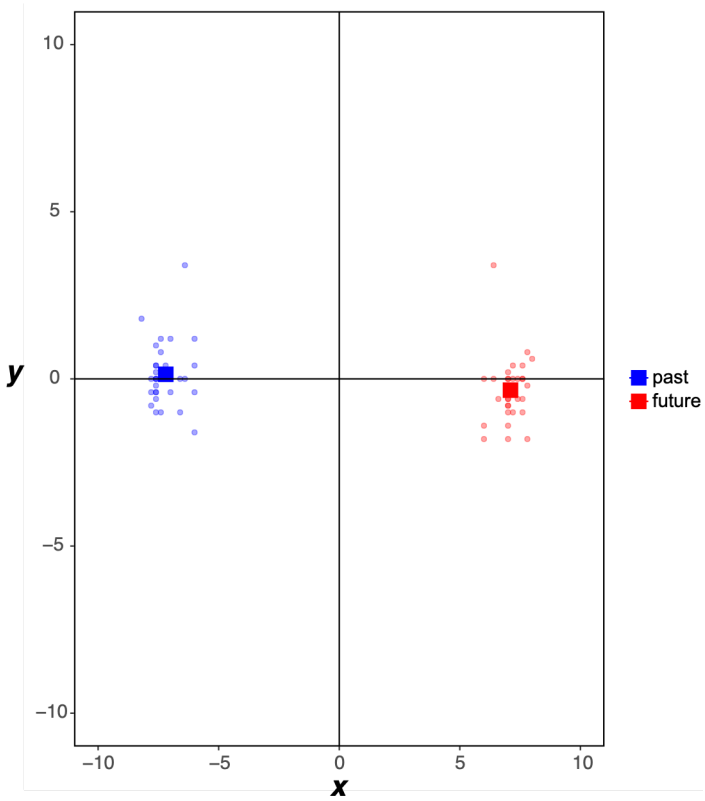
Method

AI respondents, Materials, Procedure, and Data Analysis. The method was identical to that of Experiment 2, except that the Arabic sentence "أنت متحدث أصلي للغة العربية." ("You are a native speaker of Arabic.") was added to the beginning of the prompt.

Results and Discussion

Figure 3

Results of Experiment 3



Note. Error bars represent standard errors.

The results are shown in Figure 3. For each AI respondent, the mean x coordinates of the past and future words were calculated (past words: $M = -7.194$, $SD = 0.623$; future words: $M = 7.100$, $SD = 0.530$). A paired t-test revealed that future words were placed significantly further to the right than past words, $t(31) = 77.947$, $p < .001$, Cohen's $dz = 13.779$. Thus, the typical metaphor congruency effect of the MTL (left = past, right = future) was again observed.

Experiment 4

In Experiment 3, the typical metaphor congruency effect of the MTL was observed even when the prompt explicitly stated that the model was a native speaker of Arabic. This suggests that specifying a cultural framework alone may not be sufficient to reverse the MTL. The reversal of the MTL among

speakers of Arabic is thought to arise because their reading and writing direction is opposite to that of English (e.g., Fuhrman & Boroditsky, 2010). Thus, we reasoned that the MTL might be modulated if reading and writing direction were directly reflected in the prompt. Experiment 4 tested this possibility.

Method

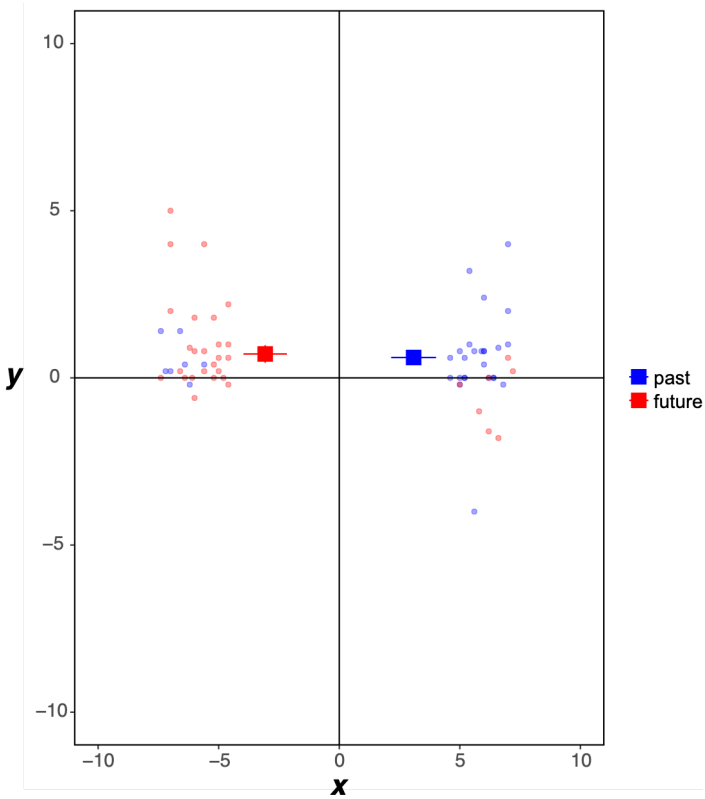
The method was identical to that of Experiment 2, except that the entire prompt was written in Japanese and that a sentence stating "You are a person from a culture in which text is read from right to left" (in Japanese: 「あなたは文字を右から左に読む文化圏の人です」) was added (Appendix C).

Results

The results are shown in Figure 4. For each AI respondent, the mean *x* coordinates of the past and future words were calculated (past words: $M = 3.084$, $SD = 5.270$; future words: $M = -3.072$, $SD = 5.098$).

Figure 4

Results of Experiment 4



Note. Error bars represent standard errors.

A paired *t* test revealed that past words were placed significantly further to the right than future words, $t(31) = 3.360$, $p < .001$, Cohen's $dz = 0.594$. Thus, an effect reflecting the reverse of the typical MTL association (i.e., left = future, right = past) was observed.

General Discussion

The present study examined whether the MTL, in which the past is associated with the left and the future with the right, is observed in ChatGPT, and whether this mapping can be reversed through linguistic and cultural manipulations. In Experiment 1, when ChatGPT performed the WAT with an English prompt, placing past and future words at any location on an *xy* plane, past words were placed to the left and future words to the right. In Experiment 2, the same pattern was observed when the task was given with an Arabic prompt. In Experiment 3, the same result as in Experiments 1 and 2 was obtained even when the prompt additionally specified that the model was a native speaker of Arabic. In Experiment 4, when ChatGPT performed the WAT with a Japanese prompt specifying that it was a person from a culture in which text is read from right to left, the opposite tendency was observed: past words were placed to the right and future words to the left. Taken together, these findings suggest that ChatGPT predominantly exhibits the left = past, right = future MTL, but that this mapping is influenced by the framing of reading direction.

The MTL is known to depend on linguistic culture. In cultures that use languages read and written from left to right (e.g., English- and Japanese-speaking cultures), the past is associated with the left and the future with the right (e.g., Santiago et al., 2007; Uchikawa et al., 2026). In contrast, in cultures that use languages read and written from right to left (e.g., Arabic- and Hebrew-speaking cultures), the future has been reported to be associated with the left and the past with the right (e.g., Fuhrman & Boroditsky, 2010; Park et al., 2024). However, ChatGPT showed the left = past, right = future metaphor congruency effect even when it was given an Arabic prompt and even when it was specified to be a native speaker of

Arabic. One possible explanation is that the text data used for training come mainly from English-speaking cultures, biasing the outputs toward the knowledge of those cultures (e.g., Aksoy, 2024; Tao et al., 2024).

Then, is the English-type MTL a fixed feature of the LLM? In Experiment 4, when the model was framed as a person from a culture in which text is read from right to left, a metaphor congruency effect consistent with left = future, right = past was observed. These findings indicate that the MTL-like mapping reflected in the LLM's outputs is not necessarily fixed. At the same time, considering the results of Experiments 2 and 3, this mapping does not appear to switch merely as a function of the surface language of the prompt or of a stated linguistic identity. The results of Experiment 4 suggest that explicit contextual information about reading and writing experience, which is thought to contribute to the formation of the MTL in humans, plays an important role in switching the MTL in the LLM. How explicit such context about reading and writing experience needs to be remains to be clarified by future research.

There are several limitations in the present study. The present experiments assessed the spatial placement of words in ChatGPT's outputs; they were not designed to determine whether ChatGPT possesses the same conceptual representations as humans. Rather, the present study shows that metaphorical correspondences similar to those observed in humans can be observed in an LLM that has learned from human-produced language data. Such observations can contribute to ongoing discussions of embodiment and conceptual metaphor (e.g., Casasanto & Gijssels, 2015; Gibbs, 1994), particularly regarding the extent to which human-like metaphorical correspondences can emerge in a system trained on language.

Appendix A

I would like you to place the following words on an

x y coordinate plane.

#Words

-next time

-last time

-future

-next year

-yesterday

-after

-before

-last year

-tomorrow

-past

#Constraints

-The x-axis represents left to right (-10 = left, 10 = right),

and the y-axis represents up and down (-10 = down, 10 = up).

-The center is (0, 0).

-Please place the words at any position within this coordinate space.

-Intuitive judgment is fine.

-The output should be in the format

“Word: (x coordinate, y coordinate)”. Please do not output anything else.

Appendix B

أريد منك وضع الكلمات التالية على مستوى إحداثي س ص.

كلمات#

-المرة القادمة

-أمس

-العام الماضي

-المستقبل

-قبل

-آخر مرة

-بعد

-غدًا

-الماضي

-العام القادم

قيود#

-يمثل المحور س من اليسار إلى اليمين (-١٠ = يسار، ١٠ = يمين)، ويمثل المحور ص من الأعلى إلى الأسفل (-١٠ = أسفل، ١٠ = أعلى).

-المركز هو (٠، ٠).

-يرجى وضع الكلمات في أي موضع داخل مساحة الإحداثيات هذه.

-الحدس جيد.

-(إحداثي س، إحداثي ص) :كلمة "يجب أن يكون الناتج بالتنسيق".

يرجى عدم إخراج أي شيء آخر.

Appendix C

あなたは文字を右から左に読む文化圏の人です。

以下の単語を x-y 座標平面上に配置してください。

#単語

-次回

-前回

-未来

-来年

-昨日

-以後

-以前

-昨年

-明日

-過去

#制約条件

-x 軸は左から右（-10 = 左、10 = 右）、y 軸は上から下（-10 = 下、10 = 上）を表します。

-中心は (0, 0) です。

-単語はこの座標空間内の任意の位置に配置してください。

-直感的な判断で構いません。

-出力形式は「単語: (x 座標, y 座標)」としてください。それ以外のものは出力しないでください。

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Data availability

All the data have been uploaded at https://osf.io/ufv2j/overview

Competing interests

The authors declare no competing interests.

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