

Language Shapes Cognition:  
Mandarin Speaker's Conception of  
Different Duration of Time

Manxin Lan

Cornell University

## Abstract

Does language shape thought? This question is answered by an experiment in this study. We found the following patterns in Mandarin and native speakers' cognition. Mandarin has four temporal prepositions that have spatiotemporal metaphors: two of them are horizontal (*qian* "front" and *hou* "back"), and the other two are vertical (*shang* "up" and *xia* "down"). In Mandarin, the horizontal terms are more frequent in a shorter duration of time, such as second and day (e. g. *qian yi tian* "front a day" which means the last day, and *qian yi miao* "front a second" which means the last second), whereas the vertical terms are more frequent in longer duration of time, such as week, month, year, and century (e. g. *shang ge yue* "up [quantifier] month" which means the last month). In this study, Mandarin native speakers are asked to answer a question about a short or long duration of time prime questions. In answering a prime question, the participants are shown a picture with a horizontal or vertical feature (for instance, a horizontal prime picture shows two dogs running from the left to the right), and we ask a yes-or-no question about the picture. We record the reaction time of each target question about time expression. The result is "short (horizontal – vertical)" < "long (horizontal – vertical)", which means that Mandarin native speakers tend to use the horizontal way to think of a shorter duration of time and use the vertical way to think of a longer duration of time. Since in Mandarin, shorter stretches of time are more frequently expressed in horizontal terms, and longer stretches of time are more frequently expressed in vertical terms, this cognitive pattern of perceiving short or long time as horizontal or vertical concepts resembles the pattern in the Mandarin language.

The language matches shorter stretches of time with horizontal terms, and this lets the speakers adapt the horizontal thinking mode for shorter stretches of time. The same process happens in vertical terms and longer stretches of time. We conclude that language is an important factor in shaping cognition.

*Key Words:* Whorf; language; time; Mandarin; metaphor.

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## **Introduction**

### **Puzzle and Question**

I want to conduct an experiment examining how spatiotemporal metaphors in Mandarin that signifies the different duration of time affect Mandarin native speakers' temporal cognition. Past studies have suggested that language spatiotemporal metaphors could affect native speakers' temporal cognition. However, few studies have examined how the duration of time in metaphors affects temporal cognition. This study contributes to further proving the Sapir-Whorf hypothesis.

The question of to what extent language could affect cognition has been debated since the Sapir-Whorf hypothesis was established. The academy commonly believes that the strong Whorfian hypothesis, which states that language determines thought, is wrong, while the weak version that the hypothesis that language could affect thought is supported by empirical evidence. How spatiotemporal metaphor in language affects temporal cognition is one of the pieces of evidence. Studies have shown that the spatiotemporal metaphor in Mandarin provides Mandarin native speakers with two ways of thinking of the time: both horizontal and vertical.

The duration of time, an important factor in temporal cognition, however, is neglected in the discussion of spatiotemporal cognition. Mandarin native speakers usually use horizontal temporal terms to talk about shorter periods, while using vertical temporal

terms to talk about long stretches of time. There might be a potential influence on temporal cognition. Mandarin native speakers might use the horizontal way to think of shorter duration while using the vertical way to think of longer duration.

## **Significance**

The research provides more evidence for the weak version of the Sapir-Whorf hypothesis. If we prove that the durational distinction does affect human temporal cognition, we could have more knowledge of the nature of the human mind. This could also help us to understand what role language play in human cognitive activity.

# Literature Review

## Introduction to Literature Review

Spatiotemporal metaphor is an important part of human languages, including Mandarin. There are two kinds of temporal terms in Mandarin: horizontal terms (*qian* “front” and *hou* “back”) and vertical terms (*shang* “up” and *xia* “down”). People tend to use horizontal temporal terms more often when talking about the shorter duration of time, such as day, minute, and second; vertical temporal terms, on the other hand, are more often used in longer duration of time, such as week and month (there are 2874 results of “front day” in CCL corpus, while there are only 206 results of “up day;” there are 7442 results of “up week,” while there are only 569 results for “front week”). This article mainly deals with how this semantical distinction in temporal terms affects Mandarin native speakers’ conception of time. This contributes to further proving the Sapir-Whorf hypothesis, which could help us to learn more about the nature of human cognition.

Past research related to this topic is in various fields: psychology and linguistics. Hypothesis and research about linguistics relativity, temporal cognition, language affecting the mind, and temporal terms in Chinese dialects are closely related to the topic of this paper. Past research has shown that spatiotemporal cognition does affect temporal cognition. In Mandarin’s case, having both horizontal and vertical terms provide Mandarin native speakers with more ways to think of time than English native

speakers (whose language only has horizontal spatiotemporal metaphors). However, few studies have shown that distinction in the duration of time in spatiotemporal metaphor affects people's conception of different duration of time. Even though there is an established theory about the relationship between language and temporal cognition, the duration of time has not been considered an important factor.

## **Literature Review**

### **Linguistic Relativity**

The hypothesis of linguistics relativity, or the Sapir-Whorf hypothesis, draws a relation between language and cognition. The strong Sapir-Whorf hypothesis states that language determines cognition, which means that linguistic categories limit and define cognitive categories. The weak Sapir-Whorf hypothesis says that language only influences cognition. Modern linguistics research agrees that the strong version is false, while the weak version has empirical evidence to support it. Whorf (1940) uses a comparison between English and Hopi languages to illustrate the relationship between language and thought. Modern researchers also researched linguistics relativity. Boroditsky (2011) talks about the diversity of language and examples of how language shapes thought. People who speak different languages describe the same event differently. She also emphasizes the role of memory in the process of cognition.

Frank et al. (2008) and Winawer et al. (2007) both use empirical data to support the



weak Sapir-Whorf. Frank et al. (2008) researched on Pirahã language in the Amazon tribe and especially its number of words. Pirahã language does not have exact numerical words such as “one,” but Pirahã speakers can distinguish large numbers. However, “they were inaccurate on matching tasks involving memory.” The study shows that number words are used as cognitive technology. Winawer et al. (2007) researched color words in Russian. Russian has distinctive words to describe navy blue and pale blue, which are “siny” and “goluboy,” respectively. The researchers experimented on how Russian native speakers and English native speakers conceptualize the discrimination of time differently. They found that “categories in language affect performance on simple perceptual color tasks.” This supports the hypothesis of language could influence thoughts.

### **Temporal Cognition**

The topic of temporal cognition is intensely investigated in the field of psychology. Past studies have shown that the concept of time has three features: abstract, flexible, and more importantly, space-related.

The concept of time is an abstract concept, which is different from those concrete ones such as “cup” and “pen.” This feature makes the concept of time different from human conceptualization. Boroditsky & Ramscar (2002) investigate how people conceptualize abstract concepts, such as time. Research has shown that the conception of abstract concepts is mostly experience-based, which means that people tend to use concrete

concepts and experiences to perceive abstract concepts. In the case of time, it is a spatial experience that is used to facilitate the conception of time. There are two types of conception: one is “ego-moving” representation, and one is “time-moving representation.” The former is that people conceptualize time as a fixed entity and it is people who are moving, while the latter is the opposite: people are still and time is moving. There is a possibility that how language represents time influences which representational strategy people utilize.

Another feature of the concept of time is that time is flexible: it could be conceptualized both long and short. Zakay & Block (1997) discuss how people conceptualize time differently in shorter and longer duration of time. Researchers conclude that while one is waiting, time attracts people’s attention and so they believe the stretches of time are longer than they are in reality. While people are doing interesting things, they are not attracted by time so they feel like time passes quickly. The duration of time plays an important role in the conception of time.

Neurological evidence also shows that temporal cognition has to do with spatial cognition. Saj et al. (2014) suggest that “patients with left spatial neglect also neglect the ‘left side’ of time,” in other words, the past. They find out that people whose right hemisphere of the brain exhibits spatial neglect also have trouble memorizing past events, the events that happen on the “left” of the mental timeline. They conclude that deficits in spatial representation also result in deficits in representing events along the

mental timeline. This suggests that temporal cognition is not only about the abstract concept of time, but also about a more solid concept, space.

The studies on temporal cognition contribute a psychology and neuroscience perspective to this paper. The mechanism of human cognition on time is important in the discussion of how language affects temporal cognition.

### **Language Affects Temporal Cognition**

According to the hypothesis of linguistics relativity, language could affect human cognition, and temporal cognition should not be an exception. Studies have shown that the native language people acquire can affect temporal cognition. Boroditsky & Gaby (2010) provide evidence from Pormpuraawan native speakers. Unlike English and Mandarin which use directions like up, down, left, and right to represent time, the Pormpuraawan language uses east and west to represent time. This is called absolute time representation. Researchers find that Pormpuraawan native speakers have “a coordinate frame that is independent of others reported previously” (Boroditsky & Gaby, 2010). This kind of temporal cognition is significantly different from the cognition of English native speakers. Evidence is also found in comparison in Mandarin and English. Mandarin and English both have spatiotemporal metaphors to represent time, and the representations are all not absolute. However, Mandarin has both vertical and horizontal metaphors, while English only has horizontal metaphors. Mandarin uses *qian* (“front”) and *hou* (“back”) to horizontally metaphor time and also uses *shang* (“up”) and *xia*

(“down”) to represent time.

On the other hand, English only has *before* and *after*, two horizontal spatial terms, to represent time. Boroditsky (2001) discusses the potential influences this linguistic difference might have on temporal cognition. Research has shown that Mandarin native speakers can think of time both horizontally and vertically, but English native speakers can think of time only horizontally. This shows that spatiotemporal metaphors in language affect temporal cognition patterns, and “one’s native language plays an important role in shaping habitual thought but does not entirely determine one’s thinking in the strong Whorfian sense.” Yang & Mao (2018) especially look at the temporal word *qian* / before in Mandarin and English. Corpus data have shown that there are fixed constructs in *qian* / before expressions: X + *qian* / before and *qian* / before + X. X could be time point, time duration, and event. Even though both languages have such constructs, Mandarin uses X + *qian* when X is a time point, duration, or event, while English uses before + X only when X is a time point and uses X + before only when X is a duration. The cognitive cause behind this phenomenon is that Mandarin prioritizes semantics over syntax, so the forms could be blurred into one. English prioritize syntax over semantics, so forming a difference that signifies semantic difference is important. The study shows the cognitive premise in the two languages, where Mandarin is “more semantic” and English is “more syntax.”

### **Temporal Terms in Chinese Dialects**

The historical meaning of the words *qian* and *hou* is complicated. The original meaning of *qian* is a verb meaning “to move without walking (such as standing on a boat),” and it later became “to move forward,” “past,” and “future.” The original meaning of *hou* is also a verb meaning: (slaves) walking slowly in shackles, following the escort. Its extended meaning includes “in the back” and “future.” Li (2021) researches the mechanism of metaphors in the words *qian* and *hou*. Mandarin uses “front day” to express “the day before yesterday,” while uses “back day” to express “the day after tomorrow,” which is difficult for English native speakers to understand. This is because Mandarin is a “time-moving” representation, while English is an “ego-moving” representation. Even though Mandarin uses *qian* (“front”) to represent the future sometimes, it does not meantime. Instead, it is more like “the scene in front of you.” Thus, having both “future” and “past” in the meanings of the word *qian* is not contradictory.

The spatiotemporal metaphor also occurs in Chinese dialects. Huaiyin dialect in Jiangsu province uses “come up” to express “originally.” Yangzhou dialect also has a similar feature: it uses “high low” to express the subject’s persistent behavior (Huang, 1996). Research on the Ningbo dialect (Shi, 2014) suggests that the dialect has space, body, and folk metaphors to express time. Hou et al. (2017) illustrate that people speaking different dialects conceptualize time differently. Mandarin and the dialect Hakka express time differently. 2:45 in Mandarin is “2 *dian* 45 fens,” while Hakka is “2 *dian* 9 *ge zi*.” Mandarin monolinguals and Mandarin-Hakka bilinguals perform differently

when they see a clock or number of times. This suggests that different Chinese dialects could affect people's temporal cognition.

## **Conclusion of Literature Review**

Past research has suggested the mechanism of temporal cognition, and have shown that different temporal metaphor could affect how people perceive time. Boroditsky (2001) points out that Mandarin and English have different spatiotemporal metaphors, which contributed to the different temporal cognition of native speakers. However, the linguistic distinction between shorter and longer stretches of time in Mandarin has not been studied yet. In Mandarin, shorter duration of time is often expressed by horizontal terms, and longer duration of time is expressed by vertical terms. This pattern has not been considered as a feature that could affect cognition. Moreover, past literature has not summarized the spatiotemporal metaphors in all Chinese languages and has not shown the potential impact they might have on temporal conception.

This article investigates how the distinction between the short and long duration of time in spatiotemporal metaphor in Mandarin affects people's conception of time. Besides, we also want to discuss the spatiotemporal metaphors in Chinese dialects. Even though Mandarin has been the official language in the country for decades, it was invented in the last century by adapting dialects. Some expressions in Mandarin might not be naturally developed. We want to discuss how the naturally developed languages, the

dialects, contribute the discussion on the relationship between language and cognition.

The study contributes to shedding light on weak linguistics relativity theory.

# **Experiment Design**

## **Introduction and Purpose of the Experiment**

Data in the CCL corpus has proved that horizontal spatiotemporal metaphors are used more frequently in a shorter duration of time, while vertical spatiotemporal metaphors are more used frequently in a longer duration of time. There might be a potential influence on Mandarin speakers' conception of time of different durations. The experiment aims at finding out whether Mandarin speakers interpret shorter and longer duration of time differently. We assume that Mandarin native speakers perceive short stretches of time horizontally and longer stretches of time vertically.

## **Experiment Principle**

The experiment uses the priming effect. The priming effect occurs when the participants are exposed to a certain stimulus that would influence the participants' behavior subconsciously. In this experiment, we use pictures as primes. The pictures show either a horizontal or vertical relationship between two objects. This would stimulate the participants to think horizontally or vertically.

## **Participants**

We invited 30 participants to the experiment, 15 of which has aged between 17 and 20, and the half has aged between 21 and 56. The average age of the participants is 27.2.



All of them are Mandarin native speakers and have an education level above secondary school. Most of the participants are bilingual with a second language of English.

## **Presumption**

Mandarin uses horizontal spatiotemporal metaphors in shorter stretches of time and vertical spatiotemporal metaphors in longer stretches of time. We expect that this would help to establish Mandarin speakers' temporal cognition. After being shown a horizontal prime, we suspect that the reaction time of answering a question about shorter stretches of time (such as seconds and days) is shorter than the one of answering a question about longer stretches of time (such as weeks, months, years and centuries), and vice versa.

## **Preparation**

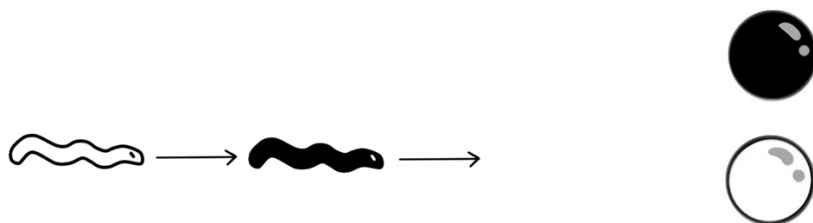
There are 2 practice questions and 12 experimental trials, 6 of which are horizontal primes and the others are vertical primes. In each practice question, 1 prime question and 1 target question are needed. In each experimental trial, 2 prime questions and 1 target question are needed. There are also 2 filler questions. We create 14 horizontal prime pictures, 14 vertical prime pictures, and 16 questions<sup>1</sup>. All the questions in the study are yes-or-no questions.

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<sup>1</sup> The prime pictures are produced by Qingyue Sun, an art student at the Affiliated High School of Peking University.

## Experiment Procedure

The Mandarin speakers are asked to watch/look at a horizontal or vertical priming picture that shows a horizontal or vertical relationship between two objects. The researchers would ask a priming question about the picture (e. g. TRUE/FALSE: the black worm is ahead of the white worm 黑虫子在白虫子前面). All languages used in this experiment are Mandarin.



**FIG 1. Horizontal and vertical primes examples**

The participants are then asked a target question related to time. The time in the question would be divided into different stretches of time: day, week, month, year, and century. All questions contain spatiotemporal metaphors, either horizontal or vertical. The target questions contain no spatiotemporal metaphor such as *qian* “front,” *hou* “back,” *shang* “up,” and *xia* “down.” We do not include questions about seconds in the experiment because sentences like “the first second comes earlier than the third second” are not naturally used in Mandarin. The target questions are listed below.

## Day

四月一号比四月四号早。 *April the first comes earlier than April the fourth.*

周日在一周中比周五晚。 *Sunday comes later than Friday.*

## Week

第三周比第四周早。 *The third week comes earlier than the fourth week.*

第五周比第一周晚。 *The fifth week comes later than the first week.*

## Month

三月比四月早。 *March comes earlier than April.*

十二月比二月晚。 *December comes later than February.*

## Year

二零一七年比二零二三年早。 *2017 comes earlier than 2023.*

二零一三年比二零零八年晚。 *2013 comes later than 2008.*

## Century

十九世纪早于二十世纪。 *The 19<sup>th</sup> century comes earlier than the 20<sup>th</sup> century.*

十三世纪晚于十世纪。 *The 13<sup>th</sup> century comes later than the 10<sup>th</sup> century.*

Each participant is asked 2 practice questions and 12 experimental trials. Each experimental trial consists of two priming questions (both horizontal or both vertical)

and one target question. The experimental trials were arranged such that the first prime question was FALSE, the second was TRUE, and the target question was TRUE. The answers are arranged in this way because we want to distribute TRUE and FALSE answers evenly in the prime questions. All the answers to target questions are true because FALSE questions might take longer time to answer, so we want to eliminate this confounding factor. Filler questions are randomly inserted into the process in case that the participants find the preceding pattern of answer. The answers to the filler questions are FALSE, and the questions are the reverse of the target questions. Two filler questions are inserted into a participants' experiment. In each trial, the researcher records the answers to the target questions and use the spectrogram to calculate the response time (the time when the sound of the question ended minus the time when the participant first makes a sound).

## Result and Analysis

### Experiment Result

The reaction time of the experiments shows that in answering both questions about short and long stretches of time, the average reaction time after viewing a vertical prime is shorter (as Table 1 shows).

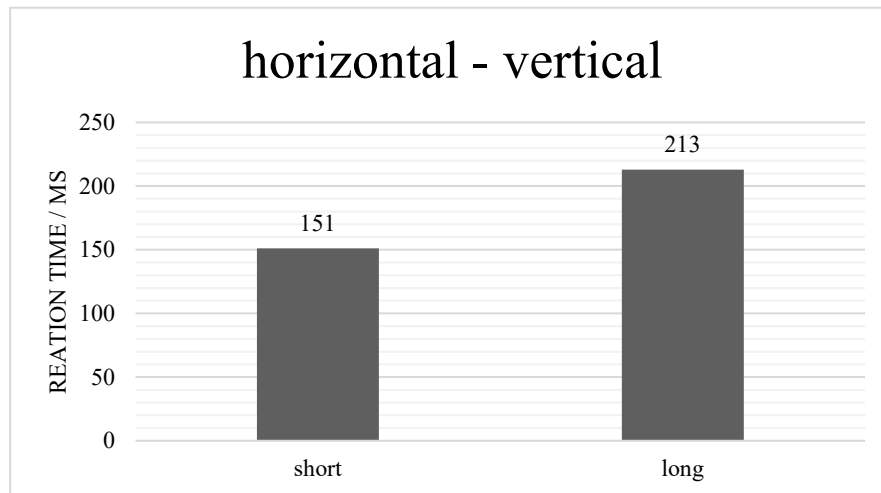
**Table 1. The reaction time of time type versus prime type (in milliseconds)**

Time / prime type	Horizontal	Vertical
Long time	792.9	580.1
Short time	843.3	692.4

We construct a Chi-square test for independence with a null hypothesis that different prime types produce similar reaction times for different stretches of time. An alternative hypothesis of different prime types affects the reaction time.  $p=0.12 > 0.01$ . We fail to reject  $H_0$ . We could not say that the reaction time of different time types is necessarily associated with prime types.

However, if we look at the difference between reaction times of prime types, there is a difference. The average difference in reaction time for answering short time questions is significantly smaller than the difference in reaction time for answering long time questions (horizontal minus vertical). This shows that after viewing a horizontal prime,

answering short time questions takes a shorter time and that after viewing a vertical prime, answering long time questions takes a shorter time (see FIG 2.).



**FIG 2. Differences in reaction time in answering questions about short and long stretches of time (horizontal prime – vertical prime)**

This shows that Mandarin does influence people's cognition over the different duration of time. Mandarin native speakers tend to think of shorter duration of time (such as days) in horizontal ways and think of longer duration of time (such as weeks, months, years, and centuries) in vertical ways because Mandarin assigns different spatiotemporal metaphors to the different duration of time.

We could not conclude with a relationship between time type and prime type because we do not have enough sample size to show the significance. The difference between reaction times of different prime types indicates a tendency that questions about short duration are easier to answer after a horizontal prime, whereas questions about long

duration are easier to answer after a vertical prime.

## **Analysis**

The first data analysis looks at the absolute difference between reaction time of answering target questions, while the second method focuses on the relative difference. The Chi-square test shows that there is no association between prime types and time types, but the difference between horizontal and vertical primes in the two time types suggests the pattern that horizontal primes facilitates the answering of question of short stretches of time, and vertical primes facilitates the answering of questions of long stretches of time. The first test concluded this way because the reaction time after answering a vertical prime question is always smaller than the time after answering a horizontal prime question.

Although the experiment has suggested that language affect habitual thought, cultural factors are still to be concern. “One important factor to consider is that of writing direction.”<sup>2</sup> Even though the Chinese writing direction today is horizontal, traditionally, it was vertical. The vertical thinking mode thus might be easier to activate.

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<sup>2</sup> Boroditsky, L. (2001). Does language shape thought?: Mandarin and English speakers' conceptions of time. *Cognitive psychology*, 43(1), 1-22.

Another factor that might affect the result might be some answering strategies used by the participants. We interviewed some of the participants after the experiment, and one of them said that she answered the questions by comparing the numbers in the question instead of thinking about the temporal terms such as Monday and Tuesday. In Mandarin, the word for Monday could be directly translated to *zhou yi* “week one,” the first day in a week. Similar things happen in the names of months: *yi yue* “one month,” *er yue* “two month,” etc. This is different from English, which does not use numbers in the names of days and months. Participants might just compare the numbers in the questions but not think about the time. Even though not all participants use this strategy, this is still an influencing factor. Further study might eliminate the factor by interviewing all the participants after the experiment and eliminate the answers given by participants who used this strategy.

## **Further Discussion on Chinese Dialects and Cognition**

We already discussed the effects Mandarin has on temporal cognition. There are also massive spatiotemporal metaphors in Chinese dialects. Dialects in Jiangsu, Ningbo, Henan, and Hakka have spatiotemporal metaphors. Huang (1996) discusses Chinese dialects and their temporal terms. Among all the temporal terms, Hakka, Jiangsu, Ningbo, and Henan dialects use words like “high” “low” “front” and “back” to talk about time. Some of them are similar to Mandarin, but some also show additional



features. Henan dialects, for instance, use “front” to talk about morning (the first half of the day). This further proves our assumption that Chinese languages tend to use horizontal spatiotemporal metaphors in shorter stretches of time.

The dialects discussed above are all from southern provinces in China. Mandarin, however, is based on northern dialects. Southern dialects are believed to preserve more features of ancient Chinese features, while many vocabularies in Mandarin are invented in the recent centuries. Even though Mandarin tends to use horizontal metaphors to talk about shorter stretches of time, “morning” in Mandarin could be directly translated into *shang wu* “up noon,” which is against our assumption, but the Henan dialect uses “front” in the word “morning.” This might show the difference between northern and southern dialects, and this also might show the difference between modern modifications and the ancient language.

Further research could be done by looking at the historical development of dialects and Mandarin along with continuing the experiment about cognition in people whose native language is a dialect.

## Conclusion

Mandarin native speakers' temporal cognition of different duration of time resembles the pattern in temporal terms in Mandarin: they use the horizontal way to think of shorter time units such as second and day and use the vertical way to think of longer time units such as week, month, year, and century. This resembles the pattern in Mandarin because, in the context of a shorter duration of time, horizontal spatiotemporal metaphors (*qian* “front” and *hou* “back”) are more frequent than vertical spatiotemporal metaphors (*shang* “up” and *xia* “down”). On the other hand, vertical spatiotemporal metaphors are more frequent than horizontal spatiotemporal metaphors in the context of a longer duration of time. These are proved by the data in the CCL corpus.

Our experiment shows that the reaction time of answering questions about a shorter duration of time after answering horizontal and vertical prime questions (horizontal – vertical) is shorter than the reaction time of answering questions about a longer duration of time. This means that the Mandarin native speakers tend to use the horizontal way to think of a shorter duration of time (such as second and day), and they tend to use the vertical way to think of a longer duration of time (such as week, month, year, and century).

This study provides evidence for the Whorfian hypothesis: language shapes thought. Language is an important factor that influences our cognition, even though this factor

is often neglected.

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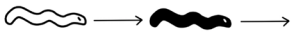
## Appendix

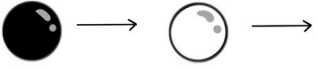


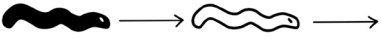

**Table 2. Raw data of the experiment (in seconds)**

prime / time type	hor\short 1	ver\short 1	ver\short 2	hor\long 1	hor\short 2	ver\long 1
1	1.82	2.17	2.43	0.32	0.5	0.48
2	1.17	0.44	1.38	0.69	0.43	0.81
3	2.1	0.36	0.46	2.01	0.42	0.73
4	0.39	0.38	0.25	0.99	0.36	0.33
5	1.22	0.16	0.3	0.33	0.45	0.08
6	0.62	0.57	0.52	0.25	0.38	0.37
7	0.26	0.86	0.42	0.93	0.59	0.95
8	0.3	0.21	0.33	0.38	0.88	0.39
9	0.54	0.36	0.4	0.41	2.78	0.11
10	1.73	0.26	0.19	0.23	0.52	0.47
11	0.74	0.48	0.5	0.33	0.47	0.3
12	0.64	0.53	0.67	0.58	0.23	0.38
13	0.26	0.37	1.14	0.89	0.25	0.57
14	0.63	0.52	0.7	0.52	0.66	0.6
15	1.54	1.07	0.69	0.7	0.27	0.39
16	0.82	0.32	0.51	0.56	0.77	0.42
17	1.68	0.71	0.3	1.43	0.66	1.01
18	0.73	0.36	0.5	0.54	0.29	0.57
19	0.65		0.76	9.44	0.65	2.72
20	2.6	2.12	1.76	0.91	0.49	0.6
21	0.22	0.23	0.58	0.4	0.29	0.25
22	4.02	0.4	1.57	4.63	1.44	1.13
23	0.56	0.34	0.37	0.83	0.31	0.35
24	0.66	0.38	0.29	0.67	0.1	0.3
25	2.26	1.07	1.47	1.04	0.8	0.61
26	1.66	0.23	0.48	0.61	1.43	2.07
27	2.05	0.73	1.05	0.82	4.14	0.9
28	2.34	0.92	1.57	1.07	0.92	0.7
29	0.76	0.38	0.95	1.64	0.69	0.8
30	0.38	0.24	0.59	0.25	0.15	0.15

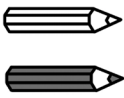


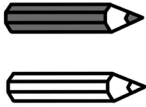

prime / time type	hor\short 1	ver\short 1	ver\short 2	hor\long 1	hor\short 2	ver\long 1
1	1.82	2.17	2.43	0.32	0.5	0.48
2	1.17	0.44	1.38	0.69	0.43	0.81
3	2.1	0.36	0.46	2.01	0.42	0.73
4	0.39	0.38	0.25	0.99	0.36	0.33
5	1.22	0.16	0.3	0.33	0.45	0.08
6	0.62	0.57	0.52	0.25	0.38	0.37
7	0.26	0.86	0.42	0.93	0.59	0.95
8	0.3	0.21	0.33	0.38	0.88	0.39
9	0.54	0.36	0.4	0.41	2.78	0.11
10	1.73	0.26	0.19	0.23	0.52	0.47
11	0.74	0.48	0.5	0.33	0.47	0.3
12	0.64	0.53	0.67	0.58	0.23	0.38
13	0.26	0.37	1.14	0.89	0.25	0.57
14	0.63	0.52	0.7	0.52	0.66	0.6
15	1.54	1.07	0.69	0.7	0.27	0.39
16	0.82	0.32	0.51	0.56	0.77	0.42
17	1.68	0.71	0.3	1.43	0.66	1.01
18	0.73	0.36	0.5	0.54	0.29	0.57
19	0.65		0.76	9.44	0.65	2.72
20	2.6	2.12	1.76	0.91	0.49	0.6
21	0.22	0.23	0.58	0.4	0.29	0.25
22	4.02	0.4	1.57	4.63	1.44	1.13
23	0.56	0.34	0.37	0.83	0.31	0.35
24	0.66	0.38	0.29	0.67	0.1	0.3
25	2.26	1.07	1.47	1.04	0.8	0.61
26	1.66	0.23	0.48	0.61	1.43	2.07
27	2.05	0.73	1.05	0.82	4.14	0.9
28	2.34	0.92	1.57	1.07	0.92	0.7
29	0.76	0.38	0.95	1.64	0.69	0.8
30	0.38	0.24	0.59	0.25	0.15	0.15

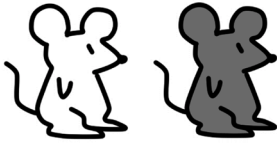



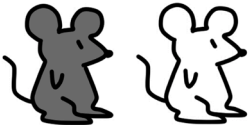
**Table 3. Questions and pictures used in the experiment**


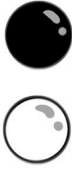
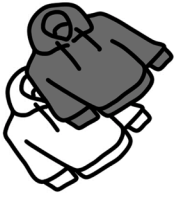

Question type	Prime picture	Question in Mandarin and English translation
Practice - prime		<p>白虫子在黑虫子前面。</p> <p>The white worm is ahead of the black worm.</p>

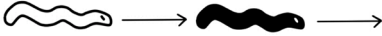

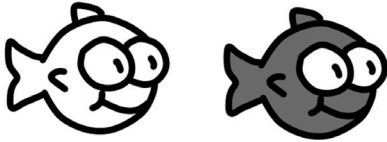
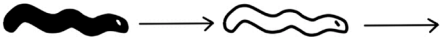
Practice - prime		白球在黑球前面。 The white ball is ahead of the black ball.
Practice - target	-	三月比四月早。 March comes earlier than April
Practice - prime		白球在黑球后面。 The white ball is behind the black ball.
Practice - prime		黑色的鱼输了。 The black fish lost.
Practice - target	-	二零二三年比二零一七年早。 2023 comes earlier than 2017.
Prime		黑虫子在白虫子前面。 The black worm is ahead of the white worm.
Prime		白车被黑车追上了。 The white car is overtaken by the black car.
Target	-	五月十五日比五月十三日晚。 May the fifteenth comes later than May the thirteenth.

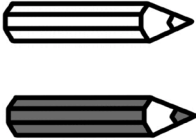






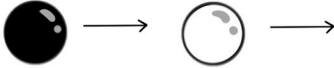


Prime		<p>黑笔在白笔上面。 The black pencil is above the white pencil.</p>
Prime		<p>白猫在黑猫下面。 The white cat is below the black cat.</p>
Target	-	<p>四月一号比四月四号早。 April the first is earlier than April the fourth.</p>
Prime		<p>白虫子在黑虫子下面。 The white worm is below the black worm.</p>
Prime		<p>白笔在黑笔下面。 The white pencil is below the black pencil.</p>
Target	-	<p>八月八日比七月一日晚。 August the eighth is later than July the first.</p>
Prime		<p>白车要被黑车追上了。 The white car is overtaken by the black car.</p>

Prime		白色的老鼠在黑色的老鼠后面。 The white rat is behind the black rat.
Target	-	二零一三年比二零零八年晚。 2013 comes later than 2008.
Prime		黑狗赢了。 The black dog won.
Prime		黑球在白球前面。 The black ball is ahead of the white ball.
Target	-	十二月十三日比十二月四日晚。 December the thirteenth comes later than December the fourth.
Filler - prime		白猫赢了。 The white cat won.
Filler - prime		黑色的老鼠在白色的老鼠后面。 The black rat is behind the white rat.
Filler - target	-	十二月比二月晚。

		December comes later than February.
Prime		黑壁虎赢了。 The black gecko won.
Prime		黑球在白球上面。 The black ball is above the white ball.
Target	-	十九世纪早于二十世纪。 The nineteenth century is earlier than the twentieth century.
Prime		白衣服在黑衣服上面。 The white hoodie is above the black hoodie.
Prime		黑壁虎赢了。 The black gecko won.
Target	-	第三周比第四周早。 The third week is earlier than the fourth week.

Prime		白虫子在黑虫子前面。 The white worm is ahead of the black worm.
Prime		黑色的鱼输了。 The black fish lost.
Target	-	三月四号比三月三号晚。 March the fourth is later than March the third.
Prime		黑色的鱼输了。 The black fish lost.
Prime		白虫子在黑虫子前面。 The white worm is ahead of the black worm.
Target	-	十三世纪晚于十世纪。 The thirteenth century is later than the tenth century.

Prime		<p>白笔在黑笔下面。 The white pencil is below the black pencil.</p>
Prime		<p>白衣服在黑衣服上面。 The white hoodie is above the black hoodie.</p>
Target	-	<p>十五世纪比十八世纪早。 The fifteenth century is earlier than the eighteenth century.</p>
Filler - prime		<p>黑球在白球下面。 The black ball is below the white ball.</p>
Filler - prime		<p>黑壁虎输了。 The black gecko lost.</p>
Filler - target	-	<p>四月五号比十二月十三日早。 April the fifth is earlier than December the thirteenth.</p>

Prime		黑狗赢了。 The black dog won.
Prime		白球在黑球前面。 The white ball is ahead of the black ball.
Target	-	二月比七月早。 December comes earlier than July.
Prime		白虫子在黑虫子下面。 The white worm is below the black worm.
Prime		白猫赢了。 The white cat won.
Target	-	二月十五号比二月二十七号早。 December the fifteenth is earlier than December the twenty-seventh.