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The linguistic transparency of first language calendar terms affects calendar calculations in a second language

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A R T I C L E I N F O

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A B S T R A C T

Calendar calculations – e.g., calculating the *n*th month after a certain month – are an important component of temporal cognition, and can vary cross-linguistically. English speakers rely on a verbal list representation-processing system. Chinese speakers – whose calendar terms are numerically transparent – rely on a more efficient numerical system. Does knowing a numerically transparent calendar lexicon facilitate calendar calculations in an opaque second language? Late Chinese-English bilinguals and English native speakers performed a Month and a Weekday Calculation Task in English. Directionality (forward/backward) and boundary-crossing (within/across the year/week boundary) were manipulated. English speakers relied on verbal list processing, and were slower in backward than forward calculations. In spite of the English calendar system's opaqueness, bilinguals relied on numerical processing, were slower in across- than within-boundary trials, and under some conditions had faster RTs than the native speakers. Results have implications for research on temporal cognition, linguistic relativity and bilingual cognition.

1. Introduction

Calendar calculations are an important component of temporal reasoning which is used in everyday life, for instance in establishing on which day of which month a certain task should be completed. Conventional time units such as months and weekdays however are represented differently in different languages. Crucially, the level of linguistic transparency of calendar terms across languages varies, so that speakers of different languages perform calendar reasoning tasks differently. This effectively means that such tasks may be easier for speakers of certain languages. Do such differences and advantages remain when speakers of a language with transparent calendar terms are tested in a second language with opaque terms? A comparison of Chinese and English native speakers tested in English can help answer this question. While calendar terms in English are opaque, Chinese calendar terms represent months and weekdays as a numerical system. If knowledge of more than one language affects thinking, then native speakers of Chinese tested in English may perform calendar calculation tasks differently from English native speakers. Such a finding would have consequences for both research on temporal cognition and research on bilingual cognition.

1.1. Calendar representation and processing

In Friedman's (1983, 1984) influential view of calendar representation and processing, the months of the year are represented as a verbal sequence in a *verbal-list system*. Calendar reasoning tasks that involve calculating the exact temporal distances between two calendar units – such as identifying the month that comes *n* months after a given month – are performed using *verbal-list processing*, by overtly or covertly reciting the sequence of units and counting them. Friedman (1983) found the following evidence for the verbal list system: 1) interference from simultaneous verbal tasks; 2) a *directionality effect*, because reciting a sequence is more difficult backward than forward; 3) a *distance effect*, because the sequential activation of units takes longer when the target is further away from the stimulus; and 4) participants' verbal reports of overt or covert reciting. However, Friedman's views of calendar representation and processing were based exclusively on data from English speakers. Since conventional time representations vary across languages, other languages may afford different ways of performing calendar calculations. An interesting comparison is that between speakers of English and speakers of Chinese.

The calendar lexicons of the Chinese and English languages have different levels of linguistic transparency. English weekday and month names are opaque (*Monday*, *January*). Chinese calendar terms instead

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follow a transparent numerical structure. Month names follow the format 'numeral + month', and weekdays are 'week + numeral':

一 月
yī *yuè*
i55 jyɛ51
one month
'January'

星期 一
xīngqī *yī*
ɕiŋ55.tɕʰi55 i55
week one
'Monday'[1]

The only non-numerical calendar term is the word for 'Sunday', which is lexicalised as 'week + *rì* or *tiān* (/zɨ51/, 'sun', and /tʰiɛn55/, 'sky', respectively)'; or even just 'week'.

Research shows that Chinese speakers reason about months of the year and weekdays differently from English native speakers, because of the numerical transparency of the Chinese calendar naming system. Huang (1993) found that Chinese speakers perform month reasoning tasks using *numerical processing*, namely arithmetic operations. For instance, a Chinese speaker who needs to calculate which month comes five months after January (lit. 'one month') can add five to 'one month' to obtain 'six month' ('June'). Huang (1993) found no direction or distance effects in Chinese adults because – unlike English speakers' verbal list strategy, which takes longer in reverse and with longer distances – Chinese speakers' addition and subtraction require similar amounts of time. Chinese adults' numerical processing was also demonstrated by a *boundary effect*. Since arithmetics is on base-10, and months of the year are a modulo-12 list, some calendar calculations based on mental arithmetics involve crossing a boundary. For instance, calculating the seventh month after 'eleven month' (November) yields 'eighteen month', and it is necessary to subtract twelve to obtain the answer 'six month' (June). This adds one step to the process, and therefore Chinese speakers are slower with month calculations that require year boundary crossing, compared with within-boundary calculations. Jiang and Fang (1997) found the same boundary effect in weekday calculation tasks.

There is direct evidence that numerical processing is due to the transparency of Chinese calendar terms, rather than cultural or other factors. Huang (1999) compared two groups of Chinese adults, who performed calendar calculation tasks either with solar months or with the twelve units of the traditional lunar calendar, whose names are opaque (e.g. the first unit is called *dà xuě*, /ta51 ɕyɛ325/, 'heavy snow'). Participants, who came from rural areas, reported equal proficiency and frequency of use of the two calendars. Calendar calculations were faster and more accurate in the solar calendar group. Furthermore, the lunar calendar group displayed direction and distance effects, whereas the solar calendar group displayed a boundary effect. Self-reported strategies confirmed that the solar calendar group used arithmetic calculations and the lunar calendar group used verbal lists. It appears that knowledge of a numerically transparent lexicon for one type of calendar does not translate into use of numerical processing for calendar calculations in another calendar system with different units and opaque terms.

While studies reported above only tested either Chinese or English speakers, Kelly, Miller, Fang, and Feng (1999) were the first to compare directly calendar calculations in Chinese and English speakers. Chinese and English-speaking primary school children and adults performed a weekday and a month-of-the-year calculation task. The Chinese group was overall faster than the English-speaking group, showed no effects of directionality, was negatively affected by boundary crossing, and mostly reported using arithmetic calculations. In comparison, English speakers were affected by directionality but not by boundary crossing, and mostly reported covert reciting. In conclusion, calendar reasoning appears to differ in Chinese and English speakers because of the linguistic transparency of the two languages' calendar lexicons. The next question is whether these two levels of transparency affect bilinguals who know numerically transparent and opaque terms for the same calendar system, when tested in the language with an opaque lexicon.

1.2. Temporal and numerical cognition in bilinguals

Much research has investigated whether learning new words or grammatical rules in a second language can result in the acquisition of new concepts and categories, or the restructuring of existing ones. These conceptual changes may happen when the first and second language carve the same continuum into different categories, for instance having two colour categories corresponding to English *blue*, or when the language groups different entities in the same category, or when the two languages require speakers to pay attention to different aspects of reality, for instance whether it is obligatory in the language to state the agent of an action or not. For example, when the second language has a linguistic label for 'orange' corresponding to colours that the native language categorises as shades of yellow or red, second language speakers may establish a new concept of 'orange' (Jameson & Alvarado, 2002). The possible outcomes of exposure to two languages are captured by the traditional distinction between subordinate, coordinate and compound bilingualism: the bilingual may have only native concepts (subordinate); two concepts, each one used when speaking the relevant language (coordinate); or an integrated concept, including features of L1 and L2 concepts (or indeed a novel concept, which is more than the sum of the concepts of either language) (compound). Researchers mostly focussed on how knowledge of more than one language may affect bilinguals' categorisation (for instance, whether something is categorised as a 'glass' or a 'cup'), attention (for instance, how much attention is paid to the endpoint of a motion event), and memory (for instance, memory for the agent of an action; for a review, Bassetti & Cook, 2011). Only limited research has investigated linguistic relativity effects on other aspects of cognition, such as reasoning and problem-solving, and on every day, as opposed to laboratory, tasks. A study of calendar calculation addresses this gap.

While there has been no research on the effects of calendar term transparency on bilinguals' calendar calculations, two lines of previous research may be relevant: research on linguistic effects on bilinguals' temporal cognition, and research on the effects of numerical transparency on bilinguals' mathematical cognition. The former shows that bilingualism affects performance in some temporal cognition tasks; the latter shows how bilinguals perform arithmetic calculations, which is relevant to the present study's question of whether bilinguals use arithmetics for calendar calculations.

Research on the effects of bilingualism on temporal cognition has mostly focussed on mental representations of the directionality of time, linking them to the directionality of writing and to time metaphors. First, while speakers of languages that are written left-to-right conceive of time as flowing from left to right, and vice versa (Tversky, Kugelmass, & Winter, 1991), children who learn a second language that is written in opposite direction to their first language accept both directionalities for time (Kugelmass & Lieblich, 1979). Second, there is some evidence of a link between time metaphors and bilinguals' concept of time's directionality, so that native speakers of Chinese, a language with vertical time metaphors, conceive of time as flowing from left to right more the more proficient they are in English, a language that has horizontal temporal metaphors (Boroditsky, 2001; Boroditsky, Fuhrman, & McCormick, 2011; but for failures to replicate see Chen, 2007; January & Kako, 2006, among others).

The study with aims closest to those of the present study is Yang and Zhang's (2011) investigation of bilinguals' calendar calculations. The researchers tested the effects of having a linguistic label for a temporal

[1] *Xīng qī* ('week') has two synonyms, due to regional variation and levels of formality: 周 (*zhōu*, /tʂou55/) and 礼拜 (*lǐ bài*, /li325.pai52/).