THE PAST AND FUTURE ARE IN YOUR HANDS:

HOW GESTURES AFFECT OUR UNDERSTANDING

OF TEMPORAL CONCEPTS

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DECLARATION

I hereby declare that this thesis is my original work and it has been written by me in its entirety. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

Ng Mai Rong, Melvin

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Summary

Spatial metaphors are commonly used by individuals to represent and reason about time. In English, such spatial metaphors are arranged primarily along the sagittal axis (e.g., "Looking *forward* to tonight's dinner"; Radden, 2004). These metaphors are often paired with gestures when people talk about time that reveal the possible axes along which an indvidual's internal conceptualisation of time may be aligned against (e.g., gesturing towards the space in front when talking about a future-related subject; Casasanto & Jasmin, 2012). Previous experimental investigations that employed the response congruency methodology as their means of investigation have found that time is represented along the lateral axis in English speakers with the past on the left and the future on the right, despite an absence of metaphors arraying time along this axis. In such investigations (e.g., Lai & Boroditsky, 2013), participants were required to respond in conventional ways for some blocks (with the past on the left and the future on the right), and non-conventional ways in others (past on the right, future on the left). An issue faced by these studies is the usage of a forced spatialization of responses as a proxy to investigate space-time associations in the mind. This usage of such specific motor responses along the lateral plane may emphasize and predispose participants into adopting this plane for temporal representation. As such, their findings could have been a result of their experimental methodology, rather than how time is actually represented in the minds. Ultimately, however, a mode of response is necessary in order to tap the temporal representations that exist in the mind. A priming paradigm using temporal gestures as primes was proposed as an alternative means to investigate how time is represented in the minds. By shifting the congruency effect to an earlier point in the processing stream while keeping responses constant, the advantages of the priming paradigm may be accrued and temporal concepts in the mind can be accessed directly. Participants made temporal classifications of words after watching a gestural prime. Results revealed effects of congruency along the sagittal axis, but not the lateral axis. This suggests that individuals primarily represent time along the sagittal axis when not constrained by a particular response format. Implications for models of how individuals represent time as well as methods of investigating how time is represented in the mind are discussed.

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Chapter 1: Introduction

The aim of the present study is to further our understanding of how people represent time in the mind. This introduction will first give an overview of the literature on how time is represented in the mind. This will be followed by the problems faced by past studies and why such problems could potentially lead to a misconstrual of how time is actually represented in the mind. The present study and its novel paradigm will then be described in detail, as well as how it seeks to overcome the problems raised.

How is time represented in the mind?

According to Lakoff and Johnson's (1999) Conceptual Metaphor Theory, abstract concepts such as time are grounded in more concrete dimensions such as space or motion. For example, in English, as well as the majority of languages of the world, metaphors referring to time are arranged primarily along the sagittal axis (Radden, 2004), e.g., "I am looking *forward* to tonight's dinner" and "It is good that we put our past *behind* us". In addition to the usage of such spatial words, cultural artefacts such as timelines, orthography and calendars are also used extensively by cultures around the world to aid in the representation of time (Clark, 1973). People also appear to automatically generate spatial representations when conceiving temporal concepts, aligning such concepts along one of the three possible planes of reference (Fuhrman & Boroditsky, 2010; Gevers, Reynvoet & Fias, 2003; Isihara, Keller, Rossetti & Prinz, 2008; Torralbo, Santiago & Lupianez, 2006; Weger & Pratt, 2008).

Boroditsky (2011) highlights the following factors that could potentially influence how an individual thinks about time: Firstly, the pattern of spatial metaphors used in speech may influence how individuals represent time, and the axis that is preferred for such representations. Lai and Boroditsky (2013) demonstrated that metaphor use may have a causal role in how people construct temporal representations in their minds at the point in time when such metaphors are used. In their second experiment, they had Mandarin-English bilinguals point to regions of space to refer to particular temporal events with respect to a predetermined reference point directly in front of the participant. For example, a participant might have been asked to point to a region in space that might have stood in for “the previous week” with respect to “this week” being the reference point. Participants were all tested in Mandarin, a language that has both vertical and sagittal metaphors referring to time. Half of the participants was tested with up-down metaphors whilst the other half was tested using front-back metaphors. They found that the metaphors that they used to test the participants affected how they represented time. Participants who were prompted with vertical metaphors were more likely to arrange time vertically compared to the participants prompted with sagittal metaphors, pointing to points either above or below the reference point. Conversely, participants prompted with sagittal metaphors were more likely to arrange time along the sagittal axis, pointing to points either in front of, or behind the reference point. Furthermore, it has been found that patterns in metaphor of different languages also affect how their speakers communicate about time in gesture. Casasanto and Jasmin (2012) found that English speakers gesture sagittally when speaking about time, placing the past behind with the future ahead, mirroring the sagittal temporal metaphors commonly used. Aymara speakers, on the other hand, who place the future behind the individual and the past in front, were found by Nunez and Sweetser (2006) to gesture along the sagittal axis in the reverse direction compared to English speakers. For more details regarding how the different languages represent time, please refer to Table 1.

Table 1: Arrangement of spatial metaphors used to describe time in English, Mandarin and Aymara

Language	Axes recruited	How is time represented along the axis?	Examples
English	Sagittal	Future is ahead, past is behind	looking *ahead* to tomorrow, looking *back* on the past
Mandarin	Sagittal	Earlier events are qián or "in front", later events are hòu or "behind"	the previous year, 前年; the year after, 后年
	Vertical	Earlier events are shàng or ‘‘up,’’ later events are xià or ‘‘down.’’	last week, 上个星期; next week, 下个星期
Aymara	Along the sagittal axis	Future is behind, past is in front	*nayra mara* (lit: front year, "last year"); *qhipa marana* (lit: back/behind year, "next year")

Secondly, cultural-specific artefacts such as writing, reading direction and calendars have also been found to shape people’s representations of time (Chan & Bergen, 2005; Fuhrman & Boroditsky, 2010; Tversky, Kugelmass, & Winter, 1991). For example, Tversky and colleauges (1991) found that Hebrew speakers (who read and write from right to left) are more likely to arrange time with past concepts on the right and future ones on the left. Conversely, English speakers (who read and write from left to right) are more likely to show the reversed pattern.

To summarize, the pattern of metaphors used in speech and writing and cultural-specific artefacts have been found to influence how people represent time in their minds.

The Lateral and Sagittal Mental Timelines

Of the three possible planes, previous studies have often focused their investigation on the lateral and sagittal planes (refer to Figure 1 for an illustration of the two planes).

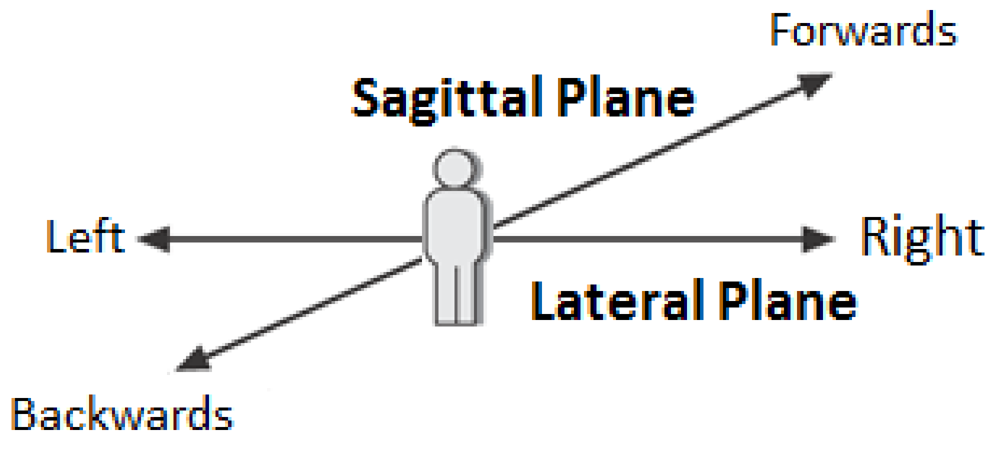

Figure 1. The lateral and sagittal planes.

Along the lateral plane, which extends to either side of the body, past-related or “earlier” concepts are situated on the left, while future-related or “later” concepts are placed on the right for English speakers. This mirrors the direction in which they read and write (e.g., Boroditsky, Fuhrman & McCormick, 2011) as well as cultural artefacts like the organisation of calendars and graphs (Tversky, Kugelmass & Winter, 1991). In their study, Tversky and colleagues asked children and adults to place stickers on a page as markers to indicate when breakfast and dinner should be placed relative to a lunch sticker situated in the middle of the page. They found that English speakers placed breakfast to the left of the lunch sticker and dinner on its right. In contrast, Arabic speakers arranged it in an opposite fashion and placed breakfast on the right of the lunch sticker and dinner on the left. These arrangements are consistent with not just the reading and writing directions in English and Arabic, but also with the way the distinct cultures organized time on their calendars.

Further evidence into a direct link between the direction of orthography and the lateral timeline is provided by Casasanto and Bottini (2010), who demonstrated that reading and writing direction may play a causal role in shaping the direction of the lateral timeline. In their study, they presented phrases in standard Dutch orthography (left-to-right, as in English) to half of their participants, while the other half received phrases that were in mirror-reversed Dutch. They found that Dutch-Speakers who were presented with the former were faster at judging past-oriented phrases when responding using the left button and future-oriented phrases using the right button. In the case of the latter half, participants showed an opposite pattern of reaction times, responding faster to past-oriented phrases using the right button and future-oriented phrases with the left, consistent with results found in Arabic and Hebrew speakers (Fuhrman & Boroditsky, 2010). In short, it appears that experience in reading a reversed orthography was able to reverse the direction of a reader's mental timeline, though perhaps, transiently.

In addition to the lateral timeline, it is often argued that speakers also possess a sagittal timeline that extends along the front and back of the individual. This sagittal timeline is shaped by the spatial expressions that we commonly use when we express temporal relationships (e.g., Ulrich, Eikmeier, de la Vega, Fernández, Alex-Ruf, & Maienborn, 2012). In English, the past lies *behind* us, while the future, *ahead* of us. This is also reflected in gestural data for deictic time, which are time concepts that exist with respect to a "now" point of the speaker. Examples of deictic time could comprise events like an individual's retirement or fifth birthday; such events may be past- or future-related with respect to an individual's "now". As with the linguistic instances, English speakers have been found to gesture forward for future events and backwards for past events (Casasanto & Jasmin, 2012). However, studies that have attempted to systematically investigate the possibility of a sagittal timeline reported mixed evidence.

Ulrich and colleagues (2012) employed a unique means of response that involved a device with a slider that allowed for movement either away from or towards the participant to investigate the possibility of a front-back mental timeline. In their study, participants were required to respond with movements either forward or backward along this device using a handle to future- or past-related German sentences. After which, a spring returned the slider to the start position in the centre. Touch-sensitive sensors registered the reaction time (RT) required from the presentation of the sentence to the onset of the participants' response. In some cases, the direction of the movement was congruent with the temporality of the sentence (e.g., moving forward and away for a future-related sentence) and in other cases, it was incongruent (e.g., moving towards the participant for a future-related sentence). They found effects of congruency with participants responding faster to future-related sentences by pushing the handle forwards compared to when they had to pull it back, and vice versa for past-related sentences. Their results suggested a linkage between time and space along the sagittal axis that mirror the metaphors found in everyday German speech and writing. As such, it appears German speakers do indeed possess a sagittal timeline in their minds that mirrors the spatial metaphors with which they use to talk about time.

On the other hand, Fuhrman and colleagues (2011) failed to find any evidence indicating a linkage between space and time along the sagittal axis in their study of English and Mandarin speakers. In their experiment, participants were to judge if a picture was an earlier or later event with respect to the picture that came before it (e.g., a picture of an unpeeled banana following a previously shown reference picture of a half-peeled banana). Their participants responded on a 3 x 3 keypad that was mounted on a rotating ball head that allowed it to be aligned with the various axes. In the case of the sagittal axis, the keypad was oriented parallel to the tabletop in front of the participant and such that it was flush with it. In other words, the keypad was perpendicular to the participant in an attempt to simulate a sagittal plane extending in front of the participant (please refer to Figure 2 for a diagram of the input device used in their experiment). The response keys were the ones that were nearest to the participant, and the one that was farthest.

Figure 2. The input device used by Fuhrman et al. (2011) in their experiment

In some blocks, marked as canonical with respect to how time is represented in language, the key that was nearer to the participant was assigned as “earlier” and the further key, “later”. For blocks marked as non-canonical, this was reversed with the nearer key assigned as “later” and the further key, “earlier”. They found that both English and Mandarin speakers did not show any time orientation preference along the sagittal axis. While their findings appear to suggest that the sagittal axis is not recruited for the conceptualization of time, they do admit that their response task may not have been well tuned to test time representations along the sagittal axis. In essence, their response task did not capture “front” or “back” of the participant in the true sense of each word, given that the points were placed in front of the participant, and were either nearer or farther relative to their bodies.

In short, while many studies have demonstrated the existence of a lateral timeline, the sagittal timeline remains one of much contention, despite the overwhelming majority of sagittal metaphors in languages around the world (and the almost complete absence of lateral metaphors for time; Radden, 2004). The present study aims to resolve the controversies on the temporal representation along sagittal timeline by adopting a cross-modal semantic priming paradigm in order to investigate how individuals represent time in the mind.

Priming as an alternative means of investigation

In traditional studies that made use of response congruency to investigate how people represent time in the minds (e.g., Fuhrman et al., 2011), researchers often place the incongruency at the response stage and the focus is on how incongruencies (or congruencies) between response and stimuli might hinder (or facilitate) the participant's response. Typically, participants are required to respond in a manner that is congruent with respect to how time is conventionally represented (e.g., left button for past, right button for future) in one block of trials, while responding in a manner that is incongruent with how time is represented (e.g., right button for past, left button for future) for the other block of trials.

However, restraining participants to a particular response format may predispose them into adopting transient frames which they then adopt to represent time. In the above example, requiring participants to respond in a congruent, and then an incongruent (or vice versa) manner along the lateral plane would emphasize and predispose participants into arranging temporal concepts along this plane. Ultimately, however, a mode of response is necessary in order to tap the temporal representations that exist in the mind.

A possible way to resolve this is to keep responses constant and shift the incongruency to an earlier stage in the information processing stream. This is much akin to priming, where the manipulation of congruency occurs much earlier than the point where subjects are required to make a response.

Semantic priming is characterised by the facilitation in processing of a target (e.g., "*doctor*") when it is preceded by a related prime (e.g. "*nurse*") as compared to when it is preceded by an unrelated prime (e.g., "*dog*"; Neely, 1991). While the semantic priming effect is commonly used in visual word recognition paradigms (see McNamara, 2005 for an extensive review), variations of the priming task have also been previously explored as a means of investigating how individuals represent time in the mind. The usage of priming would allow us to access and activate representations of time directly among participants while circumventing any inclination towards a particular axis that may arise as a result of the imposition of specific response frames. Torralbo, Santiago and Lupianez (2006) primed participants using irrelevant spatial information comprising thought bubbles that appeared either in front of or behind the silhouette of a head (please refer to Figure 3 for examples of the stimuli used in their experiment).

Figure 3. An example of the stimuli used by Torralbo et al. (2006).

They found that when the thought bubble appeared in a spatial location that was congruent with the temporal phrase or word that it contained (e.g. “He saw” appearing behind the head), participants’ were faster to classify it as either a past- or future-related word or phrase vocally as compared to if it had appeared in an incongruent spatial location. However, while they argue that their stimuli captures the sagittal plane, it is unlikely that it can capture the full sense of an individual’s front and back, given that it is a 2D silhouette presented on a flat screen. In addition, the lateral and sagittal planes are conflated, with the thought bubbles that appear in front of (or behind) the head being positioned on the left on some trials, and on the right on others.

By shifting the incongruency instead to an earlier point of the processing stream to the stimulus stage (while keeping responses constant), the benefits of the priming paradigm may be accrued. For one, there is the advantage of having each target serve as its own control given that across participants, all targets were preceded equally often by congruent and incongruent primes. By holding all other aspects of the experiment constant, it is subsequently possible to determine if the conditions evoked by the prime are responsible for any differences observed.

In the case of a temporal experiment, if the prime (e.g., an indication towards a spatial location along a particular axis) is meaningfully related to the target (e.g., a temporal word), any differences in response would be attributable to the conditions elicited by the prime. In other words, when preceded with a related prime, responses should be facilitated compared to if it had been preceded with an unrelated one. Such an indication would suggest that spatial information along this axis is indeed meaningful when processing temporal information. On the other hand, if the spatial location is not meaningfully related to the temporal target, no differences in response would be expected.

Furthermore, rather than relying on specific responses as proxies (which may, themselves, then heavily influence how people represent time, if transiently), if the mental timelines found using traditional response congruency methods are likewise found using a different paradigm, it would provide further evidence that timelines in the mind can exist above and beyond the responses that are required at the point of the experiment.

In brief, the priming paradigm provides us with a potential avenue to investigate how time is represented in the mind that may have advantages over traditional response congruency methods.

Utility of gestural primes and auditory tokens in the present study

In the present study, we adopted a cross-modal semantic priming paradigm to examine whether individuals represent time along the sagittal plane (Experiment 1) and / or along the lateral plane (Experiment 2). Specifically, we use gestures as our priming stimuli and binaural auditory tokens as the targets. As mentioned briefly above, speakers have commonly been found to produce gestures along both sagittal and lateral planes when talking about time (Casasanto & Jasmin, 2012). For example, a person referring to a past-related event may make a throwing gesture over the shoulder, referring to the space behind the body. To elaborate, a speaker might gesture backward while saying "where I had been," when referring to his past to a listener. Even though gesture and speech are produced in different modalities, the two combine to deliver a coherent message to the listener, forming a single, unified communication system (Goldin-Meadow, 1997; McNeill, 1992). As such, the prevalence of gestures accompanying temporal speech may imply a possible role of bodily motion in temporal cognition and the communication of such temporal concepts.

Previous studies have demonstrated that iconic gestures, when used as experimental stimuli, are also capable of priming semantically related words and concepts (Wu & Coulson, 2007; Yap, So, Yap, Tan & Teoh, 2011). Such iconic gestures demonstrate, or simulate, referents via the motion or shape of the hands. An instance of this would be a speaker saying the "*The bird flew away*" while making a flapping motion with their hands to convey information about the bird's actions or attributes. In this scenario, the iconic gesture referring to a bird would prime the word "bird".

The temporal gestures that will serve as primes for the present study belong to a branch of gestures known as metaphoric gestures, which represent abstract ideas or concepts. An example of this is a gesture towards the space behind the speaker, as mentioned above, or to the left to represent an event that occurred in the past. In essence, gestures present a means to access the very same objects or concepts they represent, and the usage of gestures as primes may allow us to access the temporal concepts in an individual's mind.

While gestural primes provide us with a means to access and activate temporal concepts in the mind, there still remains the question as to what should be used to probe these said concepts. Binaural auditory tokens were chosen as such a means to probe these temporal concepts, and have been found to be as effective as visual stimuli in doing so (Ouellet, Santiago, Israeli & Gabay, 2010). These auditory tokens will consist of isolated temporal words that are either past- or future-related.

Previous studies have often used visually-presented sentences or phrases as a means to probe temporal concepts in the mind, but as mentioned above, this choice of stimuli could have themselves predisposed participants into adopting the frames provided to represent time at the point of the experiment (Casasanto & Bottini, 2014). In the case of English sentences or phrases, the very act of reading from left to right could predispose participants into adopting this left-right directional frame for the purpose of representing past and future in the experiment. In addition to these convenient cognitively available frames, the reading of such sentences would enable participants to reflect on time representations and allow for strategic processes that would then obscure how time is naturally represented in the mind. As such, by having participants respond as quickly as possible to isolated words, we would encourage a more automatic form of processing, allowing us to tap the underlying temporal representations.

To summarize, gestural primes, in conjunction with auditory targets will provide us with a potentially naturalistic means by which we can tap temporal concepts in the mind.

Summary of Aims/Goals

The aim of the present study is to further our understanding of how people represent time in the mind. Results from previous studies that demonstrate that time is represented along the lateral, but not sagittal axis may have been a product of their experimental design. By having participants respond in both canonical (e.g., “Past is Left”) and non-canonical (e.g., “Past is Right”) ways along the lateral plane, or reading sentences or phrases, participants may have been predisposed into adopting a left-right directional frame in the experiment. As such, a new paradigm is suggested in which a cross-modal priming paradigm is used instead to directly tap an individual’s representation of time.

The usage of priming as our means of investigation would allow us to access and activate representations of time in the minds of our participants and allows for the advantage of control, allowing us to determine if it is the conditions evoked by the prime that are responsible for any differences observed. In addition, if the mental timelines found using traditional response congruency methods are likewise found using a priming paradigm, it would provide stronger support for the view that timelines in the mind can exist above and beyond the responses that are required at the point of the experiment.

Gestural primes provide a potentially naturalistic means by which we can access and activate these temporal concepts in the mind, given the prevalence of gestures accompanying temporal speech, and the findings from previous studies on the efficacy of gestures in priming semantically-related words and concepts. These gestural primes, in conjunction with auditory tokens as targets will allow us to investigate how individuals represent time in the mind.

By combining a semantic priming paradigm with gestures as the priming stimuli, we will be able to access temporal concepts in the mind via a naturalistic stimulus. In addition, the usage of gestures as primes not only provides meaningful stimuli (as participants are able to interpret the information communicated from the gesturer's perspective and hence yoke the axis of interest to the gesturer), but also allows us to overcome the shortcomings of previous experiments. Namely, gestures will allow us to capture a true “front” or “back”, as compared to previous studies such as Fuhrman et al. (2011) which had points of response in front of the participant that were either nearer or farther relative to their bodies. This is also true in comparison to the stimuli used by Torralbo et al. (2006) in which the sagittal plane is conflated with the lateral given that they used 2D silhouettes displayed on a flat screen.

In the following experiments, participants will perform a categorisation task in which they are to classify auditorily presented words as either past- (e.g., “yesterday”), or future-related (e.g., “tomorrow”). The primes that precede these words will either be a gesture indicating a congruent spatial location (e.g., a point towards the back + “yesterday”) or a gesture indicating an incongruent spatial location (e.g., a point towards the back + “tomorrow”). Participants should respond faster if the auditory target is preceded with a gesture indicating a congruent spatial location than if it had been preceded with an incongruent gesture if the prime is meaningfully related to the target. In other words, if spatial information along the axis that is being investigated is indeed meaningful when processing temporal information, a related prime should facilitate responses compared to if it had been preceded with an unrelated one.

The specific experimental hypotheses will be stated at the start of each experiment.

Chapter 2: Experiment 1 – Sagittal Axis

The following experiment will investigate if individuals represent time along the sagittal axis. My hypothesis is as follows: if speakers represent time along the sagittal axis in a manner that reflects the vast majority of metaphors in written and spoken language, a temporal gesture that indicates the space behind an individual should prime past-related concepts and aid in the temporal judgement of past-related words, and vice versa for future-related words. In other words, when a primed temporal gesture is congruent with the word to be judged (e.g., a temporal gesture indicating "forward" + "tomorrow"), responses should be faster than when the primed temporal gesture was incongruent (e.g., a temporal gesture indicating "backward" + "tomorrow").

Method

Participants.

Forty-four undergraduates from the National University of Singapore participated in the study for course credit or payment. All participants were English-Mandarin bilinguals who have studied in Singapore for at least 10 years. Participants reported their level of proficiency in English and Mandarin using a language background questionnaire and indicated that their first language was English and they had better proficiency in it than Mandarin[1].

Design.

A 2 (Temporality: past- vs. future-related word) x 2 (Congruency: congruent vs. incongruent) within-subject design was used. Congruency was determined with respect to the gesturer, so a point towards the back is considered to be congruent if it was paired with a past-related word, and incongruent if paired with a future-related one.

Materials.

Time-related words were chosen from the online Oxford Dictionary (2015) based on their definitions. Ten students from the same population sample, but who did not take part in the main experiments, rated how past- or future-related the words were. A 5-point Likert scale was used, with 1 representing a strongly past-related word, 5 a strongly future-related word, and 3 being a temporally neutral word. A final set of 80, with an equal number of past- and future-related words, was chosen from words that were rated as either past- (<3) or future-related (>3). Interrater reliability was high and there was high agreement between raters on

[1] Only English-Mandarin bilinguals who were more proficient in English were chosen to control for any differences that might arise due to any cultural influences in how individuals represent time. No additional analysis was done on this as this was not the focus of the study.

whether a word was past- or future-related, Cronbach's α = .967. Characteristics of the chosen words are summarised in Table 2 and the words themselves can be found in the Appendix.

Table 2: Average Word Properties of the Word Sets in the Experimental Conditions

	Past-related words		Future-related words	
	M	*SD*	*M*	*SD*
Word Duration (ms)	853.38	166.27	821.68	165.16
Log HAL Word Frequency	8.08	2.17	9.08	1.96
Phonological neighbourhood size	1.40	3.74	4.00	7.52
No. of Phonemes	6.70	1.86	6.58	2.21
No. of Syllables	2.55	0.88	2.53	0.78
Phonological Levenshtein distance	3.02	1.06	2.55	1.01
Temporality rating	1.58	0.39	3.99	0.24

Within each temporal category, the words were further divided into two equal sub-lists, with each sub-list being either paired with a congruent gesture (e.g., the model pointing to her back + “yesterday”) or an incongruent gesture (e.g., the model pointing to her front + “olden”). Sub-lists were counterbalanced across participants using a balanced latin-square, so that across participants, all targets were preceded equally often by congruent and incongruent gestural primes.

As past and future words could not be made identical, separate one-way analyses of variance (ANOVAs) were conducted between each sub-list to ascertain that the words were properly distributed between sub-lists. Results showed the temporal words were matched across sub-lists on word duration, log-transformed hyperspace to analog (HAL) frequency, phonological neighbourhood density, number of phonemes, number of syllables and phonological Levenshtein distance (all Fs < 1).

Binaural auditory tokens were created as a means to probe the temporal concepts as they have been found to be as effective as visual stimuli in doing so (Ouellet, Santiago, Israeli & Gabay, 2010). All stimuli were spoken by a linguistically trained female speaker and recorded digitally in 16-bit mono, 44.1 kHz, .wav format.

Two gesture video clips were paired with either congruent or incongruent temporal words. These gesture clips were constructed by recording silent videos of a female actor facing and looking at the camera and pointing either backwards or forwards along the sagittal axis. The video included the actor’s face. One video was made for each gesture of interest, with an emphasis on its stroke. (Figure 4 shows a snapshot of the gestural stimuli used; please refer to Appendix B for a full set of gestural stimuli used)

Figure 4. Snapshot of the gestural stimuli with the gesturer pointing forwards.

Procedure.

The experiment was conducted using E-Prime 2.0 and the data was collected using the PST Serial Response Box (Schneider, Eschman, & Zuccolotto, 2002). Participants were seated in front of a 17-inch screen and instructed to make a temporal judgement, as quickly and accurately as possible, of the word using the response box with the left- and right-most buttons labelled *Past-related* and *Future-related*, respectively. To minimize the imposition of a spatial frame, the response box was situated at a central location relative to the participant, and the response keys were situated in close proximity to one another. Each trial began with a gesture video clip lasting 1000 ms, immediately followed by an auditorily presented temporal word to be judged as either past- or future-related. Reaction time (RT) was measured from the onset of the auditory target. Please refer to Figure 5 for the basic outline of each trial.

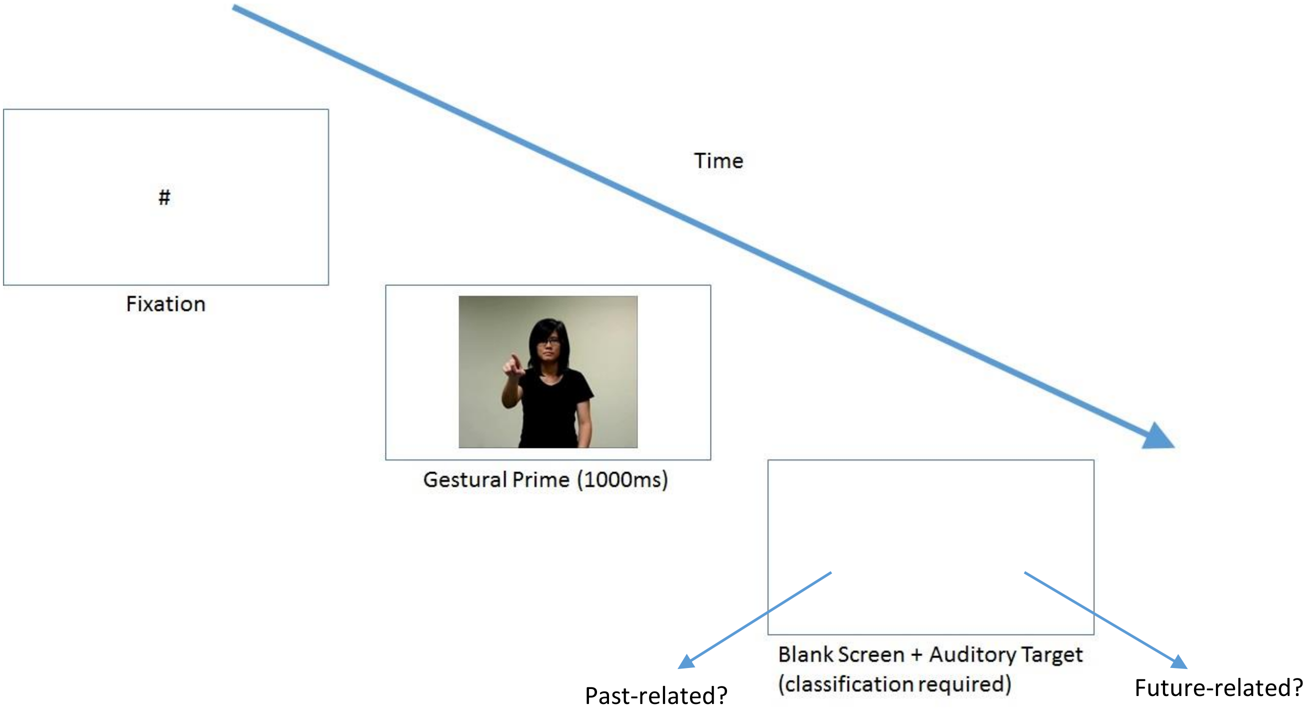

Figure 5. Basic outline of each trial

Prior to the actual experiment, 10 practice trials were administered to familiarize the participants with the experiment. There were a total of 80 experimental trials and participants were allowed a break after every 20 trials

Results and Discussion

For the reaction time (RT) data, only correct judgements with RTs more than 200 ms and less than 3000 ms were included in the analyses. Following which, the overall mean and *SD* of each participant's RT was calculated and trials with latencies being 2.5 *SD*s above or below each participant's mean RT were removed. These trimming criteria resulted in a removal of 5.00% of accurate trials. Overall accuracies were all very high (M = .91, SD = .06).

The mean RTs across the 4 conditions in Experiment 1 are summarised in Figure 6. A two-way repeated-measure ANOVA was conducted on participants' mean RTs by congruency (congruent vs. incongruent) and temporality (past vs. future).

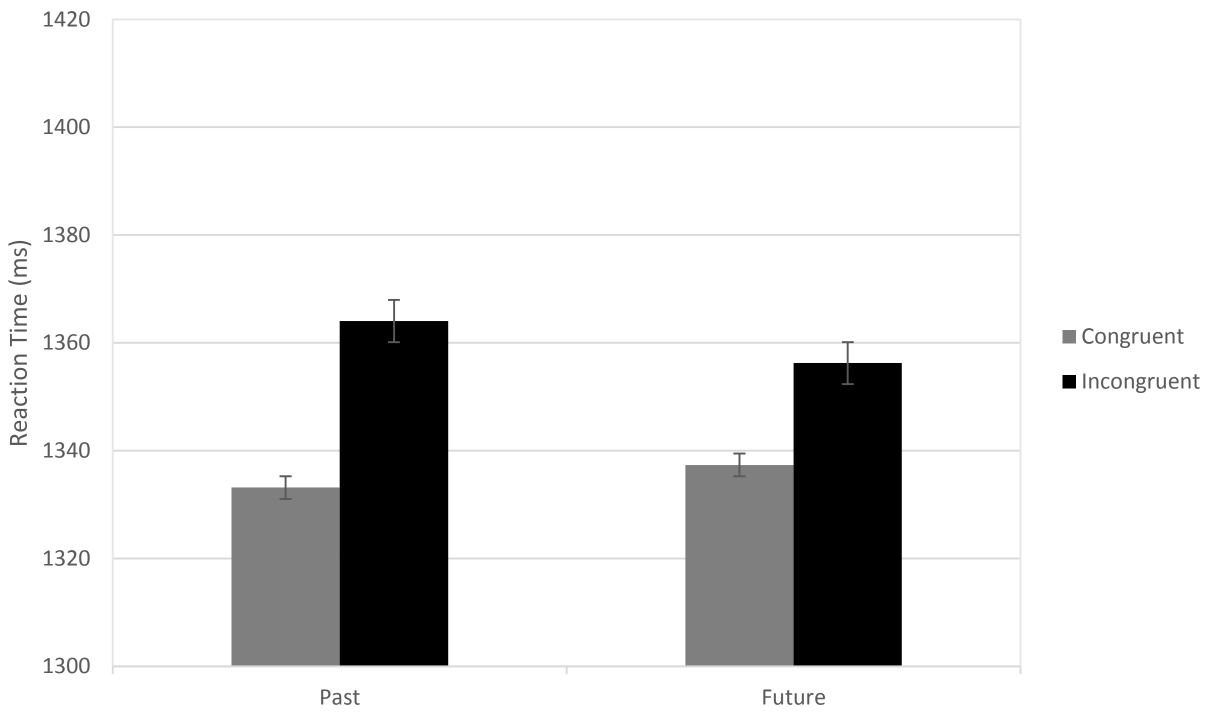

Figure 6. Average RTs for responses in Experiment 1 (error bars indicate 1 standard error above and below the mean)

Participants were found to judge past-related and future-related words equally quickly (1348ms vs 1346ms), $F < 1$. More crucially, participants were found to respond faster to congruent gesture-word pairs (1335ms) than to incongruent pairs (1360ms), $F(1,43) = 4.372$, $MSe = 6238$, $p = .042$. The interaction between the two variables was not significant ($F < 1$).

In other words, an effect of congruency was found along the sagittal plane indicating that gestures were able to prime temporal concepts that were either congruent or incongruent with the auditory target. Furthermore, the effect of congruency was found to mirror the spatio-temporal metaphors commonly recruited to talk about time, with the past situated behind the individual and the future, ahead. A more detailed discussion will be conducted in the General Discussion

Chapter 3: Experiment 2 – Lateral Axis

Having established that our paradigm was capable of priming temporal concepts, we proceeded to investigate the lateral axis using the same method. My hypothesis for this experiment is as follows: if speakers also represent time along the lateral axis in a manner that reflects cultural artefacts and reading and writing direction, we expected that when a primed temporal gesture was congruent with the word to be judged (e.g., a temporal gesture indicating “left” + “yesterday”), responses would be faster than when the primed temporal gesture was incongruent (e.g., a temporal gesture indicating “right” + “yesterday”). Since past-related concepts have previously been found to be situated on the left, a temporal gesture that indicates the left should prime past-related concepts and aid in the temporal judgement of past-related words, and vice versa for future-related words. Furthermore, if the lateral mental timelines previously found using traditional response congruency methods are likewise found using a priming paradigm, it would provide stronger support for the existence of lateral mental timelines.

Method

Participants.

Forty-four undergraduates from the National University of Singapore participated in the study for course credit or payment. All participants were English-Mandarin bilinguals who have studied in Singapore for at least 10 years. Participants also reported their level of proficiency in English & Mandarin using the same language background questionnaire as in Experiment 1 and indicated that their first language was English and they had better proficiency in it than Mandarin.

Design.

The same design as Experiment 1 was used.

Materials.

The same words in the previous experiment were used. Two gesture video clips were constructed by recording silent videos of the same female actor pointing either left or right the lateral axis. One video was made for each gesture of interest, with an emphasis on its stroke. Figure 7 shows a snapshot of the gestural stimuli used; please refer to Appendix B for a full set of gestural stimuli used.

Figure 7. Snapshot of the gestural stimuli with the gesturer pointing to her left.

Procedure.

The experiment employed the same procedure as in Experiment 1.

Results and Discussion

The same trimming criteria were used as in Experiment 1, and resulted in the loss of 5.97% of accurate trials. Once again, overall accuracies were very high (*M* = .90, *SD* = .06).

The mean RTs across the 4 conditions in Experiment 1 are summarised in Figure 8. A two-way repeated-measures ANOVA was conducted on participants' mean RTs, by congruency and temporality.

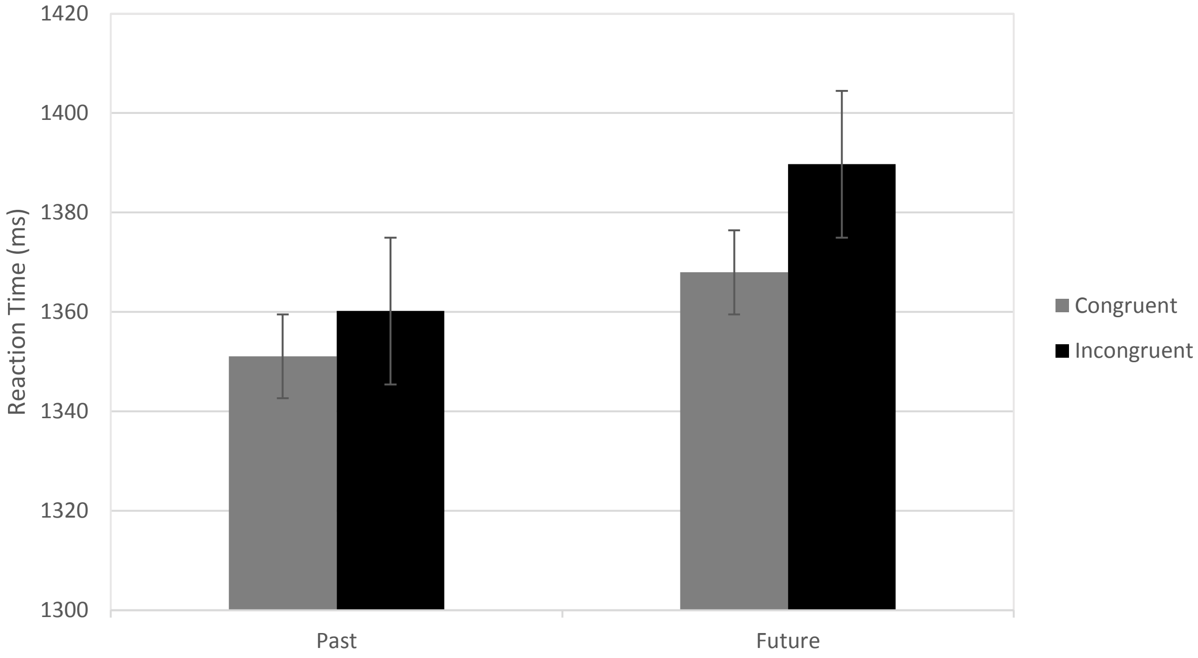

Figure 8. Average RTs for responses in Experiment 2 (error bars indicate 1 standard error above and below the mean)

Overall, neither IV was found to exert an effect on the obtained RTs. There was no difference in response latencies between congruent and incongruent pairs (1359ms vs 1374ms), $F < 1$, as well as past- and future-related words (1355ms vs 1378ms), $F(1,43) = 1.68$, $MSe = 607152$, $p = 0.20$. In addition, the interaction was also not statistically significant ($F < 1$). It is worthy to note at this point that there appeared to be a sizeable (though not significant) advantage for the classification of past-related words over future-related ones of 23 ms, which appears similar in magnitude to the priming advantage in Experiment 1 (25 ms).

A possible reason behind this peculiar finding is that the lateral gestures were simply not as meaningful as the sagittal ones for the purpose of temporal classification, resulting in greater variability in participants' responses. This is evident as well in the larger error bars for Experiment 2. Our results appear to run contrary to previous findings of individuals favouring the lateral axis for representing time, reflecting both reading and writing directions (see Fuhrman et al., 2011). This discrepancy is discussed further in General Discussion.

Chapter 4: General Discussion

Objectives and findings of the present study

In the present study, we investigated how individuals represent time in the mind using a cross-modal priming paradigm with temporal gestures as primes and auditory tokens as the targets. If individuals possess a mental timeline along the sagittal axis that mirrors the metaphors that we use to talk about time in English, they should respond faster to temporal words when presented with spatially congruent temporal gestures than if they had been presented with spatially incongruent temporal gestures. This should likewise be the case if individuals also represent time along the lateral axis, mirroring reading and writing directions. Using our priming paradigm, we found effects of congruency along the sagittal axis, but not the lateral one, suggesting that the former is preferred for the representation of time in the mind.

Implications for how individuals represent time in the mind

Our results support the notion that spatiotemporal metaphors found in language reflect temporal concepts in the mind (Lai & Boroditsky, 2013; Lakoff & Johnson, 1999). The overwhelming abundance of metaphors aligned along the sagittal plane in English (Radden, 2004), coupled with the almost complete absence of lateral spatiotemporal metaphors would predispose individuals in representing time along the sagittal axis, rather than the lateral axis. This is in agreement with a psycholinguistic point of view which lends particular relevance along the back-front dimension given that almost all languages in the world associate time along the sagittal axis. As such, it would be conceivable that the sagittal axis would be preferred over the lateral one when people process temporal meaning.

In addition, the present study also demonstrates that metaphor use may have a more pervasive effect than initially proposed. As mentioned in the introduction, Lai and Boroditsky (2013) demonstrated in the second experiment of their study that metaphors may have a causal role in how people construct temporal representations in their minds at the point in time when such metaphors are used. Our study adds to this by demonstrating that the mental timeline aligned along the sagittal axis that mirrors the metaphors that we use to talk about time persists even when such metaphors are not cognitively available or used as stimuli.

Problems of response congruency as the traditional means of investigating time

Participants in our study did not show evidence of a mapping of time along the lateral axis. This suggests that it might be possible that the previously found conceptualization of time along the lateral axis is a result of the response congruency methodology often employed by previous studies as their main means of investigating how individuals represent time (e.g., Fuhrman et al., 2011). This methodology is based on the view that if time and space are related in the mind, participants should respond faster when a temporal event and the spatial location of the response are consistent with patterns found in language and culture.

This method is analogous to the SNARC (Spatial-Numerical Association of Response Codes) effect, in which smaller numbers facilitate left-side responses as compared to right side-responses, and larger numbers facilitating right-side responses vs. left-side responses. In essence, responses are fastest when response mapping is consistent with the left-to-right number line mapping. This has been taken to suggest the existence of ‘mental number line’ that runs from left to right with smaller numbers on the left and bigger numbers on the right (Dehaene, Bossini & Giraux, 1993).

In the case of temporal studies, this is termed the spatial-temporal association of response codes (STEARC) effect, and “past-related” or “earlier” responses have been found to be responded to faster from a congruent location than an incongruent one (e.g., in the case of the lateral timeline, “past” responses made with the left hand/button/key should be faster than if the response had to be made on the right). Conversely, this time-response congruency effect between temporal event and spatial location is taken to suggest the existence of a ‘mental time line’ (Ishihara et al., 2008; see Figure 9). In studies that use response congruency as their main means of investigation, a forced spatialization of responses is commonly used, with left and right responses being paired with either “past” or “future” responses in some conditions, and vice versa in others.

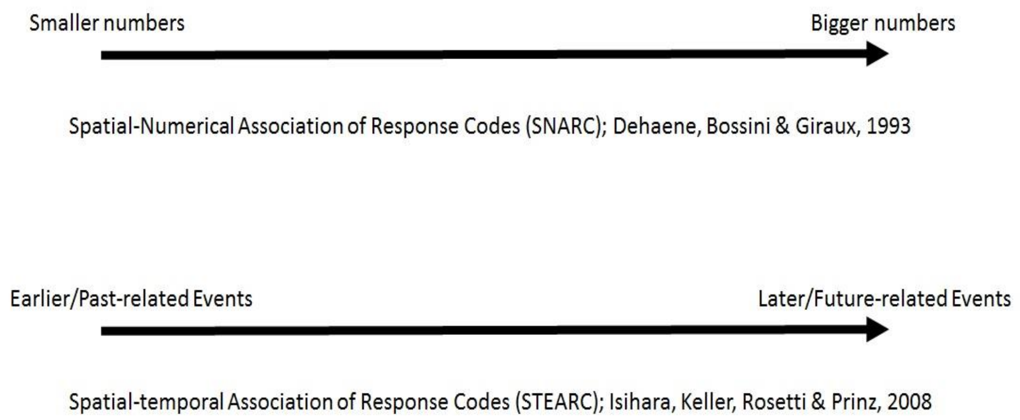

Figure 9. A comparison between the SNARC and STEARC effects.

However, restraining participants to a particular response format may predispose them into adopting transient frames which they then adopt to represent time. Previous studies have demonstrated that the presence of spatial representations or reference frames that are available in the immediate context could modulate peoples' thinking about time. People recruit spatial representations that are most cognitively available to think about time and these comprise frames such as motion (e.g., Matlock, Ramscar & Boroditsky, 2005). Matlock and colleagues found that exposing participants to stimuli that induced fictive motion (i.e., motion that is mentally simulated rather than experienced in the physical world) was sufficient to influence how people reasoned about time. For example, when presented with a statement that induced fictive motion ("the bike path *runs* alongside the creek"), participants responded to ambiguous temporal questions like "If next Wednesday's meeting has been moved forward two days, what day is the meeting now?" differently as compared to when participants had been responded to neutral sentences ("the bike path is beside the creek"). In the former scenario, participants were more likely to respond with "Friday", as if they themselves had moved forward in time. In fact, simply having individuals read a sentence or time-related phrase, or acquiring a novel reading ability like the ability to read from right to left was found to be sufficient to influence the direction with which the mental timeline flows.

In previous experiments that made use of response congruency to investigate how people represent time, the required mode of response naturally becomes the spatial frame that is most cognitively available for participants to co-opt for thinking about time. In addition, exposing participants to orthographies or having stimuli in the form of text to be read (e.g., Casasanto & Bottini, 2010; Casasanto & Jasmin, 2012) would also have provided participants with a convenient frame by which they can then organise temporal concepts on the spot. As such, findings of a lateral plane (and the absence of a sagittal plane) may be a product of the response congruency methodology, rather than how people naturally represent time in their minds.

However, it is unlikely that this possibility can account fully for previous findings as studies that do not employ response congruency methods have also found evidence for time representations arrayed along the lateral axis (e.g., Tversky et al., 1991). It should be noted, however, that although these studies did not employ response congruency as their means of investigation, participants were still constrained to a particular plane for their responses. For instance, in the study conducted by Tversky and colleagues (1991), the sheet of paper with the "lunch" sticker is laid out in front of the participant on a flat surface. It is conceivable that by employing such means, the lateral plane is best represented.

On the other hand, it would be difficult to adequately present the sagittal alternative that runs from the participant's front to his/her back. In essence, it is possible that rather than the lateral timeline being a product of the paradigm, it could be that the response congruency methodology serves to make prominent this lateral representation, thereby predisposing participants to preferentially adopt that frame for thinking about time at the point of the experiment.

Reconciling the present findings with previous findings of a lateral temporal plane

Why then did our lateral temporal gestures not predispose our participants into adopting a conceptualization of time along the lateral axis? After all, it has been proposed by Casasanto and Jasmin (2012) that the lateral axis is of greater informational value and changes along this axis are often easier for interlocutors to perceive than the sagittal axis.

A possible reason behind this unexpected finding could be due to the nature of the stimuli chosen for our experiments. Words such as "primordial" or "impending" presented in isolation are more akin to general deictic expressions of time that point in the direction to either the "past" or "future" with respect to the "present". This is in contrast with sequential expressions of time that array events in a sequential manner (E.g., Monday comes *before* Wednesday or lunch comes *after* breakfast).

Such isolated words would more likely be perceived of as deictic rather than sequential, given that the latter requires a point of reference that needs to be set. As noted by Casasanto & Jasmin (2012), people are more likely to produce lateral gestures than sagittal gestures when using sequential expressions of time. On the other hand, people gesture more systematically along the sagittal axis when prompted with deictic references. Hence, it might be possible that sagittal gestures are more meaningful when paired with deictic expressions of time than lateral gestures. As such, our lateral temporal gestures would not be as useful as the sagittal temporal ones considering our largely deictic stimuli. Further studies could potentially determine if sagittal gestures aid the comprehension of deictic expressions of time while lateral gestures aid the comprehension of sequential expressions, given their greater co-occurrences.

While our new paradigm provides a useful method of investigating how individuals represent time, it is not without its limitations. For one, our method of response (using the left and right keys of a response box oriented laterally for both experiments) may have been subject to a shortcoming of the response congruency method by providing a spatial frame that participants might have then used to represent time. However, we found no evidence of it predisposing participants in adopting a representation of time along the lateral axis. Nonetheless, future studies could adopt a non-directional method of response (e.g., having the participant respond vocally “past” or “future”) in order to ensure that any effects found are not a result of an imposed spatial frame.

Alternatively, the effect might have been too weak to meaningfully predispose participants into adopting a lateral representation of time. This might especially be so in comparison to previous response congruency studies which required participants to respond with the opposite key for past-/future-related concepts mid-way through the experiment. Requiring participants to switch gears, figuratively, mid-experiment would have served to further emphasize the lateral plane for the participants since they would have to not only discard or suppress a previously learnt association, but learn a new one (e.g., “left is past” is now changed to “right is past”).

Furthermore, the effect of congruency along the sagittal plane that was found is unlikely to be a result of our response method, given that the layout is different from the plane being investigated (lateral response vs. sagittal plane). Nonetheless, future studies could adopt the use of non-spatial responses such as vocal responses (e.g., Walker et al., 2014).

Merits and limitations of the present study and implications for future studies

The present study demonstrates the usefulness of not only the priming paradigm as a means to investigate how individuals represent time in the mind, but also the viability of gestures as primes to access temporal concepts in the mind. Given the prevalence of gestures accompanying temporal speech (Casasanto & Jasmin, 2012), and how gestures were shown to be capable of priming semantically related words and concepts (Wu & Coulson, 2007; Yap et al., 2011), it is unsurprising that temporal gestures were able to access the temporal concepts in an individual’s mind.

There is, however, a possibility that there might have been a difference in visibility and salience in the gestural primes used in each experiment. For one, the lateral gestures are markedly more visible and salient as compared to those presented along the sagittal axis. As such, it could have been the case that the lateral gestures might have led to a greater amount of attention being allocated to the gestures such that attentiveness to the words was diminished. While it might have been possible to control for visibility and salience by having the gesturer face sideways for the sagittal primes, such an arrangement is unnatural and defeats the communicative purpose of gesture as the gesturer is no longer facing the participant. In addition, it is unlikely that saliency or visibility of the gestural prime might have led to any effects or differences observed. If the lateral gestures had indeed been more salient or visible, it would have led to a stronger priming effect (if time is indeed represented along the lateral axis). This was not found and accuracies for both experiments were very high, indicating that the gestures did not appreciably detract the participants' attention to the words.

In addition to this, the auditory tokens were likewise efficacious in tapping the temporal concepts activated by the temporal gestures. Previous studies have often used visually-presented sentences or phrases as a means to probe temporal concepts in the mind, but as mentioned above, this choice of stimuli could have themselves predisposed participants into adopting the frames provided to represent time at the point of the experiment (Casasanto & Bottini, 2014). In addition to providing convenient cognitively available frames, the reading of sentences and phrases may enable participants to reflect on time representations and allow for strategic processes that would then obscure how time is naturally represented in the mind. As such, by having participants respond as quickly as possible to isolated words, a more automatic form of processing is encouraged, allowing underlying temporal representations to be tapped. In addition, the binaural mode of representation is not only as effective as visual stimuli in probing temporal concepts (Ouellet et al., 2010), but also useful as a means of circumventing the possibility of predisposing participants into adopting cognitively available frames as a result of reading time-related sentences and phrases.

Despite the advantage of using isolated words to examine the automatic activation of temporal representations, it should be noted that the usage of these words may lead to the stimuli being deictic in nature, rather than sequential. Deictic expressions of time are those with respect to a particular "now". For example, the word "ancient" would be past-related with respect to the given present. On the other hand, sequential expressions of time are those which array events as being earlier or later with respect to a reference point. An example would be a picture portraying a half-eaten banana and comparing it to a reference picture of an unpeeled banana. In this scenario, the picture of the half-eaten banana portrays an event that is “later” than the unpeeled reference.

Previous studies (e.g., Fuhrman et al., 2011) that investigated mental representations using sequential expressions of time have raised the possibility that the sagittal plane may be preferred for deictic representations of time as a possible reason why they did not observe any evidence of a mental timeline along the sagittal axis. On the other hand, studies that used temporal stimuli that was deictic in nature (e.g., visually presented deictic phrases and words, Torralbo et al, 2006; visually presented deictic sentences, Ulrich et al., 2012) have found evidence of a timeline along the sagittal plane. As such, it may be possible that the sagittal axis is preferred when conceiving of deictic representations of time, though this has not been objectively tested.

The present study also has implications for future investigations into the structure of our mental timeline. When a response congruency method is not adopted, individuals are withheld from any readily available spatial frames that they might potentially adopt to transiently represent time. As a result, effects of congruency along the lateral axis are diminished, and individuals are less constrained in conceiving about time. Such findings are partially replicated in Lai and Boroditsky (2014, Study 2) where, when allowed to point to regions in space instead of being constrained along certain modes of response, participants are found to represent time along the sagittal axis as well when asked to arrange events in temporal order. In short, as noted by Walker et al. (2013), the majority of space-time associations observed thus far in response congruency experiments (e.g., Boroditsky et al., 2011; Fuhrman & Boroditsky, 2010) could have partially arisen from the particulars of the experimental paradigm being used.

Future Directions and Conclusion

Future studies may explore if these findings are particular to gesture or if other spatial stimuli (e.g., arrows) may similarly prime temporal concepts in individuals. The sagittal spatialization of time has been proposed to be oriented with respect to an individual's sagittal axis, and is grounded in the experience of front-back locomotion that our bodies are accustomed to (Clark, 1973, Lakoff & Johnson, 1999; Radden, 2004). As such, while other spatial stimuli may prime temporal representations, gestural stimuli involving seeing another person may be more effective in priming the sagittal timeline.

In addition, the gestural stimuli is meaningful as it allows participants to yoke the axis of interest to the gesturer, interpreting the information communicated from the gesturer's perspective. As an individual's representation of time appears to be heavily influenced by sensorimotor systems that coincide with human movement, having participants perform these gestures themselves may result in a greater priming of the sagittal timeline as well. This may then be reflected in larger effects of congruency in a similar paradigm wherein participants are tasked with producing the gestures themselves instead of watching a video of an actor.

Studies that investigated Mandarin speakers have also found evidence of a top-to-bottom pattern of aligning time along the vertical axis (e.g., Fuhrman et al., 2011) as well as corresponding gestures along this axis (Chui, 2011), mirroring Chinese spatiotemporal metaphors that place past concepts higher than future ones. Future investigations may also look into Mandarin speakers using vertical gestures and Mandarin words or phrases as stimuli to see if the vertical metaphors in their language would predispose them in adopting a vertical plane for the representation of time.

In conclusion, we present a novel paradigm in which gestures may act as a means by which we may access an individual's implicit spatial conceptualization of time. This paradigm may provide future researchers with a way to investigate how individuals construe time without constraining them through necessitating particular modes of response, and may reveal patterns that would otherwise be obscured as a result of task demands. In addition, the present findings provide support for the view that temporal concepts in the mind reflect spatiotemporal metaphors used to represent time in speech and writing, with time being most strongly aligned along the sagittal axis when response congruency methods and convenient frames of reference are not adopted.

References

Balota, D. A., Yap, M. J., Cortese, M. J., Hutchison, K. A., Kessler, B., Loftis, B., et al. (2007). The English Lexicon Project. *Behavior Research Methods*, *39*, 445-459.

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition*, *75*(1), 1-28.

Boroditsky, L. (2011). How languages construct time. *Space, time and number in the brain: Searching for the foundations of mathematical thought*, 333-341.

Boroditsky, L., Fuhrman, O., & McCormick, K. (2011). Do English and Mandarin speakers think about time differently?. *Cognition*, *118*(1), 123-129.

Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition*, *106*(2), 579-593.

Casasanto, D., & Bottini, R. (2010). Can mirror-reading reverse the flow of time?. In *Spatial Cognition VII* (pp. 335-345). Springer Berlin Heidelberg.

Casasanto, D., & Bottini, R. (2014). Mirror reading can reverse the flow of time.*Journal of Experimental Psychology: General*, *143*(2), 473.

Casasanto, D., & Jasmin, K. (2012). The Hands of Time: Temporal Gestures in English Speakers. *Cognitive Linguistics*, *23*(4), 643-674.

Carstensen, L. L. (2006). The influence of a sense of time on human development. *Science*, *312*(5782), 1913-1915.

Chui, K. (2011). Conceptual metaphors in gesture. *Cognitive Linguistics*, *22*(3), 437-458.

Clark, Herbert H. (1973). Space, time, semantics and the child. In T. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 27-63). New York: Academic Press

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General*,*122*(3), 371.

Eikmeier, V., & Ulrich, R. (2014). How Closely Related are Time and Space on the Left-right Axis? *Procedia-Social and Behavioral Sciences*, *126*, 172-173.

Fuhrman, O., & Boroditsky, L. (2010). Cross-Cultural Differences in Mental Representations of Time: Evidence From an Implicit Nonlinguistic Task.*Cognitive Science*, *34*(8), 1430-1451.

Fuhrman, O., McCormick, K., Chen, E., Jiang, H., Shu, D., Mao, S., & Boroditsky, L. (2011). How linguistic and cultural forces shape conceptions of time: English and Mandarin time in 3D. *Cognitive science*, *35*(7), 1305-1328.

Gevers, W., Reynvoet, B., & Fias, W. (2003). The mental representation of ordinal sequences is spatially organized. *Cognition*, *87*(3), B87-B95.

Goldin-Meadow, S. (1997). When gestures and words speak differently. *Current Directions in Psychological Science*, 138-143.

Ishihara, M., Keller, P. E., Rossetti, Y., & Prinz, W. (2008). Horizontal spatial representations of time: evidence for the STEARC effect. *Cortex*, *44*(4), 454-461.

Ji, L. J., Guo, T., Zhang, Z., & Messervey, D. (2009). Looking into the past: cultural differences in perception and representation of past information. *Journal of personality and social psychology*, *96*(4), 761.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to western thought*. Basic books.

Lai, V. T., & Boroditsky, L. (2013). The immediate and chronic influence of spatiotemporal metaphors on the mental representations of time in English, Mandarin, and Mandarin-

English speakers. *Frontiers in psychology*, *4*.

Matlock, T., Ramscar, M., & Boroditsky, L. (2005). On the experiential link between spatial and temporal language. *Cognitive science*, *29*(4), 655-664.

Miles, L. K., Nind, L. K., & Macrae, C. N. (2010). Moving through time.*Psychological Science*, *21*(2), 222-223.

Miles, L. K., Tan, L., Noble, G. D., Lumsden, J., & Macrae, C. N. (2011). Can a mind have two time lines? Exploring space–time mapping in Mandarin and English speakers. *Psychonomic bulletin & review*, *18*(3), 598-604.

McNamara, T. P. (2005). *Semantic priming: Perspectives from memory and word recognition*. Psychology Press.

McNeill, D. (1992). *Hand and mind: What gestures reveal about thought*. University of Chicago Press.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. *Basic processes in reading: Visual word recognition*, *11*, 264-336.

Núñez, R. E., & Sweetser, E. (2006). With the future behind them: Convergent evidence from Aymara language and gesture in the crosslinguistic comparison of spatial construals of time. *Cognitive science*, *30*(3), 401-450.

Ouellet, M., Santiago, J., Israeli, Z., & Gabay, S. (2010). Is the future the right time? *Experimental psychology*, *57*(4), 308.

Oxford University Press (2015). Oxford Dictionaries. Retrieved from http://www.oxforddictionaries.com/

Radden, G. (2004). The metaphor TIME AS SPACE across languages. *Zeitschrift für Interkulturellen Fremdsprachenunterricht*, *8*(2/3), 1-14.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime: User's guide*. Psychology Software Incorporated.

Sell, A. J., & Kaschak, M. P. (2011). Processing time shifts affects the execution of motor responses. *Brain and language*, *117*(1), 39-44.

Torralbo, A., Santiago, J., & Lupiáñez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science*, *30*(4), 745-757.

Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology*, *23*(4), 515-557.

Ulrich, R., Eikmeier, V., de la Vega, I., Fernández, S. R., Alex-Ruf, S., & Maienborn, C. (2012). With the past behind and the future ahead: Back-to-front representation of past and future sentences. *Memory & cognition*, *40*(3), 483-495.

Walker, E., Bergen, B. K., & Nunez, R. (2014). Investigating spatial axis recruitment in temporal reckoning through acoustic stimuli and non-spatial responses. *Center for Research in Language Technical Report, University of California, San Diego*, *25*, 1-10.

Wu, Y. C., & Coulson, S. (2007). Iconic gestures prime related concepts: An ERP study. *Psychonomic bulletin & review*, *14*(1), 57-63.

Yap, D. F., So, W. C., Yap, M.J., Tan, Y. Q., & Teoh, R. L. S. (2011). Iconic gestures prime words. *Cognitive science*, *35*(1), 171-183.

Appendices

Appendix A

List of temporal words chosen for the auditory targets

Past-Related Words		Future-Related Words	
aged	memoir	advanced	future
ancestor	nostalgia	after	hence
ancient	obsolete	ahead	impending
antique	old	anticipated	later
archaic	outdated	approaching	looming
before	passe	brewing	modern
beforehand	preceding	coming	nearing
bygone	precursor	conclusion	next
classic	predecessor	consequently	pending
dated	prehistoric	destiny	prophesy
defunct	previous	emerging	prospective
departed	primitive	ensuing	resulting
earlier	prior	eventually	someday
extinct	recollection	expect	soon
flashback	reminiscence	fate	subsequent
forefather	retrospect	final	succeeding
former	stale	following	thereafter
fossilized	timeworn	forecast	tomorrow
history	vintage	foretell	ultimately
initial	yesterday	forthcoming	upcoming

Appendix B

Full set of snapshots for gestural stimuli used for each experiment. Snapshots are of dynamic videos lasting 1000 ms

Snapshots of gestural stimuli used for Experiment 1 – Sagittal Axis

Snapshot of the model pointing backwards

Snapshot of the model pointing forwards

Snapshots of gestural stimuli used for Experiment 2 – Lateral Axis

Snapshot of the model pointing to her left

Snapshot of the model pointing to her right