Bilingualism in Multimodal Language Processing: A priming study on processing of gestures in English temporal expressions

Flerspråkighet och multimodal språkbearbetning: En priming-studie om gest-bearbetning i engelska tidsuttryck

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At its core, language is multimodal (Kendon, 1986; McNeill, 1994), and information presented through different channels of information, such as visually, in the shape of gestures, or verbally, in the shape of speech or signs, together facilitate online language processing (Kelly, Healey, Özyürek, & Holler, 2015; Kelly, Özyürek, & Maris, 2010). This thesis extends previous studies on multimodal processing (Kelly et al., 2015) into the domain of TIME, and additionally investigates the influence of bilingualism on integration of speech and gestures in a priming experiment. The task of 75 monolingual speakers of English and 75 English-Mandarin Chinese bilingual participants was to decide whether a written prime (PAST or FUTURE) was related to different temporal expressions in English. The temporal expressions were accompanied by a matched or mismatched gesture along the sagittal line (front to back). Response accuracy and response times were analysed with two Bayesian generalised linear mixed models. Gesture (mis)match was shown to have an effect on response time (mismatched trials were predicted to have longer response times of approx. 150 ms). Accuracy, on the other hand, was not influenced by gesture (mis)match. No certain effect of bilingualism was found for response accuracy, nor response time. An interaction effect between gesture (mis)match and bilingualism was not found either. This study therefore fails to show any effect of bilingualism on multimodal language processing, but provides further support for the integrated-systems hypothesis, according to which gesture and speech are integrated automatically and early in language comprehension.

1 Introduction

Acquiring another language is a complex process in many regards. The complexity is not limited to learning novel ways to mark tense, diving into a soundscape of new phonetic properties, or collecting whole libraries of new words, which are appended to the already rich vocabulary of our native language, or other languages we may know. Semantic knowledge, such as the scope of certain words, or identification of the prototypical member of different domains (i.e. what is considered the "bluest" blue) can certainly also pose a challenge to the eager language learner, especially as there is great cross-linguistic diversity as to how different domains are conceptualised.

One may find oneself grasping for a word in one language, but only reaching the corresponding lexical item in another. Fortunately for language learners, they can find support in knowing that a majority of the world indeed is bilingual (Grosjean, 2010), and that whatever challenge they might experience has been experienced by many before. The constant navigation, the attenuation and boosting of viable alternatives between more or less active languages (Dijkstra, Grainger, & van Heuven, 1999; Kroll & Bialystok, 2013; Kroll, Bobb, & Hoshino, 2014) has been suggested to lead to cognitive consequences in the bilingual brain, both in regard to neural structure (DeLuca, Rothman, Bialystok, & Pliatsikas, 2019; Grundy, Anderson, & Bialystok, 2017; Pliatsikas, 2020), as well as function. For instance, bilinguals tend to perform better at tasks testing inhibitory functions than monolinguals (Wimmer, Marx, Stirk, & Hancock, 2021).

The brain of the bilingual speaker (or signer) is not equal to the sum of the brains of two monolinguals. This holds true not only for the function or structure of the brain: languages affect languages, so to speak, on all levels, including phonetics (Bergmann, Nota, Sprenger, & Schmid, 2016), phonology (Flege, 1987), semantics (Ameel, Malt, Storms, & Van Assche, 2009), morphology (Hohenstein, Eisenberg, & Naigles, 2006; Sánchez, 2012), syntax (Sánchez, 2012), gesture-behavior (Brown & Gullberg, 2013), as well as (non-linguistic) conceptualisations (Pavlenko, 2011a). The inter-lingual influence can be bi-directional, meaning that the first language (L1) may affect the second (L2), and vice versa (Pavlenko, 2011a). To provide an example from phonetics of how an L1 may be influenced by an L2, the vowel formants of native speakers of German, that had moved abroad to an English-speaking country, shifted towards more English-like formant patterns, even in vowel production in their L1, namely German (Bergmann et al., 2016).

As concepts, objects, or whole domains seldom have one-to-one mappable equivalents in another language, the meeting of two or more languages in the bilingual individual may lead to different conceptual consequences. Some examples are conceptual co-existence (two domains existing simultaneously and separate from each other), shift (a shift towards either more L1-like patterns, or L2-like patterns), convergence (both conceptualisations becoming more alike), or attrition (disappearance of previously learned concepts) (Pavlenko, 1999, 2011a). To illustrate conceptual shift in the color domain, Athanasopoulos (2009) showed that the prototypical dark-blue colour ("ble" in Greek) of L1-speakers of Greek, who had learned English as a second language, shifted towards a more English-like prototype of "dark-blue".

Due to its complex and somewhat covert nature, the conceptual level is generally challenging to study, as it tends to encompass elements not necessarily expressed in speech. However, language is fundamentally multimodal, and other modalities may offer a window into the conceptualisations of a speaker (McNeill, 1994). The domain of TIME[1] is one example of how cross-cultural and cross-linguistic differences

[1] capitalised, to signify a concept

may be realised not only through speech, but through the investigation of gestures, as these may reveal underlying conceptualisations that speech cannot (Casasanto & Jasmin, 2012; Kendon, 1986; McNeill, 1994).

This is enabled by the fact that gesture and speech are two intricately linked aspects of the language system, which have been argued to jointly make up utterances (Kendon, 1986, 2015; McNeill, 2005). Information presented visually (i.e. gestures) is automatically integrated with speech, and together, speech and gesture facilitate speech comprehension (Kelly et al., 2010). In cases where gesturally presented information does not match the spoken content of the utterance, i.e. it is *mismatched*, this may interfere with language processing, resulting in, for example, longer response times (Kelly et al., 2015). A theoretical framework that has been used to explain results like these is *the integrated-systems hypothesis* (Kelly et al., 2010), which states that information provided through speech and gesture is automatically integrated early in language comprehension.

As of now, little research has been done on the effect of bilingualism on multimodal language processing. The aim of this thesis is threefold: Firstly, it aims to extend the *integrated-systems hypothesis* into the domain of TIME, and more specifically temporal expressions. Secondly, possible effects of bilingualism on multimodal language processing are investigated. Thirdly, potential interactions between bilingualism and gesture-speech integration are explored, in order to lay the ground for further research on conceptual change, as expressed through gestures, in the domain of TIME. In this thesis, multimodality refers to utterances containing both auditory and visual information, i.e. speech and gestures. Bilingualism refers to the phenomenon of knowing, or having considerably interacted with, more than one language.

2 Theoretical background

The bilingual mind

The mind of the bilingual is, contrary to general assumption, not equal to the combination of two monolingual minds. Au contraire, the acquisition of multiple language brings about intricate and complex bidirectional changes in phonology (Flege, 1987), gesture behavior (Brown & Gullberg, 2013), syntax (Sánchez, 2012), semantics (Ameel et al., 2009), and conceptualisations (Pavlenko, 1999, 2011a). Additionally, bilingualism tends to be connected to structural, as well as functional cognitive changes (Pliatsikas, 2020). Due to its highly dynamic nature, as well as the many possibly influencing factors (such as age of acquisition, age of fluency, exposure to languages, proficiency, contexts in which a language is used, etc.), it has been called a ”messy” topic (Grosjean, 2010). There is as of yet no consensus regarding the structure or representation of the language systems (with respect to e.g. separated or common lexicon and concepts). The cognitive mechanisms and processes underlying comprehension and production of different acquired languages do unfortunately not paint a clearer picture. Given that a majority of humans in fact use[2] more than one language (Grosjean, 2010), the historical ignorance towards bilingualism might, however, seem surprising, and the phenomenon deserves further attention.

[2]This includes both speaking and signing, i.e. both unimodal and bimodal bilingualism, the latter of which, for good reason, has gained well-needed attention recently (Emmorey, Giezen, & Gollan, 2016).

As all languages known by a bilingual have been proposed to be active simultaneously, to varying degrees, bilinguals are constantly forced to engage several executive functions, such as inhibition (when inhibiting the languages that are not currently used), alternative selection (during lexical selection), or task switching (Dijkstra et al., 1999; Kroll & Bialystok, 2013; Kroll et al., 2014). Task-switching is especially relevant when bilinguals speak (or sign) two or more languages in the same contexts, and therefore can engage in code-switching, i.e. switching languages or repertoires based on context. The training of constant amplification and attenuation of more or less active languages, in different contexts, is claimed to be echoed in more general cognitive functions and structures (Prior & Gollan, 2011).

It must be mentioned that other studies (Arizmendi et al., 2018; Desjardins & Fernandez, 2018), as well as several meta-analyses (Cespón & Carreiras, 2020; Degirmenci, Grossmann, Meyer, & Teichmann, 2022), have found no unanimous support for a bilingual advantage, with the exception for inhibition tasks (Degirmenci et al., 2022).

The functional differences between bilinguals and monolinguals are often associated with certain structural changes as well. These do not fit within the scope of this thesis, but for an overview of a framework attempting to integrate results from key research on this topic, the reader is referred to Pliatsikas (2020).

Conceptual change

Pavlenko (1999, 2011b) discuss several possible ways in which the conceptual system of bilinguals may be restructured when another language is acquired. These include conceptual co-existence, transfer, restructuring, internalisation, shift, attrition, and convergence.

Conceptual co-existence refers to the separate storage of two or more conceptualisations in the bilingual mind, which is a consequence often associated to acquisition of languages *in different contexts* (Pavlenko, 1999). When asked to retell the same story in two different languages, Koven (1998) found that bilingual speakers of French and Portuguese referred to language-specific concepts, and used specific repertoires in the two different linguistic conditions, which led Koven (1998) to draw the conclusion that the speakers had separate language-specific conceptual spaces that co-existed, each activated only when speaking the specific language. Further support stems from memory studies, which have shown that the autobiographical memories that are most accessible to bi-cultural bilinguals are dependent on the language in which a memory is prompted (Marian & Neisser, 2000).

In contrast to the results from this body of research of co-existing conceptualisations, other potential consequences of bilingualism on conceptual space have been discovered: Brown and Gullberg (2013) found that motion events described by English and Japanese bilinguals did not correspond to the common pattern of framing of motion events of either monolingual group, which the authors interpreted as *conceptual convergence*, i.e. ”enhancement of similarities” between two languages, possibly for economic reasons.

Conceptual convergence can also apply to other linguistic levels: gesture behavior undergoes similar changes to those described above. Brown and Gullberg (2008) investigated the interplay between gesture and speech in description of motion events by English-Japanese bilinguals. These two languages differ in their way of framing manner and path of motions, following Talmy's motion typology (Talmy, 1985). Some languages, English being one of them, prefer to encode the path of motion in a "satellite" (such as a verb particle), while others encode it directly on the verb (so called verb-framed languages), such as Japanese (Talmy, 1985). Brown and Gullberg (2008) found that Japanese learners of English, compared to monolingual Japanese speakers, more often encoded manner of motion gesturally, which typically is a trait of English speakers, which suggests a shift towards more English-like gesture behavior in their first language. It could, however, also reflect a more general effect of bilingualism, as bilingualism has been shown to correlate with a general higher frequency of gestures (Nicoladis, Pika, & Marentette, 2009).

Not all domains necessarily undergo the same processes of restructuring. Further, the position of a concept in a domain may influence how easily conceptual change occurs. For instance, Jarvis (2011) found that conceptual (or semantic) transfer occurred more easily for central or prototypical concepts in specific domains, while metaphoric or non-central concepts were less transferable.

In an attempt to cover the ground outside of the Western-focused research milieu and explore other multilingual linguistic contexts, Yager and Gullberg (2020) investigated similar processes in the Northern Aslian (Austroasiatic) langauges Jedek and Jahai, spoken in a long-term multilingual setting. More specifically, the authors looked at the grammatical morpheme *klɛŋ*, which exists in both languages, but with different semantics. The Jahai morpheme *klɛŋ* is a more specific marker denoting containment, while in Jedek, it is used as a general locative marker. Conducting a picture-naming task, Yager and Gullberg (2020) found a bidirectional influence only for Jahai speakers, while for Jedek speakers, a unidirectional influence was found: the latter still preferred the, more general, Jedek semantics. This relates to conclusions presented by Gathercole, Stadthagen-González, Pérez-Tattam, and Yavaş (2016), that found a general tendency towards broader semantic categories over more specific ones.

There is still an ongoing debate as to which factors play a role for the degree of conceptual convergence. For instance, in a study on motion verbs of Spanish and English bilinguals, Hohenstein et al. (2006) found that age of acquisition of Spanish in L1-English speakers was negatively correlated with the number of manner verbs produced when describing an event (i.e. more Spanish-like motion event framing). In other words, the earlier the speaker had acquired Spanish, the more Spanish-like the motion-framing was. On the other hand, Brown and Gullberg (2011) found that restructuring of conceptualisations occurs early in acquisition, even before speakers have reached a high proficiency level.

Other potential conceptual changes include *L1-transfer*, meaning the the lexical items of a newly acquired language simply map onto pre-existing conceptualisations in the L1 (Athanasopoulos, 2006), or *reverse transfer*, which entails conceptualisation of L2 being used also in L1 (Pavlenko & Malt, 2011). A more exhaustive overview can be found in Athanasopoulos (2015); Pavlenko (1999, 2011b).

Gestures and multimodality

Gestures are multidimensional meaning-bearing manual actions that occur in close temporal synchrony with speech (McNeill, 1994). In his broad definition, (Kendon, 1986, 2004) describes gestures as being actions that are performed under volitional control and lack practical goals. McNeill (1994) defines gestures as "spontaneous movements [...] of the arms and hands [that] are closely synchronised with the flow of speech" (McNeill, 1994, p. 11).

Gestures differ from spoken or signed language in several aspects: they are non-combinatorial, meaning that two gestures together do not form a more complex gesture compound. Further, gestures, contrary to other language forms, do not have a standardised form, to which speakers (or gesturers) must conform their gestures for them to be understood (McNeill, 1994). The reason as to why gestures may still resemble each-other relates to the content of the utterance, rather than linguistic standards (McNeill, 1994).

Gestures, and more specifically their stroke (the nucleus), are temporally aligned with speech, according to certain principles. These principles include the *phonological synchrony rule* (prohibiting the stroke from occurring post phonological peak) and the *semantic synchrony rule* (stating that the same idea is uttered simultaneously through gestures and speech/signs) (McNeill, 1994). The semantic coherence of speech and gesture indicates that the two components are co-planned and make up two aspects of the same message (Kendon, 2004; McNeill, 1994).

Further support for the link between speech and gesture comes from ontogeny: Griffin (2004) notes that the first two-item phrases produced by a child often consist of both gestures and speech.

The function of gestures has been widely discussed. For instance, they aid in regulating interaction (e.g. turn-taking), and thus carry pragmatic function. Gestures can also be representational, i.e. carry information about the discourse and content of the utterance, that is not necessarily expressed in speech. Additionally, gestures have been shown to serve in uncovering processes of spatial cognition (Alibali, 2005; Gu, Mol, Hoetjes, & Swerts, 2017; Hostetter & Alibali, 2008; Walker & Núñez, 2016), aid the speaker's mental representation of abstract domains (e.g. time) (Winter & Duffy, 2020), or to reveal implicit conceptualisations of said domains (McNeill, 1994).

Although it has long been established that language in its nature is multimodal, many of the earlier models of language processing have not paid any attention neither to how the visual components themselves are interpreted, nor how the visual information is incorporated into the utterance as a whole. In the late 20th century, however, the field of gesture studies began to really flourish, driven by pioneers McNeill and Kendon (Kendon, 1986, 2015; McNeill, 2005), who highlighted the importance of gestures in language comprehension.

It has been claimed that the foundation for speech and gesture as two sides of the language coin is related to the tight link between language and action (Pulvermüller, 2005). These two systems, that were long thought to operate independently of each other, are in fact neurally linked. For instance, action word processing involves activation of regions that are active during actual performance of certain actions (Hauk, Johnsrude, & Pulvermüller, 2004). This can, at least partly, explain why spoken language and manual actions (such as gestures) are tightly linked.

The *Gesture as Simulated Action* framework, which claims that mental representations engage simulations of the perceptual or motor systems, illustrating a tight link between action and perception (Hostetter & Alibali, 2008), is compatible with the framework presented by Pulvermüller (2005). If the simulation of a certain percept or motor activity is high enough, it may reach the so called gesture threshold, after which a gesture is produced. Based on observations that spatially strong individuals gesture more (Hostetter & Alibali, 2007), the authors claim that the gesture threshold can differ between individuals. Other factors include strength of the premotor-motor connections.

Psycholinguists and cognitive scientists have investigated the temporal aspects, and cognitive underpinnings, of gesture production, in relation to other language production processes (such as lexical selection, formation of the conceptual message, etc.). Kita and Özyürek (2003) are proponents of the *Interface hypothesis*, which posits that gestures are influenced both by lexical possibilities, as well as spatio-motoric aspects. This suggests that there might both be cross-linguistic differences in the shape of gestures (attributed to the language-specific features that may differ between languages), as well as similarities, related to the spatio-motoric information of certain events. This was supported by a cross-linguistic investigation on English, Turkish, and Japanese speakers, in which Kita and Özyürek (2003) found that gestures produced in the three different languages both displayed striking differences (arising from differences in lexicon), but also were surprisingly similar, despite the linguistic differences of the languages. This supports the Interface Hypothesis.

Multimodal language processing

Previous paragraphs have summarised research on gestures, including rules about temporal alignment between gestures and speech, as well as descriptive, rather than normative, principles that state the gestures and speech generally convey the same meaning. However, this alone does not let us conclude that gestures are a meaningful component of an utterance. Evidence for the meaningfulness of gestures mostly stem from studies using electroencephalography (EEG), and psycholinguistic experiments.

Firstly, to be useful to addressees, gestures must be discriminated from other movements, including both object manipulations or self-regulatory movements (such as pushing away a strand of hair from the face, or adjusting the position of your glasses). The difference between such movements and gestures pertains to their representational quality (Novack, Wakefield, & Goldin-Meadow, 2016). As it turns out, humans skillfully distinguish gestures from other types of movement, presumably based on a number of factors, such as presence of an object. When presented with silent video clips of movements in different conditions (actions on objects, actions off objects with objects present, and actions with no objects), participants understood movements as object-oriented only if the objects were acted upon (Novack et al., 2016). The same movements in the absence of objects, or with objects present but not manipulated, were described as representational gestures by the participants. Even in the absence of speech, actions can be interpreted as meaningful gestures, according to Novack et al. (2016). However, when adding speech (intelligible or unintelligible), the authors also found that intelligibility of speech increased the likelihood of identifying the movement as a meaningful gesture (Novack et al., 2016).

Secondly, support for gestures *being processed* as meaningful comes from different EEG-studies. A commonly studied ERP-component is the N400-component, a centro-parietal negative deflection peaking approx. 400 ms after stimulus onset (Kutas & Hillyard, 1980). The N400 is related to semantic processing, and the effect size is believed to be determined by the degree of semantic unexpectedness or lexical predictability (Kuperberg, Brothers, & Wlotko, 2020), where greater amplitudes of the N400-component (i.e. a more negative deflection) is elicited by more unpredictable items.

Multiple studies have investigated how different representational gestures affect the overall comprehension of multimodal utterances. For instance, mismatched gestures typically produce a larger N400-effect than matched gestures (Özyürek & Kelly, 2007; Wu & Coulson, 2011). This further supports the view of gestures as a meaningful component of a utterance.

In a study from 2018, Chui, Lee, Yeh, and Chao (2018) compared the N400-effect for emblems (culture-specific, conventional gestures, such as the victory-sign that is produced by raising the index and middle finger into a V-shape from the fist), self-regulators, and representational gestures (Chui et al., 2018). The authors showed that semantically related representational gestures facilitate language processing, while emblems and self-regulators produce larger N400-effects than the related meaningful gestures did.

The integrated-systems hypothesis

Kelly et al. (2010) proposed *the integrated-systems hypothesis*, with the aim to connect theories on gesture production with findings of gesture comprehension. The authors firstly hypothesised that integration of gesture and speech would be obligatory, that is, even when only one modality is of importance for the task, both gestures and speech would be processed. Secondly, the authors posed that ”gesture and speech should mutually interact” (Kelly et al., 2010, p. 261), meaning that mismatched information, irrespective of modality, should interfere with the processing of the other modality. To test this, they conducted a priming study, where the task was to relate a prime to either a target gesture or word. Crucially, the target was always presented simultaneously to matched or mismatched information in the other modality. To exemplify this, the participants may have read the prime *cut*, and later been presented with a multimodal video of a person saying ”chop”, while simultaneously producing a ”pouring water-gesture. This mismatch between spech and gesture was hypothesised to lead to interference in language processing, reflected in increased response times and lower response accuracy.

Results were affirmative, supporting the integrated-systems hypothesis' claim of the mutual interaction of gesture and speech. Furthermore, Kelly et al. (2010) ran the same experiment, but explicitly told participants not to pay attention to the gestures. Despite these instruction changes, the effect remained, which further supports the view of obligatory processing of speech and gesture, as well as an early integration of the two modalities.

Early, automatic processing of gesture was also found in a psycholinguistic experiment conducted by Feller and Gellatly (2016). This facilitating effect of the presence of relevant gestures has also been found when comparing multimodal utterances to their uni-modal equivalent, i.e. utterances containing only speech, and no gestures (Hostetter, 2011).

Abstract representational gestures

Gestures do not need to depict *physical* spatial relations. The framework also includes metaphoric gestures of abstract concepts. Abstract target concepts may also be expressed gesturally, enabled by the tight conceptual connection between bodily grounded mental representations between abstract and concrete representations (Lakoff & Johnson, 1980).

Hostetter (2011) investigated the effect size for different types of gestures, and found that motor or spatial gestures demonstrated a greater facilitating effect, than abstract gestures. Although Hostetter (2011) raises the possibility that the effect difference may be a consequence of processing differences between different types of gestures (iconic vs. metaphoric, as introduced by McNeill (2005)), it may also be a methodological artifact relating to the number of representational and iconic gestures, respectively, discussed in the studies included in the meta-analysis. A study on the electrophysiological reverberations of gesture mismatching and matching in metaphor comprehension, however, found a greater negativity around 350-650 ms, interpreted as a higher N400-effect, when the metaphor was accompanied by an incongruent gesture, than when the gesture was congruent (Cornejo et al., 2009). The conclusions drawn by the authors were that visual information was meaningful, not only in language comprehension of literal meaning, as has been demonstrated before, but also in metaphorical meaning.

Conceptualisation of time

The abstract domain of TIME is generally considered to be conceptualised in terms of the schematically similar, but more concrete domain SPACE (Lakoff & Johnson, 1980; Lewandowska-Tomaszczyk, 2016). The linguistic realisations of the conceptual mapping between the two domains may vary greatly between languages, which in turn gives rise to a great cross-cultural and cross-linguistic variety of the conceptualisation of TIME. Many languages, English being one of them, use the subordinate mapping TIME IS A LINE, and employ an ego-centric sagittal (front-back) line in various linguistic expressions, such as ”in the weeks ahead” or ”back in the days” (Casasanto & Jasmin, 2012). The future is therefore conceptualised as being in front of the speaker, and the past behind.

There are also examples of the opposite mapping in other languages, where the future is located behind speakers, as it has not yet been experienced, and therefore is unknown (not visible to the eye) (Núñez & Sweetser, 2006). Despite their differences, both of these possible conceptualisations are examples of TIME IS A LINE along the sagittal axis. Other possible egocentric axes are the vertical (up-down), as well as the lateral (left-right) line.

The linear conceptualisation of time is not prevalent in all languages though, providing support for the anti-universalists. To exemplify, Rodríguez (2019) found that speakers of the Mayan language Chol, spoken by approx. 200,000 people, did not make use of such a mapping. Similarly, TIME-mappings in Tupí Guaraní languages, were not grounded in the physical processes that according to the universalists underpin the TIME IS A LINE-mapping, but rather in emotional, and other embodied processes. In Tupí Guaraní languages, the future is conceptualised as being in the head, while the past is located in the heart (da Silva Sinha, 2019).

Metaphoric structures of TIME are not only found in the spoken (or signed) language of a person: it is, in its most literal sense, made visible through gesture behavior of people (Cooperrider & Núñez, 2009; Núñez & Sweetser, 2006).

Time in Mandarin Chinese

Mandarin Chinese is an example of a language that uses all three axes described above. First, the vertical axis is found in linguistic expressions, such as the ones in examples 1-2 below. The examples illustrate that the future can be conceptualised as DOWN, and the past as UP. This mapping is also realised gesturally, at least when the gesture co-occurs with vertical temporal expressions (Chui, 2011; Gu, Mol, Hoetjes, & Swerts, 2013; Gu, Zheng, & Swerts, 2019).

(1) shàng ge lǐ-bài
up CLASS[4] week
'last week'

(2) xià ge lǐ-bài
down CLASS week
'next week'

Additionally, speakers of Mandarin Chinese employ the sagittal axis in some temporal expressions, see examples 3-4. The direction of the axis in these expressions is FUTURE-IS-BEHIND and PAST-IS-IN-FRONT. In combination with sagittal temporal expressions, almost half of gestures are produced along this axis (Gu et al., 2019). In non-sagittal temporal expressions, only 14.04% were sagittal gestures (Gu et al., 2019).

(3) hòu-tiān
back-day
'the day after tomorrow'

(4) qián-tiān
front-day
'the day before yesterday'

Making the matter more complex, the gestures do not always map onto the FUTURE-IS-BEHIND direction of the axis illustrated in examples 3-4. A majority of the gestures accompanying neutral temporal expressions in fact follow the reverse direction (PAST-IS-BEHIND and FUTURE-IS-IN-FRONT) (Gu et al., 2019), which is also found in several linguistic expressions, such as those in examples 5-6.

(5) zhǎn-wàng wèi-lái
unfold-gaze.into.distance future
'looking far into the future'

(6) huí-shǒu guò-qù
turn.around-head past
'looking back to the past'

Evidently, speakers of Mandarin Chinese can, and sometimes do, think of the future as being behind them, and the past as in front of them. However, gestures that occur together with temporal expressions tend to do the reverse (Gu et al., 2019). Furthermore, the lateral axis is also employed liberally when gesturing. In summary, speakers of Mandarin Chinese employ all three linear axes, some in speech, and some gesturally: the vertical, lateral, as well as the sagittal, the latter of which bidirectionally.

[4]classifier, obligatory element between demonstratives and nouns in Mandarin

Time in English

English temporal expressions generally follow two main patterns: they either explicitly evoke the sagittal time-line (where the future is in front, and the past behind, as in the expressions ”leave the past behind” or ”in the upcoming years”), or they do not (as in so called ’neutral’ expressions, such as ”last week” or ”next March”) (Walker & Núñez, 2016).

Gestures accompanying ”sagittal” expressions occur along both the sagittal and the lateral axes (Walker & Núñez, 2016). However, a majority of gestures in neutral expressions follow the lateral axis (Casasanto & Jasmin, 2012), despite it not being realised linguistically. The same behavior is found in speakers of Mandarin Chinese, and it is generally believed to be culturally, rather than linguistically, driven (Casasanto & Jasmin, 2012; Gu et al., 2019). Additionally, Walker and Núñez (2016) discuss that when using the lateral axis, the timeline is visualised in front of the speaker, which is more efficient for visualisation purposes, as it makes the temporal relations between different events more clear.

Results from a variety of different psycholinguistic experiments fail to show any effect of an active conceptualisation of time along the sagittal timeline (Walker & Núñez, 2016). This raises the question of how active the sagittal axis is, when it is not deliberately activated by drawing special attention to it (through lexical choice, for instance).

English-Mandarin bilinguals' temporal gestures

To the knowledge of the author, only one study on English-Mandarin bilinguals' gesturing about TIME has been conducted (Gu et al., 2017). It investigates production and perception of temporal gestures in English with the aim of exploring whether production of gestures is lexically or conceptually driven, in order to test the *Interface hypothesis* (according to which gestures arise from an interface between linguistic framing and spatiomotoric aspects of an object or event). The authors argue that participants, if gestures are lexically driven, should be expected to use different types of gestures for spatial temporal expressions (such as the up/down-structure presented above) and neutral temporal expressions. Further, English and Mandarin accompanying gestures should differ from each other. However, if participants actually employ the same conceptualisation in both languages, these differences should not be found (Gu et al., 2017).

Gu et al. (2017) found that vertical metaphors to a higher degree were accompanied by vertical gestures than neutral temporal expressions in Mandarin Chinese. Comparing the two languages, the authors found that more vertical gestures were produced in Mandarin Chinese than in English. When only looking at the neutral expressions, there was no significant difference in number of vertical gestures between the languages.

Gu et al. (2017) conducted a follow-up perception experiment, where participants were asked to judge whether or not gestures produced in silence (along either the vertical or horizontal axis) fit certain temporal expressions. For both Mandarin expressions using verticality, as well as the English equivalents, participants preferred the vertical gestures over horizontal ones. In the neutral condition, however, both vertical and horizontal gestures were rated as equally fitting (Gu et al., 2017). These results taken together seem, according to the authors, to suggest that the shape of gestures depends both on lexical choice, but also on the spatio-motoric aspects of time (i.e. the conceptualisations that are not expressed in speech, supporting the interface hypothesis). However, as was presented earlier, these results may just as well be a consequence of conceptual change, possibly in the form of conceptual convergence.

3 The current study

The cognitive changes that are driven by language experience, as well as the facilitating effect of multimodality on language comprehension (Kelly et al., 2015), together raise the question of potential differences in multimodal processing in bilinguals. Although the two fields of research are growing, few attempts have been made to bring them closer together. The current thesis aims to investigate differences between monolinguals and bilinguals in processing multimodal utterances in the abstract domain time in their dominant language (English).

Gestures have been shown to reveal implicit conceptualisations in speakers that may not necessarily be encoded linguistically (McNeill, 1994). Mandarin Chinese and English both employ the conceptual mapping between TIME and SPACE (Lakoff & Johnson, 1980), which has previously been shown to be easily communicated through gestures. Both languages employ the sagittal axis (front-back) onto which FUTURE and PAST align, but there are differences in regard to the direction of time along this axis. This enables the investigation of the influence of bilingualism on conceptualisation of the domain.

Based on methods from previous work (Arbona, Seeber, & Gullberg, 2022; Kelly et al., 2015), a comprehension study of English sentences with matched or mismatched gestures (that is, representational gestures that either match the content of speech, or not) is conducted. The participants' task is to determine whether the spoken content of the sentence is related to a written prime presented prior to the utterance, as quickly as possible.

The research questions that the current thesis aims to answer are thus the following:

1. Does a speech-gesture (mis)match influence processing of temporal expressions?
2. Does bilingualism influence processing of temporal expressions?
3. Does bilingualism modulate the effect size of speech-gesture (mis)match on processing of temporal expressions?

Based on the methodology of Kelly et al. (2015), language processing is measured as response time and response accuracy of relating the prime to the spoken temporal expression.

The hypotheses that the study tests are the following:

Hypothesis 1a *Response accuracy will be lower in gesture-mismatched trials.*

Hypothesis 1b *Response times will be higher in gesture-mismatched trials.*

In the study by Kelly et al. (2015), response time was found to be higher when gesture and speech were mismatched. Response error rates also increased when gestures were mismatched to the spoken content. Evidence for H1a-b would provide further support for automatic integration of gestures and speech.

Hypothesis 2a *Response accuracy will be higher for bilingual participants.*

Hypothesis 2b *Response times will be lower for bilingual participants.*

As bilinguals often perform better in inhibition tasks than monolinguals (Degirmenci et al., 2022), it is expected that the bilingual participants more easily ignore mismatched information. Therefore, hypotheses 2a and 2b concern the main effect of bilingualism on response time and accuracy.

Hypothesis 3a *Bilingualism will modulate the effect of gesture (mis)match on response error rates.*

Hypothesis 3b *Bilingualism will modulate the effect of gesture (mis)match on response time.*

Hypotheses 3a and 3b aim to reveal potential interaction effects between bilingualism and gesture (mis)match, which could potentially give some insight to conceptual changes.

4 Method

To investigate the effect of bilingualism on the domain of TIME, a priming experiment was conducted (Kelly et al., 2015), in which the participants were faced with the task of relating a written prime (either PAST or FUTURE) with the spoken content of a multimodal sentence. The experiment aimed to measure the efficiency of speech- and gesture-integration in gesture-matched, and mismatched conditions, and compare this between bilinguals and monolinguals. Thus, independent variables for the following analysis were *gesture-match* (either mismatched or matched), as well the factor *linguistic background* (either bilingual or monolingual). The dependent variables included response times and response accuracy (i.e. correct identification of the relation between speech and prime) in each trial.

Participants

Participants (N=150) were recruited via the online research-sharing platform *Prolific*. The initial language background criteria hosted on the website ensured that only L1-English speakers and learners of Mandarin Chinese were recruited. Participants, who were fluent in other languages, were excluded to minimise the risk of possible transfer effects from other languages. All participants (in both groups) reported that English was their first, and primary, language. Participants in the monolingual group declared that they were raised with their native language only, and that English was their earliest language in life. The bilingual group reported that they were proficient in their native language, as well as another language, which they all specified as Mandarin Chinese.

Table 1 shows the participant profile for both bilingual and monolinguals. The data is taken from the participants' answers in the Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian, Blumenfeld, & Kaushanskaya, 2007) which was used to collect data on the linguistic background of each participant. A t-test showed a significant difference of age between the two groups (t = 9.1).

Stimuli

Sixteen temporal expressions (8 describing the future, and 8 describing the past) were chosen to create 32 target sentences in total (each temporal expression occurred twice). To avoid any frequency effects, temporal expressions of interest were matched based on frequency in the Corpus of Contemporary English (Davies, 2008). Temporal expressions in English can be both non-spatial (e.g. *yesterday*) or spatial (e.g *in the coming years*), but in this study only non-spatial lexical items were chosen, to ensure that activation of the sagittal axis was not driven by the lexical form of the temporal expressions.

The sentences followed a basic structure of *personal pronoun + verb + object + temporal expression*. Sixteen verbs were chosen and matched for frequency (Davies, 2008). Every verb occurred once in the past tense and once in the future tense. They were followed by two different nouns (which were equally plausible to follow each verb). This yielded 16 sentence pairs, and 32 target sentences in total. Two examples are given below (examples 7-8). For the complete list, refer to Appendix A.

7. He checked the record last month.
8. She will check the website next month.

Each sentence was recorded twice, once with a backwards pointing gesture, and once with an open palm forward gesture (see Fig 1 and 2) by a right-handed native speaker of American English. Prior to the recording session, the actor gave informed consent to use the videos for the intended purpose. She was compensated with two cinema tickets for her help.

The actor was considered to have native expertise on temporal gestures in English, and thus the shape of the gesture was chosen after a short discussion with her. She was instructed to temporally align the start of the gesture and spoken temporal expression, i.e follow both the semantic, as well as the phonological synchrony principle (McNeill, 1994).

The actor kept her hands together in front of her, and the gesture onset was considered to be the first frame after separation of the hands. The backwards gestures were produced with a closed fist with an extended thumb, lifted up to point backwards over the shoulder. The forwards-gesture stroke, on the other hand, had the shape of an open palm descending from the height of the collarbone. It was preceded by a preparational phase, of the actor lifting her hand to the position of the start of the stroke. The gesture was considered to be *matched* to the spoken content, if a future temporal expression coincided with a forwards gesture, or a past temporal expression with a backwards gesture. It was considered to be mismatched if the gesture did not correspond to the direction of time along the sagittal axis in English. In other words, forwards gestures with temporal expressions of the past were considered mismatched, and vice versa.

The recording and editing of the stimulus was done in the Humanities Lab (LU). The camera used for the video recordings was a Sony PXW-Z190V, XDCAM with 4K resolution. The audio was recorded with a Sennheiser MKE 600 and the teleprompter used to present the actor with the sentences was Prompter People. The final editing was done in Adobe Premiere Pro.

The gesture onset timing and the onset of the temporal expressions for each recording was then coded to ensure that both audio and visual information occurred simultaneously. The coding was done in (*ELAN, Version 6.5*, 2022).

Each target sentence could appear in one of four conditions: the written prime that preceded the sentence was either related or unrelated, and the direction of the gesture was either matched or mismatched to the spoken temporal expression.

Table 1. The language background of the participants, based on self-reports on a selection of questions of the Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian et al., 2007).

	Bilinguals (*N*=69)		**Monolinguals** (*N*=75)	
	M	*SD*	*M*	*SD*
Background				
Age	25.4	9.0	43.3	13.9
English				
Age of acquisition (yrs)	1.6	1.5	0.8	1.3
Age of fluency (yrs)	5.7	3.9	3.9	2.6
Current exposure (%)	87.4	11.0	99.1	5.8
Self-rated proficiency, speaking (0-10)	9.8	0.6	9.9	0.2
Self-rated proficiency, comprehension (0-10)	9.9	0.3	9.9	0.3
Mandarin Chinese				
Age of acquisition (yrs)	6.0	11.3	0	0
Age of fluency (yrs)	11.3	7.8	0	0
Current exposure (%)	12.1	13.4	0	0
Self-rated proficiency, speaking (0-10)	5.5	2.7	0	0
Self-rated proficiency, comprehension (0-10)	6.3	2.5	0	0

Figure 1. Forward gesture

Figure 2. Backwards gesture

Sixty filler sentences were also recorded. These contained equally frequent verbs as the target sentences did. The accompanying gestures were either pragmatic, representational, or deictic. Each sentence contained a gesture, and its stroke always co-occurred with the onset of the adverbial phrase, to resemble the target items as much as possible. This means that all 92 stimulus sentences contained a gesture aligned with an adverbial phrase (either temporal, or not).

Prior to the experiment, four lists containing a pseudo-randomised selection of the 32 target sentences and possible written primes (PAST or FUTURE) were created. Each list contained each target sentence in one of the four possible conditions, as well as all fillers (*N*=60). The number of related vs unrelated primes, as well as matched vs mismatched gestures were kept the same for each list. No target items occurred directly after another target item.

Procedure

The experiment was conducted online. Participants were informed of the purpose of the study, and provided consent by pressing a key to continue the experiment. At any time, they were allowed to end the experiment, at the cost of not receiving any monetary compensation.

The instructions that they received before starting the experiment are given below:

> In this experiment, you will listen to some sentences about different events. After having listened to them all, you will receive some questions about the content.
>
> Before each sentence, a word will appear on the screen. Your task is to decide whether the word is related to the content of the sentence as fast as possible. If you believe them to be related, you press the key ”r” (for related) on your keyboard. If you believe them to be unrelated, press the key ”u” (for unrelated).

Each of the 92 trials started with the written prime, which was displayed for 500 ms, followed by a 500 ms. blank screen, see Figure 3, following Kelly et al. (2015). The task of the participant was to determine whether the written prime was related to the content of the speech. They did so by pushing one of two possible keys, *U* for *unrelated* or *R* for *related*, on their own computer keyboard. As soon as the video started playing, the participants were able to provide a response. However, only trials where participants responded *after* the onset of the temporal expression were included. Further details are found in the section on Design and statistical analysis below.

After they had completed the main part of the experiment, the participants were redirected to a language background survey, hosted on Pavlovia (www.pavlovia.org), where they responded to a selection of questions from the Language

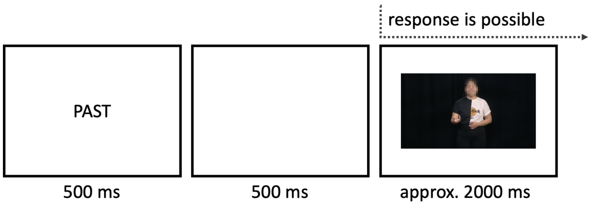

Figure 3. Example of a trial. Participants were allowed to respond from the beginning of the video.

Experience and Proficiency Questionnaire (LEAP-Q), which provides an overview over the language background of the participants (Marian et al., 2007). They were once again asked to confirm that they fit the participant description, i.e. either monolingual English speakers, or bilingual English-Mandarin speakers.

The participants were compensated for their participation via Prolific. They received approx. £2.50 for the 20 minutes.

Design and statistical analysis

The entire statistical analysis was done in R (R Core Team, 2023), version 4.2.3, using the brms-package (Bürkner, 2017).

Independent variables were the within-subject variable gesture-match (match vs. mis-match), as well as the between-subject variable linguistic background (monolingual vs. bilingual). The dependent variables that were measured were response time and response accuracy for each trial. Gesture match and linguistic background were assumed to be interacting effects.

Response times (RT) and accuracy were analysed with one Bayesian generalised linear mixed effects model (GLMM) each, where fixed effects included gesture (mis)match and linguistic background. A random slope was assumed for gesture-(mis)match for each participant. Further random effects were attributed to each item. The formulas for the two models are found below.

Model 1: accuracy ∼ gesture (mis)match * linguistic background + ((mis)match|participant) + (1|item)

Model 2: RT ∼ gesture (mis)match * linguistic background + ((mis)match|participant) + (1|item)

Since the output variable of Model 1 was binary (success vs. failure), the model assumed a Bernoulli-distribution. Model 2, on the other hand, assumed a lognormal distribution, given that the logarithm of the response times followed a normal distribution. Response times were calculated from the beginning of the temporal expression, which co-occurred with the onset of the gesture. It was possible for participants to respond before the temporal expression and gesture, but as gestures impossibly could have had an effect on the comprehension of the utterance if the response times were negative, these trials were excluded (N=17), together with the trials with response times above 5,000 ms (N=89), leaving 4114 trials for analysis of response error rates. Following Kelly et al. (2015), Model 2 was only run on accurate trials (N=3817, after exclusion of 297 inaccurate trials).

5 Results

In the following section, the results from the study will be presented. The estimated parameter values of Model 1 and 2 can be found in Table 2 and Table 3, respectively.

The influence of gesture (mis)match on processing of temporal expressions

Comparisons of accuracy between mismatched and matched trials, aggregated for each participant (both bilinguals and monolinguals), show that the mean response accuracy in matched trials was 93.5% (*SD*=7.4), and 91.9% (*SD*=9.4) in mismatched trials. The mean aggregated response time in matched trials was 1740 ms (*SD*=492). This was 156 ms shorter than the mean response time in mismatched trials, which was 1896 ms (*SD*=504).

The probability of a correct response in matched trials was predicted to reach 95.1%, 95% CI [93.2, 96.7], based on fitted values from Model 1. The likelihood to respond correctly in mismatched trials, on the other hand, was estimated to 94.2%, 95% CI [91.5, 96.2]. The most likely main effect of gesture *mismatch* therefore was -0.9%, 95% CI [-3.4, 1.2]. The predicted accuracy is visualised in Figure 4a.

The most credible response time, as estimated by Model 2, was 1681 ms, 95% CI [1531, 1830], in matched trials, and 1836 ms, 95% CI [1646, 2025] in mismatched trials. The most credible effect size of mismatch was a longer response time of 153 ms. The model predicted that 100% of the posterior distribution was positive, strongly suggesting that gesture mismatch had an effect on response time. The effect of gesture (mis)match on response times, as estimated by Model 2, are visualised in Figure 4b.

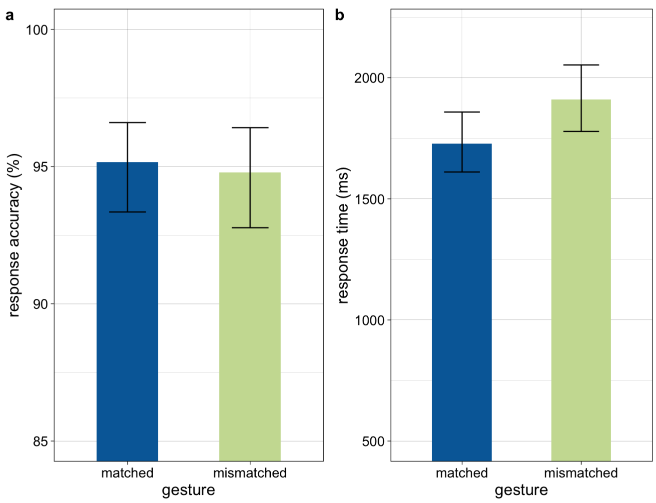

Figure 4. a. Estimated likelihood to respond correctly in trials where speech and gesture are matched, vs. mismatched, based on fitted values of Model 1. The error bars show 95% CI. **b**. Estimated response times in speech-gesture matched vs mismatched trials, as predicted by Model 2. Error bars indicate 95% CI.

The influence of bilingualism on processing of temporal expressions

With regard to accuracy, irrespective of gesture-speech match, the mean accuracy for bilinguals, after aggregation, was was 92.2% (*SD*=9.2). Monolinguals, on the other hand, had a mean

Table 2. Summary of estimated parameter values, estimated error, and confidence interval (CI) of Model 1. All values are given in log-odds.

	Estimate	Est.Error	Lower 95% CI	Upper 95% CI
Intercept	2.98	0.18	2.64	3.35
Gesture mismatch	-0.08	0.20	-0.46	0.31
Bilingual	-0.00	0.25	-0.51	0.49
Bilingual * mismatch	-0.2	0.26	-0.72	0.31

Table 3. Summary of estimated parameter values, estimated error, and confidence interval (CI) of Model 2, given in log-transformed values.

	Estimate	Est.Error	Lower 95% CI	Upper 95% CI
Intercept	7.4	0.04	7.33	7.47
Gesture mismatch	0.10	0.02	0.07	0.13
Bilingual	-0.06	0.05	-0.16	0.04
Bilingual * mismatch	-0.03	0.02	-0.07	0.02

accuracy of 93% (*SD*=7.8). The mean response time, aggregated over bilingual participants, was 1747 ms (*SD*=406). For monolinguals, this number was 1877 ms (*SD*=566).

Model 1 predicted that the likelihood of monolinguals to respond correctly was 95.0%, 95% CI [93.0, 96.5]. Bilinguals were expected to respond with 94.4% accuracy, 95% CI [91.5, 96.5]. The predicted contrast between monolinguals and bilinguals, based on the fitted values from Model 2, was -0.5%, 95% CI [-3.5, 1.9]. These estimates are shown in Figure 5a.

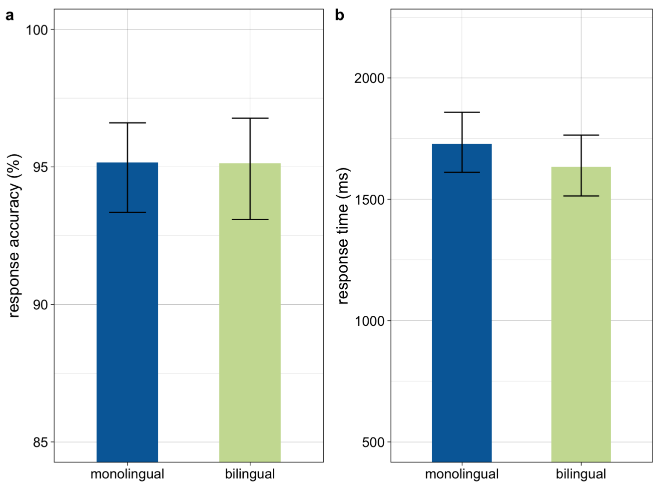

Figure 5. **a**. Probability of correct responses of bilinguals vs monolinguals, as predicted by Model 1. Error bars show 95% CI. **b**. The estimated response time of bilinguals and monolinguals, based on Model 2 predictions. Error bars show 95% CI.

The predicted response time of bilinguals was 1695 ms, 95% CI [1531, 1877]. The most credible response time of monolinguals, irrespective of gesture condition, was 1813 ms, 95% CI [1628, 2026], yielding a main effect of bilingualism corresponding to 117 ms shorter response times, 95% CI [-307, 58]. The most credible response time of monolinguals, irrespective of gesture condition, was 1813 ms, 95 % CI [1628, 2026]. That 91% of the posterior distribution of the main effect *bilingualism* was negative suggests a weak effect of bilingualism on response time. These results are visualised in 5b.

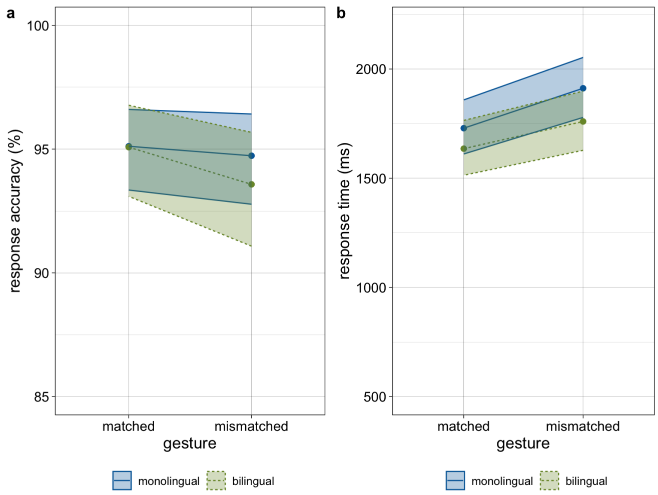

Figure 6. **a**. Interaction effects between bilingualism and gesture-speech mismatch on response accuracy. 95% CI are shown in the error-bars. **b**. Predicted effect of gesture-speech match for each group (bilinguals vs monolinguals).

The modulation of bilingualism on the effect of gesture (mis)match on processing of temporal expressions

As can be seen in Table 2 and 3, the β-coefficient for the interaction between gesture (mis)match and bilingualism was -0.2, and -0.03, respectively, indicating little to no interaction between effect sizes of mismatch and bilingualism for either response accuracy or response times.

The following reported estimates are fitted values from Model 1. The effect size of gesture-speech mismatch for monolinguals was -0.4, 95% CI [-2.2, 1.4]. In the bilinguals group, on the other hand, accuracy decreased with 1.5 percentage points, 95% [-3.8, 0.6], suggesting that gesture (mis)match had a slightly greater effect on bilinguals, than monolinguals.

The size of the interaction effect was predicted to be -1.1%, 95% CI [3.8, 1.4], with 79.7% of the posterior distribution being negative. These results are visualised in Figure 6a.

With regard to response time, the effect of mismatch for monolinguals was 181 ms, 95% CI [128, 238], while the same number for bilinguals was 124 ms, 95% CI [69, 182]. The predicted difference in effect of gesture mismatch was therefore 57 ms between groups, 95% CI [-20, 132], with 92.8% of the posterior distribution being positive. This is illustrated by a slightly steeper slope for monolinguals than bilinguals in Figure 6b.

6 Discussion

The current study has investigated the effect of gesture (mis)match and bilingualism on multimodal language processing (measured in response time and accuracy), as well the interaction effect of these two predictors. Results from the priming experiment, which was based on a design by (Kelly et al., 2015), showed that gesture mismatch with high certainty influenced response time (leading to higher response times of approx. 150 ms), but not response accuracy. This partly replicates results by Kelly et al. (2015), and further extends it into the metaphorical domain of TIME.

The main effect of bilingualism was not as certain, although a trend towards lower response times in bilinguals (estimated to be 117 ms faster generally) was found.

No conclusions can be drawn regarding any interaction effect between gesture (mis)match and bilingualism on either response accuracy nor response time. Model 2 showed a weak indication of a greater effect of mismatch for monolinguals (of 57 ms).

Only one null-hypothesis could be rejected with over 95% certainty, namely Hypothesis 1b: *Response times will be higher in gesture-mismatched trials*.

The effect of gesture (mis)match on language processing

Although participants were specifically instructed to pay attention to the spoken sentence, and compare only this to the written prime (i.e. not taking into account the visually presented information, that is the gestures), the gestures seem to have been processed irrespective of this, as response times increased in trials where gestures provided mismatched information in relation to the spoken content. This provides further support for theories claiming that integration of gesture and speech, due to their fundamental relation, is obligatory and automatic (Feller & Gellatly, 2016; Kelly et al., 2015, 2010), such as the integrated-system hypothesis (Kelly et al., 2010).

No effect of gesture (mis)match was found on accuracy rates, in contrast to results by Kelly et al. (2015), who found highly significant results of gesture match on accuracy ($p<0.001$). However, the differences between conditions in the source paper were also small (in gesture-matched condition, accuracy was 97.4%, compared to the 95.2% in mismatched condition). The task therefore seems to be rather easy for the participants, and it is unclear to which degree the error rates actually can reveal complex processing patterns. It is possible that the task needs to be made more complex to avoid ceiling effects.

Kelly et al. (2015) found response times of about 1260-1300 ms after stimulus onset. Compared to Kelly et al. (2015), response times in the current experiment were a lot higher. This may potentially be a consequence of a speed-accuracy tradeoff, where accuracy is prioritised over speed, further explaining why there was no effect of speech-gesture mismatch on accuracy.

Another potential explanation for the long response times in comparison to Kelly et al. (2015) concerns the stimuli. The differences between the stimuli of this thesis and Kelly et al. (2015) is twofold: Firstly, Kelly et al. (2015) investigated concrete verb phrases with corresponding actions and gestures, while this thesis, as it aimed to explore the comprehension of temporal gestures, used metaphorical target items. As much experimental research has found that literal and metaphoric meanings are accessed simultaneously (Blasko & Connine, 1993; Gildea & Glucksberg, 1983; Harris, 1976; Keysar, 1989; McElree & Nordlie, 1999), it is less likely that metaphoric processing could explain longer response times. The second difference pertains to the structure of the stimulus: Kelly et al. (2015) used only verb phrases, while the targets in the current study were whole sentences. The long response times are therefore most plausibly a consequence of the sentence structure, as the target items of this thesis always occurred last in the sentence, and usually consisted of more than one word. There is, simply stated, more to process.

The lack of effect differences between bi- and monolinguals

There was no certain effect of bilingualism on response accuracy. Although the null-hypothesis of Hypothesis 2b (*Response times will be lower for bilingual participants*) could not be rejected with 95% certainty, 91% of the posterior distribution was negative, indicating that bilinguals in fact seemed to respond faster than monolinguals. However, the response times difference is presumably a consequence of the significant age difference between the groups, as age has been shown to be negatively correlated with speed of language processing (Faroqi-Shah & Gehman, 2021). In future studies, the age of participants should be more controlled for, in order to rule out age as a factor for the response time difference.

The effect of gesture (mis)match on error rates or response time did not differ significantly between bilinguals and monolinguals. This was surprising, given the body of research claiming that bilinguals generally exhibit higher performance on inhibition tasks. However, as was also mentioned in the theoretical background, some recent meta-analyses have found no bilingual advantage (Hostetter, 2011).

As an explanation for their results of a higher degree of vertical gestures in English-Mandarin Chinese bilinguals than monolinguals, Gu et al. (2017) argue that lexical availability or accessibility may enable certain shapes of gestures. In other words, since bilinguals speakers have lexical access to vertical temporal expressions, they may therefore also to a higher degree use gestures along this axis, in comparison to monolingual speakers of English, that do not have access to vertical time-metaphors. One could therefore expect that bilingual speakers also activate the FUTURE-IS-BEHIND and PAST-IS-IN-FRONT-mappings in processing of English temporal expressions, the test implications of which would be an interaction effect between bilingualism and mismatch. Admittedly, the results might have pointed towards a slightly larger effect of mismatch for monolinguals than bilinguals (of 57 ms), but the positive values of the posterior distribution did not reach the appropriate threshold of 95% (the number was in fact 92.8%). Therefore, the null-hypothesis cannot be rejected, and further research is necessary.

One reason for the lack of interaction may be that temporal expressions in English do not activate the sagittal axis in the typical direction of Mandarin sagittal expressions (PAST-IS-IN-FRONT and FUTURE-IS-BEHIND), given that the stimulus of the current thesis only included non-spatial temporal expressions. Previous research by Gu et al. (2019) showed that the number of sagittal gestures was low (14.04%) when no sagittal temporal expressions were used. Seeing the results of the current thesis in the light of this, the lack of difference between bilinguals and monolinguals may be a consequence of a general reduced use of the sagittal axis in bilinguals (similar to that of monolingual speakers of Mandarin Chinese). Further, Gu et al. (2019) also found that a majority of sagittal gestures that co-occurred with non-sagittal temporal expressions followed the FUTURE-IS-IN-FRONT and PAST-IS-BEHIND-direction of the axis, further providing speculative explanations as to why the FUTURE-IS-BEHIND and PAST-IS-IN-FRONT-mappings may undergo less conceptual change.

Furthermore, although the metaphoric mappings PAST-IS-IN- FRONT and FUTURE-IS-BEHIND are present in monolingual speakers of Chinese, if corresponding gestures generally only are driven by lexical choice (Gu et al., 2019), one should ask to what degree conceptual change is likely to occur along this axis. Possibly, conceptual change is more likely to occur along other axes, that are employed more frequently in spontaneous gesturing. This, however, needs to be explored further.

Limitations and further research

The languages investigated in this study were English and Mandarin Chinese. This linguistic profile was chosen for three main reasons. Firstly, much of previous research on bilingualism in general, but also more specifically on temporal metaphors in gestures and speech, has been conducted on English-Mandarin bilinguals, which allows for comparisons and linking these results to the extensive body of previous research. Secondly, as both languages employ the TIME IS SPACE-metaphor, but differ in the axes along which time is conceptualised (and gestured about), they make an adequate linguistic context for further studies on the gestural realisation of conceptual change. Lastly, the choice also links to more practical reasons. Early in the process, an online study was opted for, to facilitate data collection of a certain size. The aim was to find a homogenous group to minimise potential factors that could have influenced the results. The website *Prolific* is completely in English, and thus it seemed reasonable to let English be one of the two languages spoken by the participants.

It should be noted that over-reliance on English has been argued to hinder cognitive science (Blasi, Henrich, Adamou, Kemmerer, & Majid, 2022): the use of English as a baseline language, simply for reasons of familiarity or simplicity, is a common pitfall. Therefore, further research that aims to answer questions on conceptual change, multimodal processing, and bilingualism should not limit itself to speakers of English. Instead, other linguistic situations should be taken into account, to allow more general conclusions of processing changes to be drawn.

Representational gestures of the abstract domain of TIME were found have a facilitating effect on language processing. The meta-analysis by Hostetter (2011) showed that spatial gestures generally facilitate the comprehension of a multimodal sentence to a greater extent than abstract (metaphoric) gestures do. It is therefore likely that bilingualism interacts differently with the effect size of more concrete representational gesture (mis)matches in multimodal language processing. Future research will have to delve deeper into this.

Further, we cannot certainly conclude that the effects found in this thesis are driven by the conceptual incongruency of FUTURE-IS-BEHIND and PAST-IS-IN-FRONT-mappings in English. It may also be a reaction to gestures that simply were not predicted. In order to say anything conclusive on this matter, one would need to conduct further research, potentially by adding a third condition of sentences containing nonsense gestures, and compare responses to these and the mismatched gestures. Another method that could be advantageous in order to reach the more fine-grained and direct responses related to the predictability and possible semantic (or conceptual) incongruencies of the mismatched gestures is electroencephalography (EEG).

As previously mentioned, the differences in multimodal processing of spatial and non-spatial temporal expressions, as well as between directional and non-directional temporal expressions could shed some more light on potential conceptual change in the domain time. Given that the English temporal expressions all were non-spatial, it raises the question of whether some aspects of an abstract domain are more easily transferable (Gathercole et al., 2016; Jarvis, 2011).

To be able to actually gain some insight in potential conceptual changes between Mandarin Chinese and English, the performance of bilinguals would need to be compared to the performance of a second bilingual group with another language background, preferably a language, whose conceptualisation of time does not differ from English.

7 Conclusions

The aim of the thesis was to examine potential effects of bilingualism, as well as mismatched information provided through gestures (along the sagittal time-line) on multimodal language processing of temporal expressions. A priming study was conducted, and response times and accuracy were measured. Gesture (mis)match had a credible effect on response time (mismatched trials were predicted to have longer response times of approx. 150 ms), which provides support for the integrated-systems hypothesis. Accuracy was, however, not likely to be influenced by gesture (mis)match, possibly due to a speed-accuracy trade-off, for the benefit of speed. No certain effect of bilingualism was found for response accuracy or response time, and no interaction effect between gesture (mis)match and bilingualism was found either, as could have been expected if some sort of conceptual change had occurred. A possible reason that was discussed for the lack of interaction effect includes the general low use of the sagittal axis in Mandarin speakers, both gesturally and in temporal expressions. This raises further questions on how other ego-centric axes may be influenced by conceptual change, or what effect lexical availability has on possible conceptual changes.

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A Target items in the experiment

1. He supported the claim last year.
2. He checked the record last month.
3. She produced the film last fall.
4. He caused harm last weekend.
5. She forgot the purse last February.
6. She joined the conversation last Wednesday.
7. She enjoyed the meal last Friday.
8. He sought treatment last May.
9. He represented the union last year.
10. She chose the candidate last month.
11. She accepted the gift last fall.
12. She discussed the article last weekend.
13. She prepared the food last February.
14. He named the girl last Wednesday.
15. She hurt her leg last Friday.
16. He visited a friend last May.
17. She will support the hypothesis tomorrow.
18. She will check the website next week.
19. He will produce energy next month.
20. He will choose his career next decade.
21. He will forget the purse the coming year.
22. She will cause trouble the coming days.
23. He will enjoy the view next century.
24. She will seek support next summer.
25. She will represent the organisation tomorrow.
26. He will join the team next week.
27. He will accept the award next month.
28. He will discuss the matter next decade.
29. He will prepare the meal the coming year.
30. She will name the boy next century.
31. He will hurt his knee in the coming days.
32. She will visit her family next summer.