The effect of language and temporal focus on cognition, economic behaviour, and well-being

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DOI:
10.26116/ndbt-jr04

Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

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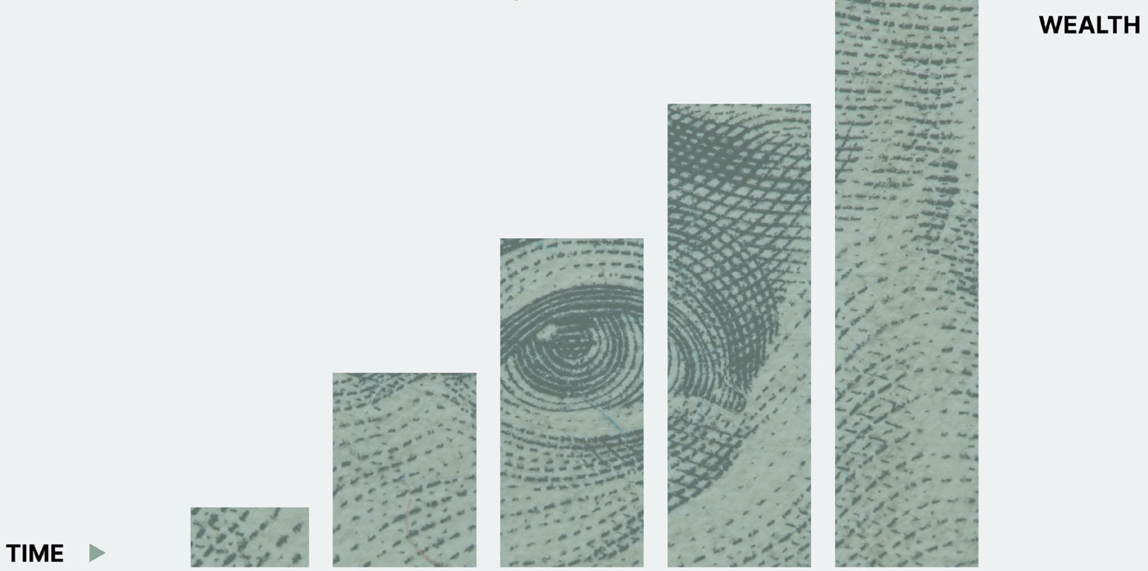

Tilburg University
NWO

The effect of language and temporal focus on cognition, economic behaviour, and well-being

Proefschrift ter verkrijging van de graad van doctor aan Tilburg University

op gezag van de rector magnificus, prof. dr. W.B.H.J. van de Donk,

in het openbaar te verdedigen ten overstaan van een door het college voor promoties

aangewezen commissie in de Aula van de Universiteit

op woensdag 31 mei 2023 om 14.00 uur

door

Yeqiu Zheng

geboren te Shandong, China

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prof. dr. J.C. van Ours (Erasmus University Rotterdam)

The author of this thesis received financial support from The Netherlands Organization for Scientific Research (NWO) Research Talent (406-15-298), Cognitive Science conference diversity & inclusion awards, Jenny Ligthart award, and some support from NWO Promoties in de Geesteswetenschappen (322-89-007), which are all gratefully acknowledged.

Cover illustration: Morgan Housel; Yeqiu Zheng

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Acknowledgements

It is true that the journey of my PhD has had its ups and downs, and the completion of this thesis would have been impossible without the support and encouragement of numerous people.

First of all, I am gratefully indebted to Arthur van Soest, my thesis supervisor, who gave me full freedom to do multidisciplinary research. I first came across an interdisciplinary study about the relationship between language and economic behavior in 2014 when I saw a TED talk by economist Keith Chen from Yale University (now at UCLA Anderson School of Management). He talked about how languages can influence saving behaviors, and also published his findings in the best journal in economics (*American Economic Review*, Chen, 2013). I was very surprised by the results and talked to Arthur later when I planned to apply for the NWO Research Talent Grant. He not only encouraged me to apply for the funding with a related topic, but also helped me enormously with the development of the proposal and preparations for the interview. I will never forget that he stayed up late in the evening to revise my proposal and insisted on having a meeting even when he was sick. At the end of 2015 I was very excited to get the NWO grant to do a PhD with Arthur. However, at the beginning of my third year of PhD (2018), my PhD project was interrupted due to pregnancy, maternity and parental leaves. When I just returned to work, Covid19 broke out, and I couldn't work efficiently as daycares were closed and I needed to take care of my baby at home. I had to admit that I was once very stressed because of all the delays in my PhD project and the hectic life with my baby (especially when my husband worked in London and could only travel back to the Netherlands at weekends). However, Arthur was always patient and ready to help. For example, I remember on Christmas Day of 2021, I sent him the first economic paper after re-picking up the PhD project with my best wishes "I hope, same as the delayed gratification, a longer waiting but a larger reward is coming." Arthur immediately responded to talk about the paper on 3rd January 2022. I truly appreciate his many inspiring suggestions on how to write a thesis and do research, as well as his patience and tolerance!

I am very thankful to Ad Backus, who provided me with uplifted support for my study in the field of linguistics and culture. Same as Arthur, Ad is very patient with my PhD project and never pushes me. Dating back to 2015, he gave me many valuable comments and suggestions on my NWO project application and later he also advised on the studies related to immigrants' languages and culture. It was also he who suggested I use a Dutch language placement test in the survey, which allowed for an objective measurement of the Dutch proficiency of immigrants in the language, labour market performance and financial wealth paper. Just at the moment of writing this acknowledgement, I am shocked to see a related paper forthcoming in the *American Economic Review* "The impact of host language proficiency on migrants' employment outcomes" (Schmid, in press). However, our paper has investigated both labour market performance and financial wealth, and I hope we can also yield a top-notch publication.

I would like to give special thanks to Marc Swerts and Rein Cozijn, who have greatly helped me gain insights into communication, cognition and information science. Particularly, without their endless help, the eye-tracking studies on space-time mappings would be impossible. I also appreciate Marc's strong support in various other aspects, as well as his always highly positive recommendation of me.

I am also very happy to collaborate with Hao Lin, who has made the unique research on sign language, deaf-print bilinguals, and labour market participation possible.

In addition, I thank Bertrand Melenberg and Peter Kort, who encouraged me to continue studying for the Research Master's programme in Economics in 2013. Without their recommendations, I would not have started doing research at Tilburg University. I thank Martin Salm for nominating me to apply for NWO research talent and I am grateful to Jan van Ours for his encouragement and valuable comments on the NWO project proposal. I thank Salikoko Mufwene and Cécile Vigouroux for awarding me the scholarship to attend the two-weeks' inspiring Summer School on Economy and Language at the University of Chicago Center in Paris in 2015. I thank Feike Drost, who shared his teaching experience of Probability and Statistics with me and also provided much support in teaching. Furthermore, I would like to thank my BIM colleagues at RSM for their kindness and support over the past year and a half.

A great thank you goes to my PhD examination committee for their careful reading and constructive comments on my manuscripts: Monique Flecken, Rob Alessie, Wei Li, Bertrand Melenberg and Jan van Ours. In addition, the original chapter 8 titled "Who is taking drugs in the Netherlands and what are the consequences" has finally not been included in the thesis, but I appreciate committee members who still gave me useful feedback.

So many warm-hearted friends have helped me in various ways, including teaching me Dutch and offering nice (non-)/academic chats, etc. Particularly, I would like to thank Elisabeth Beusch, Jingwen Zhang, Yan Xia, Qi Sun, Jiankang Song, Caixia Liu, Hans Paaijmans, Yueqiao Han, Yu Gu, Mario Rothfelder, Phoebe Mui and many others who I have not listed here.

Finally, I would like to express my gratitude to my parents, my parents-in-law and my husband Yan who have been always encouraging me and supporting me without a word of complaint. Yan, as a psycholinguist, also provides me with many useful suggestions in his field, which is very much appreciated. I would like to thank my mother-in-law who always understands me and gives me huge support. And I would like to thank my beloved daughter Emily who has brought a lot of happiness to me during my PhD journey. She is already 4.5 years old and can wait patiently without making "trouble" for me when I say "Mama is working now".

Yeqiu

Rotterdam, 16 April 2023

Chapter 0. Introduction

You must have heard of the saying “Time is money”, but have you heard of the claim that “the language you speak affects your savings”? This is called the linguistic-saving hypothesis, which was initially introduced by an economist Keith Chen, both in his (2013) TED Talk “Does language shape economic behaviour”[1], and his article in the *American Economic Review* (Chen, 2013).

Chen argues that the structure of languages (how people talk about time) can influence people’s thinking of time, which in turn influences people’s behaviour. His research is based on the assumption that the grammar of temporal language affects people’s perception of temporal distance which in turn can affect the value of future rewards. For example, English speakers can say “It is raining now,” or “It will rain tomorrow,” whereas speakers of Mandarin or Dutch would say, “Now it rains,” and “Tomorrow it rains,” without using an auxiliary timing verb but having the same grammar for both the present and the future tense. Chen proposes that the use of this less specific grammar makes speakers think less about the distinction between the present and the future. On the other hand, speakers of languages that grammatically separate past and future are more likely to think about the future as being different from now and see the future as more distant, inducing these speakers to take fewer future-oriented actions, such as retirement savings. This seminal work marks a new aspect of language and economics research, with about 1000 studies following it over the past decade, but Chen (2013) clearly stated in the abstract of his paper that “The evidence does not support the most obvious forms of common causation”, which means that language alone may not impact economic behaviour.

In addition, Chen does not test for any link between speakers’ temporal language and their perception of temporal distance, while people’s concept of time is very complicated and can be affected by a number of factors such as linguistic, cultural and bodily experience, etc (e.g., Boroditsky, 2001; Casasanto & Lupyan, 2015; de la Fuente et al., 2014). Furthermore, although Chen’s assumption on the linkage between thinking about the future and long-term savings and a healthy lifestyle seems reasonable, it is not directly investigated either. Particularly, several laboratory studies failed to replicate Chen’s (2013) findings (e.g., Chen, He & Riyanto, 2019; Roberts, Winters & Chen, 2015; Thoma & Tytus, 2017), and recent research showed no effect of the linguistic grammar of future time references on the perceived distance of future events (Jäggi et al., 2022).

Thus, there is still a lot to learn about the relationships among language, thinking about time and economic behaviour. The present dissertation contributes to this topic by studying the effects of language and temporal focus on cognition, economic behaviour, and well-being. The thesis mainly consists of three parts. In the first part, I investigate the direct relationship between language and

[1] https://www.ted.com/talks/keith_chen_could_your_language_affect_your_ability_to_save_money

temporal thinking as to whether users of different languages think about time differently. At the same time, I show how, apart from linguistic influences, cultural and bodily experience affects people's conceptualisation of time. In the second part, I study the relationship between temporal thought and various economic behaviours (e.g., pension planning, retirement savings, labour market performance), a healthy lifestyle (e.g., diet, smoking, disease) and overall well-being (financial satisfaction, happiness, life expectancy, financial wealth, etc.). Thirdly, I show a direct causal effect of language use on economic and financial outcomes. In contrast to Chen (2013)'s linguistic saving theory, I provide empirical evidence showing an alternative explanation for the variations of human cognition about time and their direct relationship with economic behaviours, based on which, I propose a 'temporal values and well-being hypothesis'. Apart from that, I show how language itself can be viewed as a form of capital that has a direct impact on earnings and wealth. Below I will briefly review some literature related to the three parts followed by a discussion of the methodology used in the thesis and a summary of each chapter.

Language and temporal thought

Speaking a language may have cognitive consequences. There have been several proposals about the relationship between language and thought. For example, linguistic determinism argues that language structures limit and determine speakers' thought, which is known as the Sapir–Whorf hypothesis and is largely abandoned nowadays. However, there is also a weak Whorfian hypothesis (also known as linguistic relativity), which proposes that the structure of speakers' language can *affect* their understanding and perception of the world (Whorf, 1956). This proposal has received a lot of attention over the past decades in different fields, from linguistics and philosophy to psychology and anthropology. For example, an increasing number of studies have shown that speakers of different languages may differ in the perception of colour, frame of reference, space-time mappings, causal reasoning, representation of musical pitch, etc. (See reviews in Boroditsky, 2011; Casasanto, 2015). In addition, there is another hypothesis claiming that speakers of different languages think differently during the process of speaking, which is known as the thinking-for-speaking hypothesis (Slobin, 1996). The hypothesis implies that some language-specific features can guide speakers to focus on certain aspects while speaking. For example, Mandarin speakers never need to think about the grammatical gender of a word whereas German speakers constantly need to worry about this.

A classic topic in the relationship between language and thought is whether language influences temporal cognition (e.g., Boroditsky, 2001; Chen & O'Seaghdha, 2013). Recently, some evidence showed that Swedish and Spanish speakers represent duration differently in their languages, which can affect their psychophysical experience of time (Bylund, Athanasopoulos, 2017). Mandarin speakers can talk about time vertically (e.g., "up-week" means "last week") and can also think about time vertically with the future above and the past below. However, their vertical conceptualisation of time can also be affected by the traditional vertical writing system (Bergen & Chan Lau, 2012; Fuhrman et al., 2011).

Therefore, how people conceptualise time is doubtlessly affected by culture. Take the conceptions of 'future' for example, Westerners typically think about the future as ahead of them whereas the Aymara and Moroccans think about the future as behind them. The future can be on the 'left' for Hebrews, on the 'west' for Pormpuraaw people, 'uphill' for Yupno speakers and 'downwards' for Chinese (see a review in Gu, 2022). In addition, time conceptions can also be affected by bodily experience. For instance, while healthy French-speaking people can think about the past on the 'left', French-speaking patients with left spatial neglect also find it difficult to think about the past (Saj et al., 2014).

Temporal thoughts and economic behaviour

The sense of time has a profound influence on behavioural motivations (Carstensen, 2006) such as planning and preventing risks, etc. Cognitive differences linked to space-time mappings further impact people's time-related judgements and behaviours. For example, displaying temporal progressions congruently with the spatial orientation of time (e.g., horizontally rather than vertically) can make English people perceive the future as more distant, thus affecting their time-relevant decisions such as inter-temporal choices (Romero, et al., 2019). The reason is that people who feel the future is more distant are less aware of the future consequences of their current behaviour, thus preferring immediate gratification and reducing future-oriented behaviour (e.g., saving) (Chen, 2013; Croote, et al., 2020).

Researchers often study the association between time perspective (opinion on the past, present or future) and economic outcomes (e.g., Levasseur et al., 2020; Zimbardo & Boyd, 1999), and have found that individual differences in time perception are related to retirement planning (e.g., Drake et al, 2008; Earl et al., 2015; Jacobs-Lawsona & Hershey, 2005). However, people's sense of time differs across cultures: People from some cultures are more past-focused whereas people from some other cultures are more future-focused (de la Fuente et al., 2014; Chapter 2). Studies have shown that cultural temporal focus affects how people value future and past events. For example, due to the differences in temporal-focus, Canadians give more monetary value to an event in the future than to an identical event in the past, whereas the reverse is true for the Chinese (Guo, et al., 2012). So far, retirement planning and time perception have not been studied in a cross-cultural context or with a focus on immigrants. In addition, no research has directly examined the relationship between people's perception of time and their income, savings and financial wealth.

Language and economic behaviour

Language not only has a cognitive function, but may also have a social function of language skills that impacts speakers' labour market performance and economic well-being. From that point of view, language itself is already a form of capital (Park, 2011). A number of studies have investigated the relationship between language proficiency and earnings, showing that the proficiency of English, immigrants' host-country language or the regional prestigious language skills correlate with immigrants' labour market participation (employment possibilities, hourly wage) (e.g., Bleakley & Chin, 2004; Dustmann & Fabbri, 2003; Dustmann & van Soest, 2001; Wong, 2022; Yao & van Ours, 2015). In addition, even sign language proficiency can predict deaf signers' occupational prestige and the possibility of having a high income (Zheng, Lin & Gu, 2023).

However, there are several limitations in the current research of language and labour market participation. First, all these studies used self-assessed proficiency which can be rather inaccurate in measuring language skills. Second, it is often difficult to separately identify whether individuals' language proficiency or their general ability affects employment and earnings. Third, few studies consider the skills of several languages at the same time to characterise their respective weight and role in labour market performance. Finally, so far no studies have investigated the role of language skills beyond their impact on employment and earnings. If language proficiency has a causal effect on income, it may also directly affect people's savings and financial wealth. If language is a form of capital, it will help to obtain information, opportunities, and social power relations that may facilitate accumulating savings and wealth.

Methodology

There are several methodological aspects which are common to the studies presented in this dissertation. These methods are well-established in the field and should be considered reliable. Using lab experiments, together with my collaborators, I examine various populations including monolinguals, spoken bilinguals, bimodal bilinguals (hearing signers) and deaf-print bilinguals and show that language and culture can influence people's conceptualisation of time in different ways, as revealed from their eye movements (Chapter 1), spontaneous gestures and signs (Chapters 2 and 3) and spatial-temporal reasoning (Chapter 4).

Furthermore, based on the notion that temporal cognition may influence decisions (Carstensen, 2006), I investigate how differences in conceptualisation of time such as the temporal focus on the past and future influence people's economic decisions and well-being. Using a survey approach, I compare immigrants' and natives' retirement planning in the Netherlands, and show that temporal values can predict people's pension planning and financial wealth (Chapter 5). Moreover, I show that the effect of temporal values can be related to different aspects of behaviour and overall well-being such as people's diet, smoking, health and chronic diseases, labour market performance, income and happiness (Chapter 6). Finally, from a sociolinguistics and economics perspective, I investigate the effects of immigrants' host-country language proficiency on earnings and savings. Using an econometric instrumental variable approach, I find a causal effect of Dutch proficiency on immigrants' labour market performance and financial wealth (Chapter 7).

The thesis contains seven empirical chapters, which are all based on peer-reviewed publications or articles that are under review or to submit. They can be regarded as self-contained papers and it is unavoidable there is some overlap in the literature review. A summary of the chapters is as follows.

Chapter 1 studies whether eye gaze patterns reveal anything about how people conceptualise the future. Westerners are reported to more often direct their eyes upward when thinking about the future and downward when thinking about the past. It is unknown whether this vertical space-time mapping is universally true. We studied Mandarin speakers' eye movements during language comprehension of sentences that referred to the past or the future. Unlike results obtained previously with westerners, Chinese had higher gazing positions when processing past-related sentences than future-related sentences. These eye-gaze related correlates of a vertical mental timeline appeared earlier when processing sentences with Mandarin vertical space-time metaphors than with neutral time expressions (Experiment 1). Furthermore, we studied Chinese people's eye movements in a mental time travelling task which did not contain any direct lexical cues. Again, Chinese directed their eyes more downward when conceptualizing the future than the past; such effects were not of a result of differences in the valence of the stimuli, and could not be due to factors such as memory and imagination (Experiment 2). The differences in eye movements between Chinese and westerners support the view that variation in people's language and culture may steer their conceptualisation of time in different ways.

Chapter 2 investigates the effect of language and culture on temporal gestures and spatial conceptions of time. The *temporal-focus hypothesis* claims that whether people conceptualize the past or the future as in front of them depends on their cultural attitudes toward time; such conceptualisations can be independent from the space–time metaphors expressed through language. In this chapter, I study how Chinese people conceptualise time on the sagittal (front-back) axis to find out the respective influences of language and culture on mental space–time mappings. An examination of Mandarin speakers' co-speech gestures shows that some Chinese spontaneously perform past-in-front/future-at-back (besides future-in-front/past-at-back) gestures, especially when gestures are accompanying past-in-front/future-at-back space–time metaphors (Experiment 1). Using a temporal performance task, the study confirms that Chinese can conceptualize the future as behind and the past as in front of them, and that such space–time mappings are affected by the different expressions of Mandarin space–time metaphors (Experiment 2). Additionally, a survey on cultural attitudes towards time shows that Chinese tend to focus slightly more on the future than on the past (Experiment 3). Within the Chinese sample, there is no evidence showing an effect of participants' cultural temporal attitudes on space–time mappings, but a cross-cultural comparison of space–time mappings between Chinese, Moroccans, and Spaniards does provide strong support for the *temporal-focus hypothesis*. Furthermore, the results of Experiment 2 are replicated even after controlling for factors such as cultural temporal attitudes and age (Experiment 3), which implies that linguistic sagittal temporal metaphors can indeed influence Mandarin speakers' space–time mappings. The findings not only contribute to a better understanding of Chinese people's sagittal temporal orientation, but also have additional implications for theories on the mental space–time mappings and the relationship between language and thought.

Chapter 3 reports on a study about the effects of Chinese Sign Language (CSL) on the production of speech-accompanying temporal gestures in bimodal bilinguals (hearing signers). Mandarin speakers often use *GESTURES* to represent time laterally, vertically, and sagittally. Chinese Sign Language (CSL) users also exploit *SIGNS* for that purpose, and can differ from the gestures of Mandarin speakers in their choices of axes and directions of sagittal movements. The effects of sign language on co-speech gestures about time were investigated by comparing spontaneous temporal gestures of late bimodal bilinguals (Mandarin learners of CSL) and non-signing Mandarin speakers. Spontaneous gestures were elicited via a wordlist definition task. In addition to the effects of temporal words on temporal gestures, results showed significant effects of sign. Compared with non-signers, late bimodal bilinguals (1) produced more sagittal but fewer lateral temporal gestures; and (2) exhibited a different temporal orientation of sagittal gestures, as they were more likely to gesture past events to their back. In conclusion, bodily experience of sign language not only impacts the nature of co-speech gestures, but also spatial-motoric thinking and abstract space-time mappings.

Chapter 4 reports three experiments about the effect of Chinese Sign Language (CSL) on deaf CSL-Mandarin bilinguals' spatial conceptualisation of time. Chinese Sign Language (CSL) has past-at-back space-time metaphors whereas Mandarin additionally allows past-in-front metaphors. In this chapter we investigated deaf CSL-Mandarin bilinguals, and investigated (1) the effect of such cross-modal/linguistic differences on their sagittal space-time mappings and (2) whether they have a different spatial-temporal reasoning than Mandarin hearing speakers. In Experiment 1 we tested deaf bilinguals' (N=123) sagittal space-time mappings first in CSL and then in Mandarin. Particularly, the temporal expressions in the Mandarin test (but not in CSL) had overt past-in-front/future-at-back metaphors indicating past-in-front/future-at-back mappings. Results showed that deaf signers, irrespective of in CSL or Mandarin, were less likely to have past-in-front/future-at-back mappings than Mandarin speakers, even after controlling for related factors such as temporal-focus and age. In Experiment 2, we used real-life questions to examine participants' understanding of time in Mandarin, related to the ego-moving and time-moving perspectives. Results showed that, Mandarin speakers mostly took the time-moving perspective whereas deaf signers, influenced by the CSL time perspective, were less likely to take the Mandarin time-moving perspective. Such results still held even when only limiting to deaf participants with higher education (highly proficient in Mandarin). Experiment 3 replicated Experiments 1 and 2 and further showed that deaf bilinguals (N=104) performed differently between CSL and Mandarin, and that age of acquisition of CSL and CSL proficiency affect signers' future-in-front/past-at-back mappings. Within Chinese culture, signers persistently displayed a different spatial-temporal reasoning than Mandarin speakers. We conclude that bodily experience of sign language (especially at an earlier age) impacts signers' spatial and temporal thinking. This first study on deaf signers' spatial temporal reasoning not only has implications for theories on space-time mappings, but also for the relationship between signed language and thought.

Chapter 5 reports a survey on pension planning and financial wealth of natives and immigrants (N=1177) in the Netherlands, in relation to their temporal values (past/future-focused), financial knowledge, IQ, and other individual characteristics. I found that compared to natives, immigrants are less financially literate and rely more on the government for their retirement income, but are more future-focused and think more about their retirement. Second, controlling for financial knowledge, IQ, saving intention, health, self-control and demographic factors, temporal values help to predict many aspects of pension planning: how much people think about retirement, their desired retirement age, whether they develop a plan to save for retirement, perceived saving adequacy, and home ownership. Furthermore, temporal values predict savings and financial wealth in 2016 and 2020, even after controlling for the financial situation in 2016. In conclusion, habitually attending to the past makes people give less priority to the future compared to the past, which has consequences for people's planning and behaviour such as retirement planning and financial well-being. The results have strong implications for policies related to pension communication and contribute to the theory on relationships between economic decisions, time and cognition.

Chapter 6 examines the effect of people's temporal values (habits of attending to past or future events) on their health, labour market performance and happiness. Participants' (N=1177) data were initially collected in 2016 and then again in a follow-up study in 2020-2021. I find that habitually more attending to the future is negatively associated with chronic diseases (heart attack; high cholesterol; diabetes; high-blood pressure; Covid19), but positively with health-related behaviour (eating vegetables and fruit; less smoking), health status (e.g., healthy weight; long life expectancy), income, hourly wages, financial satisfaction and happiness. Furthermore, such temporal values predict participants' future situation of these aspects of well-being in 2020-2021, even after controlling for the 2016 baseline situation, IQ, self-control, patience, risk aversion and demographic information. I propose a temporal values and well-being hypothesis, suggesting that individuals' temporal values can predict their concurrent and longitudinal all-around well-being. These findings have strong implications for theories of time perception, and for a better understanding of factors that influence people's health, income, and happiness.

Chapter 7 reports a 5-year longitudinal study about the effect of Dutch proficiency on immigrants' labour market performance, savings and financial wealth in the Netherlands. Different from past research, I had participants (*N*=659) take a Dutch language proficiency test apart from self-reported assessments, and measured participants' IQ, patience, saving intention, risk aversion, self-control, temporal focus, demographic data, etc. to better control for individual characteristics. Immigrants' labour market performance and financial wealth were initially interviewed in 2016, and then again in 2020-2021. I used 2016 examined Dutch proficiency to predict their (1) 2016 situation and (2) future situation while controlling for the situation in 2016 and other factors. Furthermore, I conducted three sensitivity analyses: (a) using the self-assessed Dutch proficiency to check whether the findings are different than using examined Dutch as a proficiency measurement; (b) using the first-generation immigrants to do a sub-sample analysis while additionally controlling for their length of stay; (c) using an instrumental variable approach (an econometric method allows uncovering the causal effect of the independent variable on the dependent variable), I analysed the causal effect of language proficiency. Results showed that: 1) While controlling for individual characteristics and demographic information, Dutch proficiency predicts immigrants' earnings (employment probabilities; income; hourly wages), savings, and financial wealth in 2016, and in 2020-2021 even after additionally controlling for the 2016 baseline. 2) Overidentification tests do not reject the validity of instruments. Effects of Dutch proficiency can be interpreted as causal effects. 3) Results from self-assessed Dutch proficiency are generally robust but the self-assessment underestimates the influence of language proficiency on labour market performance. This study not only finds an impact of language skills on immigrants' earnings, but also shows for the first time that, host-country language can persistently affect immigrants' savings and wealth concurrently and longitudinally. Our findings have important theoretical and policy implications.

References:

Bleakley, H., & Chin, A. (2004). Language skills and earnings: Evidence from childhood immigrants. *Review of Economics and Statistics*, *86*(2), 481-496.

Boroditsky, L. (2001). Does language shape thought?: Mandarin and English speakers' conceptions of time. *Cognitive Psychology*, *43*(1), 1-22.

Boroditsky, L. (2011). How language shapes thought. *Scientific American*, February, 63-65.

Bylund, E., & Athanasopoulos, P. (2017). The Whorfian time warp: Representing duration through the language hourglass. *Journal of Experimental Psychology: General*, *146*(7), 911–916. doi.org/10.1037/xge0000314

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

Casasanto, D., & Lupyan, G. (2015). All concepts are ad hoc concepts. In E. Margolis & S. Laurence (Eds.), *The conceptual mind: New directions in the study of concepts* (pp. 543-566). Cambridge: MIT Press.

Casasanto, D. (2015). Linguistic relativity. In *The Routledge handbook of semantics* (pp. 174-190). New York: Routledge.

Chen, M. K. (2013). The effect of language on economic behavior: Evidence from savings rates, health behaviors, and retirement assets. *American Economic Review*, *103*(2), 690-731.

Chen, J. I., He, T. S., & Riyanto, Y. E. (2019). The effect of language on economic behavior: Examining the causal link between future tense and time preference in the lab. *European Economic Review*, *120*, 103307.

Chen, J.-Y., & O'Seaghdha, P. G. (2013). Do Mandarin and English speakers think about time differently? Review of existing evidence and some new data. *Journal of Chinese Linguistics, 41*(2), 338-358.

Croote, D. E., Lai, B., Hu, J., Baxter, M. G., Montagrin, A., & Schiller, D. (2020). Delay discounting decisions are linked to temporal distance representations of world events across cultures. *Scientific Reports, 10*(1), 1-13.

de la Fuente, J., Santiago, J., Román, A., Dumitrache, C., & Casasanto, D. (2014). When you think about it, your past is in front of you: How culture shapes spatial conceptions of time. *Psychological Science, 25*(9), 1682–1690.doi:10.1177/0956797614534695

Dustmann, C., & Fabbri, F. (2003). Language proficiency and labour market performance of immigrants in the UK. *The Economic Journal*, *113*(489), 695-717.

Dustmann, C., & van Soest, A. (2001). Language fluency and earnings: Estimation with misclassified language indicators. *Review of Economics and Statistics*, *83*(4), 663-674.

Drake, L., Duncan, E., Sutherland, F., Abernethy, C., & Henry, C. (2008). Time perspective and correlates of wellbeing. *Time & Society*, *17*(1), 47-61.

Earl, J. K., Bednall, T. C., & Muratore, A. M. (2015). A matter of time: Why some people plan for retirement and others do not. *Work, Aging and Retirement*, *1*(2), 181-189.

Gu, Y., (2022). Time in Chinese hands: Gesture and sign. In Piata, A., Adriana, G. and Carrión, DA. (Eds). *Time Representations in the Perspective of Human Creativity* (pp.209- 232). John Benjamins Publishing Company.

Guo, T., Ji, L., Spina, R., & Zhang, Z. (2012). Culture, temporal focus, and values of the past and future. *Personality and Social Psychology Bulletin, 38*(8), 1030–1040. https://doi.org/10.1177/0146167212443895

Jacobs-Lawson, J. M., & Hershey, D. A. (2005). Influence of future time perspective, financial knowledge, and financial risk tolerance on retirement saving behaviors. *Financial Services Review*, *14*(4), 331.

Jäggi, T., Sato, S., Gillioz, C., & Gygax, P. M. (2022). Is the future near or far depending on the verb tense markers used? An experimental investigation into the effects of the grammaticalization of the future. *PLOS ONE*, *17*(1), e0262778.

Levasseur, L., Shipp, A. J., Fried, Y., Rousseau, D. M., & Zimbardo, P. G. (2020). New perspectives on time perspective and temporal focus. *Journal of Organizational Behavior*, *41*(3), 235-243.

Park, J. S. Y. (2011). The promise of English: Linguistic capital and the neoliberal worker in the South Korean job market. *International Journal of Bilingual Education and Bilingualism*, *14*(4), 443-455.

Roberts, S. G., Winters, J., & Chen, K. (2015). Future tense and economic decisions: controlling for cultural evolution. *PLOS ONE, 10*(7), e0132145.

Saj, A., Fuhrman, O., Vuilleumier, P., & Boroditsky, L. (2014). Patients with left spatial neglect also neglect the “Left Side” of time. *Psychological Science*, *25*(1), 207–214. doi:10.1177/0956797612475222

Slobin, D. I. (1996). From “thought and language” to “thinking for speaking.” In J. Gumperz and S. C. Levinson (Eds), *Rethinking linguistic relativity* (pp. 70-96). Cambridge: Cambridge University Press.

Thoma, D., & Tytus, A. E. (2018). How cross-linguistic differences in the grammaticalization of future time reference influence intertemporal choices. *Cognitive Science*, *42*(3), 974-1000.

Whorf, B. L. (1956). *Language, Thought, and Reality: Selected Writings of Benjamin Lee Whorf*. Edited by John B. Carroll. Cambridge, MA: MIT Press.

Wong, L. (2022). The effect of linguistic proximity on the labour market outcomes of the asylum population. *Journal of Population Economics*, 1-44.

Zheng, Y., Lin, H., & Gu, Y. (2023). The value of sign and print: Language proficiency predicts deaf signers' occupational prestige and income. *OSF Preprints*. https://doi.org/10.31219/osf.io/rn93w.

Zimbardo, P. G., & Boyd, J. N. (1999). Putting time in perspective: A valid, reliable individual-differences metric. *Journal of Personality and Social Psychology*, *77*(6), 1271–1288.

Chapter 1. Looking downward to the future: What eye movements reveal about Chinese people's conceptualisations of time

Abstract: Westerners are reported to more often direct their eyes upward when conceptualising the future and downward when conceptualising the past. It is unknown whether this vertical space-time mapping is universally true. As time can be expressed differently in Mandarin language and culture, we studied Mandarin speakers' eye movements during language comprehension of sentences referring to the past or the future. Unlike results obtained previously with Westerners, Chinese had higher gazing positions when processing past-related sentences than future-related sentences. These eye-gaze related correlates of a vertical mental timeline appeared earlier when processing sentences with Mandarin vertical space-time metaphors than with neutral time expressions (Exp1). Furthermore, when silently taking a mental time travelling, Chinese still directed their eyes more downward when conceptualising the future than the past (Exp2). Our experiments (N=66 adults) showed that variation in people's language and culture may steer their conceptualisation of time and eye movements in different ways.

Keywords: time and space, eye tracking, mental timeline, conceptual metaphor, Chinese, language and thought

Acknowledgement: This work is supported by grants from The Netherlands Organization for Scientific Research, via NWO Research Talent (406-15-298) to YQZ, and NWO Promoties in de Geesteswetenschappen (322-89-007) to YG. The paper has been orally presented at UK Cognitive Linguistics Conference (2020). An abstract of the chapter has been published as:

Zheng, Y., Gu, Y., Cozijn, R., & Swerts, M. (2020) Looking downwards to the future: the Chinese mind's eye in time space. In S. Denison., M. Mack, Y. Xu, & B.C. Armstrong (Eds.), *Proceeding of 42nd Annual Meeting of the Cognitive Science Society* (pp. 2949). Cognitive Science Society.

The chapter is based on:

Zheng, Y., Gu, Y., Cozijn, R., & Swerts, M. (minor revision invited) Looking downward to the future: What eye movements reveal about Chinese people's conceptualisations of time, *Psychological Science*.

Introduction

In English, as well as in many other languages, people often use spatial metaphors to talk about time, in examples such as "looking back to the past", "gazing ahead into the future". Interestingly, these phrasings match the way English people think of the concept of time (Ulrich & Maienborn, 2010), and it even has some effect on behavioural measures: For instance, thinking about the future or past will lead English people's body to leaning forward or swaying backward (Miles et al., 2010). Additionally, words like "looking" and "gazing" are often used in such space-time metaphors, suggesting that people's eye gaze may reveal their concept of time. Given the general belief that eyes are the window to the soul, is there any link between eye movements and people's spatial conceptualisation of time?

There is indeed evidence showing that how people spatialize time can be deduced from their eye movements. For example, Stocker et al. (2016) compared Swiss Germans' eye saccades when they listened to sentence pairs expressing the past (e.g., "Now I am watching TV. Before that I was listening to music") with saccades when listening to sentence pairs expressing the future ("Now I am watching TV. After that I will be listening to music"). Participants had significantly more upward saccades when hearing future-related concepts than past-related ones. In another study, Hartmann et al. (2014) found that when Swiss Germans mentally displaced themselves into the past or future for one minute each, they directed their eyes more to the right up when thinking of the future and more left down when thinking of the past. Across these studies there seems to be a robust vertical space-time association in eye movements, with the future mapped more above and the past more below (Beracci & Fabbri, 2022).

However, the origin of such vertical spatial-temporal associations in eyes remains an open issue. Hartmann et al. (2014) propose several accounts for the vertical mappings. A first possible explanation could be related to the view that the vertical positioning of the past below and the future above is shaped by people's universal experience of growth – human and plants grow taller as time passes, and larger size is associated with the upper space. Or they may be driven by the differences in cognitive processing between "remembering" the past and "imagining" the future in a visuospatial memory task, which may elicit different gaze behaviour (Johansson & Johansson, 2014). And third, the eye-gaze patterns could be influenced by the lexical materials, that is, triggered by the vertical spatial temporal association in language such as the *upcoming* future (Lakoff & Johnson, 1980).

The experience of vertical growth over time and cognitive processing differences between past facts and future imagination would seem like universal properties shared by most human beings. Yet, speakers of different languages may still use different vertical spatial metaphors to express time. For instance, Chinese speakers can talk about time vertically with past=up and future=down mappings (e.g., 上周/shàng-zhōu, "above week", meaning last week; 下月/xià-yuè, "below month", next month), and they also tend to produce co-speech vertical temporal bodily gestures for these time references with vertical spatial metaphors (Gu et al., 2017). Due to the Mandarin vertical space-time metaphors (also see an alternative explanation with the Chinese top-to-down writing direction in the old days, Bergen, Lau & Ting, 2012), Chinese people have been argued to use a different vertical spatial conceptualisation of time than Westerners (e.g., Boroditsky, 2001; Fuhrmam et al., 2011). With such linguistic and cultural differences in space-time mappings, it is interesting to explore whether time is mapped in similar ways in eye-gaze patterns of Chinese, as has previously been reported for Western people.

In this study we investigate Mandarin speakers' eye movements during temporal processing and mental time travelling. We aim to find out whether Chinese people display a similar pattern of eye movements to that of the previously reported Swiss Germans. The study of Chinese samples would be particularly interesting as it provides an excellent opportunity to better understand possible accounts for the gaze-related vertical spatial-temporal associations, with an additional implication for the relationship between language, culture, and cognition.

We hypothesize that if temporal processing evokes eye movements along the mental timeline in a language/culture-specific rather than universally similar way, eye movements of Chinese may reflect a different (even opposite) spatial conceptualisation of time than Swiss Germans. Especially, if language can guide speakers' eye movements (Papafragou et al., 2008; Spivey & Geng, 2001), we expect that the language-specific preferences will be strengthened when lexical cues of Mandarin vertical space-time metaphors are present. However, if human beings' eye movement behaviour during temporal processing is indeed a universal cognitive and neurological process, we expect that Chinese will also reveal a strong tendency to look more upward when thinking about the future than the past, regardless of their language and culture.

To test these hypotheses, we conducted two experiments. In Experiment 1, we investigated whether Chinese people's eyes follow a different vertical mental timeline than the one reported for Swiss Germans during language comprehension of sentences that lexically refer to the past and future. Additionally, we examined whether the Mandarin vertical spatial-temporal metaphors influenced Chinese people's eye movements. In Experiment 2, we further studied Chinese people's eye movements in a mental time travelling task which did not contain any direct lexical cues.

Open Practices Statement

All data, scripts, detailed analysis and output of results can be found in the OSF link https://osf.io/c3q5t/?view_only=c74d2cfff63243c38849d97be71b0582.

Experiment 1

Method

Participants

36 native Mandarin speakers (female=16, male=20, mean age=19.11 years, *SD*=.78) from Rizhao Polytechnic participated in the experiment in China. All gave written informed consent. Data of five participants were excluded (two failed to pass the calibration and three looked off-screen with little data tracked). The final sample size was 31 participants. Our sample size was based on those used in previous related studies, which commonly incorporated between 16 and 30 participants (e.g., Hartmann et al., 2014; Martarelli et al., 2017; Stocker et al., 2016).

Stimuli

In total we created 54 pairs of Mandarin sentences, 18 contained expressions of temporal relations and the rest were fillers. For the manipulation of temporal relations, inspired by Stocker et al. (2016) we constructed sentence pairs where the second sentence referred to the past or future. The first sentence described an event that happens in the present and always started with temporal expressions referring to the concept of now such as "today" (e.g., "Today I am repairing the TV."). The second sentence described an event that occurred either earlier or later in time than the first event, and always started with a temporal expression referring to the past such as "yesterday" (e.g., "Yesterday I was repairing the fridge."), or a temporal expression referring to the future such as "tomorrow" (e.g., Tomorrow I will be repairing the fridge"). The number of past- or future-related sentence pairs was equal. Sentences were recorded with a hypothesis-blind Mandarin female speaker in a soundproof booth. To maximize the natural temporal structure of language, the duration of both sentences within a pair was not changed artificially, except that the pause between the two sentences was slightly adjusted in Praat to make the pause duration identical (1000 ms) within a pair.

To study the effect of an immediate influence of linguistic space-time metaphors on eye movements, we introduced three types of temporal expressions (Gu, Zheng, & Swerts, 2019) in sentence pairs, including time expressions paired with (1) vertical spatial metaphors (e.g., 上/下月, "up/down month", last/next month), (2) sagittal spatial metaphors such as before and after (e.g., 前天, "front day", the day before yesterday) and (3) neutral wordings without explicitly referring to space (e.g., yesterday, last year).

Eye Movement Recording

Eye movements were recorded using a portable eye-tracker, i.e., the Eye Tribe. Data were registered at a sampling rate of 60 Hz, a spatial resolution of 0.1 degree, and a gaze position accuracy of 0.5 degree. The primary outcome of the eye tracking device were fixations, defined by a minimum fixation duration of 80 ms. The instruction was presented on a 33.8x27.1 cm (display resolution 1920x1080) monitor screen programmed in OpenSesame. Blink events were subtracted by an eye-tracking analysis programme *Fixation*.

Procedure

Participants sat behind the computer screen and were told to listen carefully to a number of sentence pairs while looking at an empty (grey) screen. The 54 sentence pairs were presented in a random order via two loudspeakers with an inter-stimulus interval of 6 seconds. To encourage semantic processing of the contents, participants were told that they should be attentive as from time to time questions about the content of some sentence pairs would be asked. In fact, there were 10 statements about the previously presented sentence pairs. Each statement appeared on the screen always after a filler sentence pair had been presented. In order to explain why there was an eye-tracker, while at the same time we wanted to hide the fact that we were interested in eye movements, we presented participants with a cover story in which we explained that this study was about the relationship between pupil size and cognitive processes during language comprehension. Participants were instructed to listen carefully to the sentences and if statements about the contents of previously presented sentences appeared on the screen, they needed to indicate as quickly and accurately as possible whether the statement was true or false by saying “yes” or “no”. Prior to each trial, a fixation cross flashed at the centre of the screen. Participants were told that they were free to move their eyes but should keep on looking at the screen. The responses to the statements were noted down by the experimenter and additionally recorded with a recorder.

Coding and Data Analysis

First, we were interested in what impact words expressing different temporal relations (e.g., past, future) had on eye movements. Because little semantic processing is expected within the time frame of a time word per se (Stocker et al., 2016), for each sentence pair we coded the onset and offset time of the part after the time word of the second sentence, labelled “Part1” (mean duration=1090 ms, emboldened in Table 1), In addition, following Stocker et al. (2016), we coded 1000 ms silence period after the second sentence as “Part2”. Such codings allowed us to compare the differences in gaze positions during Part1 that either expressed future or past conceptions, as well as during the silent period (Part2) right after Part1.

Table 1: Examples of sentence pairs for future and past temporal relations.

Temporal relations	First sentence (S1)		Time word	After time word (Part1)	Silence (Part2)
Future	S1: Today I am repairing the TV.	S2:	*Tomorrow*	**I will be repairing the fridge**.	(1000ms Silence)
Past	S1: Today I am repairing the TV.	S2:	*Yesterday*	**I was repairing the fridge.**	(1000ms Silence)

Note: S1=sentence1, S2=sentence2.

We were also interested in whether Mandarin vertical spatial metaphors for time have an online effect on eye movements. If a time expression immediately before the onset of Part1 did not have any spatial metaphors for time but used “neutral” temporal expressions (e.g., 明天, literally “bright day”, meaning *tomorrow*, or 昨天, literally “past day”, meaning *yesterday*, italicized in Table 1.1), the sentence pair was coded as a neutral pair. If the time expression immediately before Part1 consisted of a vertical or sagittal spatial metaphor for time, the sentence pair was coded as a vertical or sagittal pair.

For statistical analysis, the dependent variables were operationalised as the horizontal (x coordinate) and vertical (y coordinate) eye gaze positions which were computed using the centre of the screen (0, 0) as the reference point. The independent variables were the temporal relations (past; future), time words (neutral; vertical; sagittal) and part (Part1; Part2), as well as their interactions. A panel data random-effects linear regression model was used in Stata to deal with multiple data points from a same participant.

Results

All participants responded with correct answers for at least 8/10 of the statements, and debrief responses showed that no participants guessed what the underlying research question was of our study.

We compared the effect of temporal relations (past and future) on the horizontal and vertical fixation positions, respectively. For the x axis, the mean fixation position for the past (M=34.03 pixels) was not different from that for the future (M=30.53 pixels) (β=-1.80, p=.88, 95%CI [-25.19, 21.60]). There were no effects of time word type, part or interactions between variables (all p>0.05).

However, for the y axis, there was a significant effect of processing temporal relations on vertical eye movements. On average, Chinese participants fixed their eyes 40.11 pixels lower when processing future-related sentences (M=-52.98 pixels) than when processing past-related sentences (M=-12.84 pixels) (β=-37.98, p<.001, 95%CI [-54.27, -21.68]). Specifically, regression analysis showed that when processing sentences with vertical spatial metaphors for time, the differences were most pronounced during Part1 (sentence after the vertical time word) (β=-52.41, p=.0116, 95%CI [-93.11, -11.72]), whereas the effect was only marginally significant during the 1000 ms silence after Part1 (β=-38.41, p=.058, 95%CI [-78.13, 1.31]) (Figure 1a). In contrast, when processing sentences with neutral words for time, the differences did not approach significance (β=-15.80, p=.53, 95%CI [-64.68, 33.07]) during Part1, whereas they became significant during Part2 (β=-52.16, p=.0398, 95%CI [-101.88, -2.44]) (Figure 1b). Similarly, when processing sentences with sagittal spatial metaphors for time, the difference was only marginally significant during Part1 (β=-32.91, p=.061, 95% CI [-67.36, 1.53] but became significant during Part2 (β=-35.20, p=.0446, 95%CI [-69.56, -.84]) (Figure 1c). Despite a consistent effect of temporal relations on the y coordinate, the differences in vertical fixations between Part1 and Part2 and between different time words did not lead to a significant three-way or two-way interaction between temporal relations, part and time words. The effects of time word types and part were not significant when interactions were removed (all p values >.05).

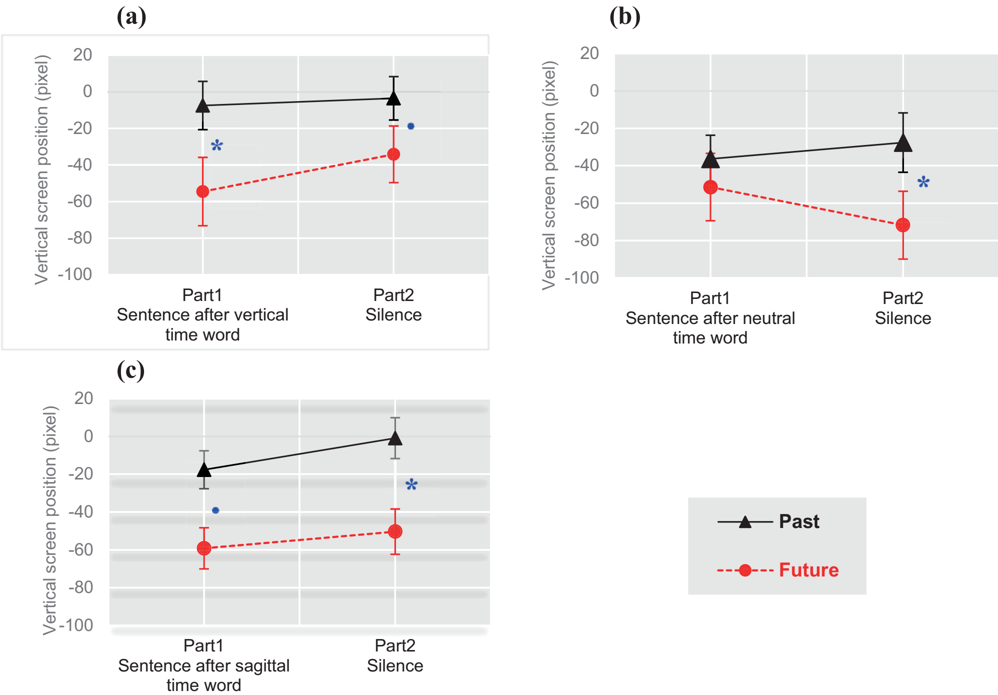


Figure 1. Mean vertical eye gaze positions (pixels) when processing the past- and future-related sentences, where temporal concepts were expressed with (a) vertical time words, (b) neutral time words, and (c) sagittal time words. Part1=the sentence after the time word in the second sentence of a pair; Part2=1000ms silence after Part1. Positive values represent gaze position in the upper (vertical) screen half. Error bars represent ±1 SE.

Discussion

The results of Experiment 1 showed that Chinese people's eye movements follow a vertical mental timeline when processing sentences that express time relations. However, opposite to the previously reported findings with Swiss-Germans who directed their eyes more upward for the future than the past, Chinese mapped the future more downward than the past. This indicated that eye movements during temporal processing are not a correlate of a universal cognitive and neurological process, but can be affected by a person's linguistic and cultural background. Notably, although we did not find evidence to support the hypothesis that type of temporal expressions may significantly influence eye movements, we did see that eye-gaze related correlates of a vertical mental timeline appeared earlier when participants processed sentences with vertical space-time metaphors than with neutral time expressions. Vertical space-time metaphors seem to activate the vertical timeline faster than neutral time expressions. This raises an interesting question as to whether the observed Chinese vertical eye movements were simply guided by language.

Especially, a previous study on motion events showed that speakers of typologically different languages can diverge considerably in their eye-fixation patterns when processing motion events. For example, when English and Greek speakers were instructed to watch animations depicting motion events which they would have to describe at a later stage, Greek speakers fixed more on path over manner than English speakers. However, when English and Greek speakers were both told to simply watch the clip, there were no differences between English and Greek participants' gaze patterns (Papafragou, Hulbert & Trueswell, 2008). These findings suggest that the semantic processing of motion language influences speakers' eye movements, but the differences disappear if there is no linguistic processing. Thus, in Experiment 2 we further examined whether the Chinese gaze related correlates of the vertical mental timeline also disappear when there is less linguistic information to process.

Experiment 2

Method

Participants

Another 30 native Mandarin speakers (female=10; male=20, mean age=19.23 years, *SD*=1.13), who had not participated in Experiment 1, from Rizhao Polytechnic participated in this experiment in China. Participants signed a consent form before the study. Data of six participants were excluded as one did not pass the calibration, and five failed to follow the instructions and looked outside the screen almost all the time which led to little data. Again, our sample size was based on those used in previous related studies, ranging between 16 and 30 participants (e.g., Hartmann et al., 2014; Martarelli et al., 2017; Stocker et al., 2016).

Eye Movement Recording The eye movement recording was similar to Experiment 1, except that the data in Experiment 2 were registered at a sampling rate of 30 Hz.

Procedure

Participants sat in front of the computer screen at an approximate distance of 57 cm. Participants read Mandarin instructions that appeared on the screen which were exactly the same as those from Hartmann et al. (2014) except that now they were in Mandarin: "In the following task, you are asked to mentally displace yourself in time to your personal past (future). Please think for one minute about your personal life circumstances one year back in the past (how your personal life circumstances may look like one year in the future). Think about what you did on a typical day one year ago (what you will be doing on a typical day one year from now in the future). Try to remember (imagine) the episodes in as much detail as possible (e.g., how does the location look like, what other people are there etc.)." Instructions were presented horizontally in black (font size=16) on a grey background.

Copying the procedure of Hartmann et al. (2014), p. 203, we introduced a cover story where participants were told that the study was about the relationship between pupil size and cognitive processes. Participants were also told that eye movements do not influence the pupil size (so that participants did not actively suppress their eye movements). After the task instruction, a calibration and validation procedure was performed, followed by a fixation cross. When participants were ready to begin the task, they pressed the space bar and the fixation cross disappeared. After 60 seconds, the recording stopped and another instruction appeared on the screen to tell participants that they now had to mentally displace themselves into the future or past, depending on what they had done in the first task. The sequence of past and future conditions was counterbalanced across participants.

After the experiment, participants were presented with a questionnaire where they filled in their background information such as experience of vertical writing and reading. They also rated the valence for their thinking about the past and the future events in the mental time travelling.

Coding and Data Analysis

Participants' horizontal (x coordinate) and vertical (y coordinate) eye movements were computed with the centre of the screen (0, 0) as the reference point. Such gaze positions (x, y coordinate) were used as dependent variables to compare the differences between the future and past mental travelling (an independent variable coded as temporal relations). Following Hartmann et al. (2014), we divided eye gaze positions into six time windows (coded as five dummy variables) to capture the time course of mental time travel: Fixations were computed over windows that started between 0–10, 10–20, 20–30, 30–40, 40–50, and 50–60 s after mental time travel onset. For each axis, a panel data fixed/random-effects linear regression was used, with the gaze position as a dependent variable, and the temporal relations, time window, and their interaction as independent variables. We changed the reference level of a time window and refitted the model to obtain the p values for six time windows.

Results

Participants had little vertical reading (M=1.38, mode/median=1) or vertical writing experience (M=1.33, mode/median=1), with 1=always horizontal, 5=always vertical (a five-point rating scale). The valence rating (1-9) for the future-related thoughts (M=7.79) was significantly more positive than for the past (M=6.08), t=3.96, p=.0006.

For the horizontal gaze positions (Figure 2a), Chinese participants' fixation positions during the one-minute future mental travelling was on average 37.25 pixels more rightward than that of the past mental travelling (β=10.92, p=.001, 95%CI [15.85, 58.66]). A regression, comparing the effect of mental time travel (future vs. past), time windows and their interaction on the x coordinate, revealed (marginally) significant differences in horizontal gaze positions in Time window 1 (β=58.08, p=.028, 95% CI [6.42, 109.74]), Time window 3 (β=60.92, p=.024, 95% CI [8.15, 113.69]), and Time window 4 (β=47.69, p=.077, two-tailed, 95% CI [-5.09, 100.46]) but not in Time window 2 (β=31.22, p=.25, 95%CI [-21.55, 83.99]), Time window 5 (β=20.68, p=.44, 95%CI [-32.09, 73.45]), and Time window 6 (β=2.54, p=.93, 95% CI [-51.41, 56.50]). These effects were always in the same direction showing that the future was fixated more rightward.

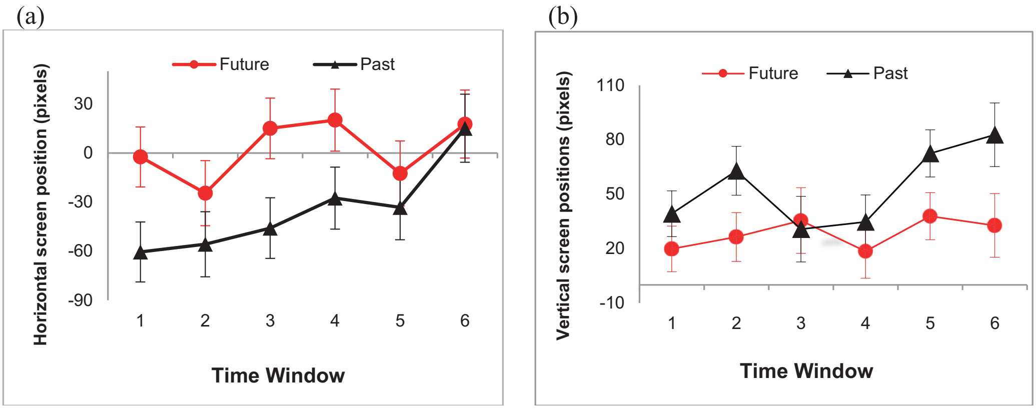


Figure 2. Mean horizontal (a) and vertical (b) eye gaze position for future and past mental time travel separate for the time windows 0–10, 10–20, 20–30, 30–40, 40–50, and 50–60 s from task onset. Positive values represent gaze position in the right (horizontal) and upper (vertical) screen half. Error bars represent ±1 SE.

As for the vertical gaze positions (Figure 2b), the mean fixation position for the future mental travelling was 25 pixels more downward than that of the past (*β*=51.26, *p*=.005, 95%CI [-42.56, -7.56]). A regression of mental time travel (future vs. past) and time windows on the y coordinate for each time window showed that the differences were mainly (marginally) significant in Time window 2 (*β*=-36.53, *p*=.09, two-tailed, 95%CI [-79.21, 6.14]), Time window 5 (*β*=-34.62, *p*=.11, two-tailed, 95%CI [-77.29, 8.06]) and Time window 6 (*β*=-49.99, *p*=.025, 95% CI [-93.63, -6.36]), but not significant in Time window 1 (*β*=-19.41, *p*=.36, 95% CI [-61.19, 22.36]), Time window 3 (*β*=4.73, *p*=.22, 95% CI [-37.94, 47.41]), or Time window 4 (*β*=-15.85, *p*=.47, 95% CI [-58.53, 26.82]). The results showed that even when these differences did not reach significance for every time window, the effect was highly significant when computed over all windows.

Discussion

The results of Experiment 2 showed that Chinese people's eye movements can both follow horizontal and vertical timelines during mental time travelling. Especially, for the vertical timeline, Chinese again directed their eyes more downward for the future than the past (so opposite to what previously has been reported for Swiss German participants), even in a task where there were no explicit vertical temporal expressions or was no online linguistic information to process.

General Discussion

In this study we investigated the relationship between eye movements and Chinese people's conceptualisation of time. We examined Mandarin speakers' eye movements when they were processing sentences expressing different temporal relations (past, future) (Experiment 1), and when they were silently taking a mental travelling to the past or future (Experiment 2). Results of both experiments showed that temporal processing evokes eye movements along the mental timeline on the vertical axis. However, more importantly, opposite to what has been reported for Swiss Germans (Hartmann et al., 2014; Stocker et al., 2016), we found that Chinese people's gaze positions were significantly higher when processing sentences expressing past relations than future relations, as well as when mentally travelling to the past than to the future.

Such a pattern cannot be due to the differences in cognitive processes that involve imagination versus memory. Arguably, when people reflect on future or past, they may rely on different cognitive resources as people imagine the future that is yet to come and retrieve a memory of past facts that have actually happened. However, if the vertical eye movements are shaped by such neurological differences (e.g., Johansson & Johansson, 2014), we would not expect to see an opposite pattern between Swiss Germans and Chinese.

Our results were also unlikely to be driven by different valences when participants were processing/thinking about the past or the future. Admittedly, in Experiment 2 where participants were asked to mentally travel through time, they attached significantly more positive valence to the future than to the past. However, according to the conceptual metaphor theory (Lakoff & Johnson, 1980), if HAPPY IS UP and SAD IS DOWN, then thinking about a positive future would instead elicit higher eye fixations than thinking about a negative past. This pattern is opposite to the results we obtained in Experiment 2 which showed that fixations for the future were lower. Additionally, in Experiment 1, even though we compared the similar sentences (e.g., both Part1) after past vs. future time words (similar valence), we obtained vertical eye movements with lower fixations for the future than the past.

Thus the results of the two experiments provided converging evidence showing that Chinese people direct their eyes differently than Swiss Germans when thinking about past or future. The pattern that future is directed more upward in Swiss Germans' eyes has been explained as being a result of English spatial metaphors for time (e.g., upcoming future, projecting the future *ahead* to *above*), growing experience of human and plant (upper is larger), or to differences in cognitive and neurological process. However, we show that Chinese language/culture-specific spatial representations of time are so powerful that they may overrule effects of other factors.

While our findings in eye movements are largely consistent with earlier findings from co-speech gestures (Gu et al., 2017), a close look at the eyes may not only reveal what is in a person's mind, but also show how abstract concepts are grounded in basic sensory-motor processes (Loetscher et al., 2010). Different from temporal gestures that are accompanying speech production, eye movements in the current study are subtle as they naturally occur during the perception of temporal relations or silent mental travelling. However, it is yet unknown as to whether such co-thought eye movements have a functional and facilitatory role in comprehending and processing abstract time. Follow-up research could address this topic by studying people's reaction time in processing future- and past-related questions while manipulating their eye movements in space/time-congruent and space/time-incongruent ways.

Furthermore, importantly, our study suggests that perception of time may induce a shift of attention to the left/right or up/down visual field. This can have implications for advertising or sales of time-related products. For example, products with their images facing toward the left (versus right) in advertising are evaluated more favourably when consumers focus on the past, whereas the reverse is true when consumers are future-focused (Zhang et al., 2018). If perceiving time with habitual spatial associations influences the allocation of attention in the visual field (Fischer et al., 2003), such mappings may in turn influence what we see and how we feel – and this could be culturally-dependent.

References

Bender, A., & Beller, S. (2014). Mapping spatial frames of reference onto time: A review of theoretical accounts and empirical findings. *Cognition, 132*, 342–382.

Beracci, A., & Fabbri, M. (2022). Past on the ground floor and future in the attic: The vertical mental timeline. *Journal of Experimental Psychology: Human Perception and Performance*, 48(4), 380–399. https://doi.org/10.1037/xhp0000988

Bergen, B., Lau, C., & Ting, T. (2012). Writing direction affects how people map space onto time. *Frontiers in Psychology*, *3*, 109.

Boroditsky, L. (2001). Does language shape thought?: Mandarin and English speakers' conceptions of time. *Cognitive Psychology, 43*(1), 1-22.

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

Casasanto, D., & Jasmin, K. (2012). The hands of time: Temporal gestures in English speakers. *Cognitive Linguistics, 23*(4), 643-674.

Cooperrider, K., & Núñez, R. E. (2009). Across time, across the body: Transversal temporal gestures. *Gesture, 9*(2), 181-206.

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

Fischer, M. H., Castel, A. D., Dodd, M. D., & Pratt, J. (2003). Perceiving numbers causes spatial shifts of attention. *Nature Neuroscience, 6*(6), 555-556.

Gu, Y., Mol, L., Hoetjes, M., & Swerts, M. (2017). Conceptual and lexical effects on gestures: the case of vertical spatial metaphors for time in Chinese. *Language, Cognition & Neuroscience*, *32*, 1048–1063

Gu, Y., Zheng, Y., & Swerts, M. (2019). Which is in front of Chinese people, past or future? The effect of language and culture on temporal gestures and spatial conceptions of time. *Cognitive Science, 43*(12), e12804.

Hartmann, M., Martarelli, C. S., Mast, F. W., & Stocker, K. (2014). Eye movements during mental time travel follow a diagonal line. *Consciousness & Cognition, 30*, 201-209.

Johansson, R., & Johansson, M. (2014). Look here, eye movements play a functional role in memory retrieval. *Psychological Science, 25*, 236-242.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago, IL: University of Chicago Press.

Loetscher, T., Bockisch, C. J., Nicholls, M. E., & Brugger, P. (2010). Eye position predicts what number you have in mind. *Current Biology, 20*(6), R264-R265.

Martarelli, C.S., Mast, F.W. & Hartmann, M. (2017) Time in the eye of the beholder: Gaze position reveals spatial-temporal associations during encoding and memory retrieval of future and past. *Memory & Cognition, 45*, 40–48.

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

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*, 401–450.

Papafragou, A., Hulbert, J., & Trueswell, J. (2008). Does language guide event perception? Evidence from eye movements. *Cognition, 108*(1), 155-184.

Santiago, J., Lupáñez, J., Pérez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin & Review*, 14, 512–516.

Spivey, M. J., & Geng, J. J. (2001). Oculomotor mechanisms activated by imagery and memory: Eye movements to absent objects. *Psychological Research, 65*, 235-241.

Stocker, K., Hartmann, M., Martarelli, C. S., & Mast, F. W. (2016). Eye movements reveal mental looking through time. *Cognitive Science, 40*,1648-1670.

Ulrich, R., & Maienborn, C. (2010). Left–right coding of past and future in language: The mental timeline during sentence processing. *Cognition, 117*(2), 126–138.

Zhang, Y., Kwak, H., Jeong, H., & Puzakova, M. (2019). Facing the “right” side? The effect of product facing direction. *Journal of Advertising*, *48*(2), 153-166.

Chapter 2. Which is in front of Chinese people, past or future? The effect of language and culture on temporal gestures and spatial conceptions of time

Abstract: The temporal-focus hypothesis claims that whether people conceptualize the past or the future as in front of them depends on their cultural attitudes toward time; such conceptualizations can be independent from the space–time metaphors expressed through language. In this paper, we study how Chinese people conceptualize time on the sagittal axis to find out the respective influences of language and culture on mental space–time mappings. An examination of Mandarin speakers' co-speech gestures shows that some Chinese spontaneously perform past-in-front/future-at-back (besides future-in-front/past-at-back) gestures, especially when gestures are accompanying past-in-front/future-at-back space–time metaphors (Exp. 1). Using a temporal performance task, the study confirms that Chinese can conceptualize the future as behind and the past as in front of them, and that such space–time mappings are affected by the different expressions of Mandarin space–time metaphors (Exp. 2). Additionally, a survey on cultural attitudes toward time shows that Chinese tend to focus slightly more on the future than on the past (Exp. 3). Within the Chinese sample, we did not find evidence for the effect of participants' cultural temporal attitudes on space–time mappings, but a cross-cultural comparison of space–time mappings between Chinese, Moroccans, and Spaniards provides strong support for the temporal-focus hypothesis. Furthermore, the results of Exp. 2 are replicated even after controlling for factors such as cultural temporal attitudes and age (Exp. 3), which implies that linguistic sagittal temporal metaphors can indeed influence Mandarin speakers' space–time mappings. The findings not only contribute to a better understanding of Chinese people's sagittal temporal orientation, but also have additional implications for theories on the mental space–time mappings and the relationship between language and thought.

Keywords: Temporal-focus hypothesis; Gesture and conceptual metaphor; Space and time; Language and thought; Cross-cultural differences; Chinese

Acknowledgments: The work is supported by NWO Promoties in de Geesteswetenschappen (322-89-007) and NWO Research Talent (406-15-298), which are gratefully acknowledged. Preliminary results of this study have been presented at CogSci2016, Philadelphia, USA, and the Perception Metaphor Workshop, MPI, Nijmegen (2016). We are grateful to Hong Wang who had helped to collect the data of Exp 3, and we thank Yufen Chi and Weidong Zheng who had helped us with conducting experiments. We thank Daniel Casasanto, Cristina Cacciari, Marieke Hoetjes, Rein Cozijn, and 10 anonymous reviewers for their constructive comments and useful suggestions on the earlier versions of this article.

The chapter is based on:

Gu, Y., **Zheng, Y**., & Swerts, M. (2019). Which is in front of Chinese people, past or future? The effect of language and culture on temporal gestures and spatial conceptions of time. *Cognitive Science, 43*(12), e12804.

1. Introduction

Across cultures people use space to represent time (Bottini et al., 2015; Casasanto & Boroditsky, 2008; see reviews Bender & Beller, 2014; Nunez & Cooperrider, 2013). The concepts of future and past are often linguistically expressed by the use of spatial metaphors. For instance, in English, we look forward to the bright future lying ahead, or look back to the hard times behind (e.g., Clark, 1973; Lakoff & Johnson, 1980). Interestingly, studies have shown that many people not only talk about time using a front-back axis, but also tend to think about time this way, that is, the past is mentally "behind," and the future "ahead" of the speaker (Boroditsky, 2000; Miles, Nind, & Macrae, 2010; Ulrich et al., 2012). This particular conceptualization seems to be consistent with the bodily experience of walking in a certain direction, so that the path that we have passed by is the past and the place that we are heading toward is the future (e.g., Clark, 1973).

Despite this general tendency in languages like English, speakers of other languages may exhibit opposite sagittal space–time mappings than the one explained above. For example, Aymara speakers can conceptualize the past as seen events in front of them, and the future as yet unseen events behind them, which is reflected in the observation that their words for past and future also mean front/seen and back/unseen (e.g., front year means last year). This past-in-front mapping is also apparent from Aymara's temporal gestures (Nunez & Sweetser, 2006).

Somewhat similar to Aymara is Mandarin Chinese, in which sagittal words for spatial "front" (前/qian)" and "back" (后/hou) are also used as temporal conceptions of "before/ past" and "after/future." Such sagittal spatial metaphors for time suggest past-in-front/future-at-back space–time mappings (Example 1, Table 1). However, how Mandarin speakers conceptualize or gesture about time using the front-back space is barely known (Yu, 2012). Based on the first attempt by Fuhrman et al. (2011), Xiao, Zhao, and Chen (2018)'s recent study aims to provide a comprehensive picture of the psychological reality of time by Mandarin speakers.

Xiao et al. (2018) (also Yu, 2012) propose that, like English, there are two kinds of time perspective-taking for Chinese people, related to a moving-ego and moving-time perspective (e.g., Clark, 1973; Gentner, Imai, & Boroditsky, 2002; Moore, 2011; Nunez, Motz, & Teuscher, 2006; Walker, Bergen, & Nunez, 2017). They argue that for the Man-darin temporal expressions such as "前天/qian-tian" ("front day," the day before yester-day) and "后天/hou-tian ("back day," the day after tomorrow), the reference point is not the observer but time (i.e., today) (earlier-times in-front-of later-times metaphor). By contrast, temporal expressions such as "过去/guo qu" (pass go, past) and "未/将来/wei/jiang lai" (hasn't come yet/will come, future, Example 2, Table 1) take the observer as a reference point, suggesting that future is ahead of and the past behind the ego (Yu, 2012) (front-to-the-future metaphor).

Table 1
Examples of Mandarin phrases suggesting past-in-front/future-at-back mappings (1) and future-in-front/past-at-back mappings (2).

Example (1)	后/qian	天/tian,	今/jın	后/hou
	back	day,	today	back
	the day after tomorrow,		from now on	
Example (2)	展/zhan	望/wang	未/wei	来/lai
	unfold	gaze-into-distance	hasn't	come
	Looking far ahead/into the future.			
	回/huı	首/shǒu	过/guo	去/qu
	turn-around	head	pass	go
	Looking back to the past.			

Xiao et al. (2018) used an illustrative example of a train to explain the sagittal temporal representation of Mandarin speakers based on linguistic analyses (Fig. 1). Time in this visualization would be analogous to a moving train with a number of carriages. The moving-time perspective (the train) refers to the relation among time points (carriages), whereby earlier time points (e.g., carriages 1 and 2) are in front of later time points (e.g., carriages 4 and 5, from the perspective of the train). The ego-moving time perspective refers to the relation between the ego (observer) and the time points, with a direction of the future (e.g., carriage 5) in front of the ego.

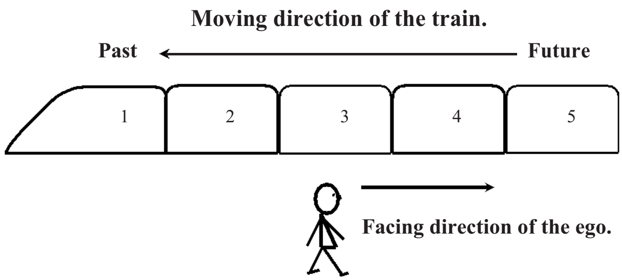


Fig. 1. According to Xiao, Zhao, and Chen (2018), time can be perceived as moving from the future to the past, where the ego faces the future (carriage 3 is now): From the time-reference-point perspective, earlier events (e.g., carriages 1 and 2) are in front of later events (e.g., carriages 4 and 5), thus the past is in the front of the timeline; from the ego-reference-point perspective (stationary or moving), earlier events are behind the ego, so the past is at the back of the ego.

Studies have shown that Mandarin space–time metaphors not only suggest different temporal perspectives, but may also have an impact on Mandarin speakers' front-back mental space–time mappings (Fuhrman et al., 2011; Gu, Zheng, & Swerts, 2019; Lai & Boroditsky, 2013). For instance, the Mandarin Chinese lexicon contains both words suggesting past-at-back/future-in-front and past-in-front/future-at-back space–time mappings, whereas the sagittal lexical signs of Chinese Sign Language (CSL) do not show this variation as they represent only past-at-back/future-in-front space–time mappings (Wu & Li, 2012; Zheng, 2009). Interestingly, deaf signers of CSL appear to display a different spatio-temporal reasoning than Mandarin speakers, and Chinese deaf signers with higher written Mandarin proficiency are more likely to have past-in-front/future-at-back space–time mappings than signers with lower Mandarin proficiency (Gu, Zheng, & Swerts, 2017).

Regardless of any effect of linguistic space–time metaphors on temporal perspectives, Xiao et al. (2018) believe that the ego of a Mandarin speaker always faces the future. However, there are also alternative views regarding the metaphorical sagittal orientation of time by Chinese people. For example, some believe that the ego faces the past (Alverson, 1994), whereas others believe that the ego can face both the past and the future (Ahrens & Huang, 2002). Given that an increasing number of studies have shown that humans' mental space–time mappings can be influenced by different factors (e.g., Casa-santo & Bottini, 2014; Duffy & Evans, 2017; Duffy, Feist, & McCarthy, 2014; Saj et al., 2014; Santiago et al., 2007; Torralbo, Santiago, & Lupanez, 2006), it is possible that Chinese people's mental orientation of sagittal time may not only be affected by linguistic space–time metaphors but may also be shaped by additional influences such as culture (e.g., Boroditsky & Gaby, 2010; Floyd, 2016; Fuhrman & Boroditsky, 2010; Le Guen & Balam, 2012; Nunez et al., 2012; Santiago, Roman, & Ouellet, 2011).

Indeed, de la Fuente, Santiago, Roman, Dumitrache, and Casasanto (2014) propose that people's sagittal mental space–time mappings are not necessarily the exclusive result of the sagittal space–time metaphors expressed in the language, as they can also be influenced more generally by the specific way cultures associate space with time. For instance, there are only future-in-front mappings but no deictic past-in-front mappings in Spanish language (as confirmed by two native Spanish speakers, one of whom is a linguist). Similarly, there are future-in-front mappings but "no such reversed spoken metaphors exist in Arabic" (e.g., Casasanto, 2016, p. 181, also see Hamdi, 2008's corpus-based study). Interestingly, despite the fact that front-back time lexical metaphors in Spanish and Arabic both only suggest future-in-front mappings, Moroccans have a strong tendency for past-in-front mapping, whereas most Spaniards have future-in-front mappings. The different space–time mappings between Moroccans and Spaniards have been argued to be related to cross-cultural differences in temporal focus (temporal-focus hypothesis). It is claimed that people who are past-focused metaphorically have a tendency to place the past in front of them, "in the location where they could focus on the past literally with their eyes if past events were physical objects that could be seen" (de la Fuente et al., 2014, p. 1684). Given that Moroccans focus more on past times and the old generation (past-oriented), and place more value on tradition than Spaniards (future-oriented), they are more likely to put the past in front than Spaniards.

According to the *temporal-focus hypothesis*, people conceptualize either the future or the past as in front of them to the extent that their culture (or subculture) is future oriented or past oriented. Thus, space–time mappings in people's minds are conditioned by their cultural attitudes toward time, which are dependent on attentional focus and can be independent of the way space–time mappings are lexically expressed in language (de la Fuente et al., 2014).

Inspired by the temporal-focus hypothesis, when seeking evidence for how Chinese cultural values toward time can influence Chinese people's sagittal space–time mappings, there are also surprisingly contradictory findings regarding the temporal focus of Chinese culture. Some studies have suggested that Chinese people show a tendency to be future-oriented (e.g., Brislin & Kim, 2003), but others argue that Chinese are primarily past-oriented (e.g., Ji, Guo, Zhang, & Messervey, 2009). Evidence for the latter would be that Chinese perceive objects in the past as being much more valuable than Americans do (Guo, Ji, Spina, & Zhang, 2012). Nevertheless, how exactly a Chinese cultural temporal-focus of attention influences their space-time mapping is still unclear. In short, studies on Mandarin speakers' mental sagittal space–time mappings seem to be inconclusive.

Given the fact that Mandarin speakers use lexically expressed sagittal space–time metaphors that may influence speakers' temporal orientation or perspective-taking (e.g., Gu et al., 2019; Lai & Boroditsky, 2013; Xiao et al., 2018), and given that cultural attitude toward time has been shown to be an important determiner of individuals' space–time mappings (which can be independent of linguistic space–time metaphor; see, for example, Moroccans, de la Fuente et al., 2014), the study of Mandarin creates an opportunity to test how language-based space–time mappings interact with more culturally motivated temporal-focus-based mappings. Such an attempt can not only provide a better understanding on Chinese people's metaphorical sagittal temporal orientation, but may also enrich our understanding of how language and culture can co-influence people's mental space–time mappings.

To achieve this general research aim, in the current study, we will study how Chinese people conceptualize time on the front-back axis, that is, whether they conceptualize the past as in front of or behind them. In particular, we will conduct a survey on Chinese cultural values toward time (temporal-focus of attention), and several experiments to investigate Chinese people's spontaneous temporal gestures and action performances in space–time mappings, while taking different Mandarin sagittal spatial metaphors for time into consideration.

First, in Experiment 1, we will look at spontaneous gestures, as these can be seen as a "vivid and naturalistic source of evidence for the use of space in abstract reasoning" (e.g., Casasanto & Jasmin, 2012; Cienki, 1998; Cooperrider, Gentner, & Goldin-Meadow, 2016; Cooperrider & Nunez, 2009; Nunez & Sweetser, 2006), and can provide a window into spatial cognition (Alibali, 2005; Goldin-Meadow, 2003; Gu, Mol, Hoetjes, & Swerts, 2017; Hostetter & Alibali, 2008; Kita, Danziger, &

Stolz, 2001; Walker & Cooperrider, 2016). A previous case study described how a Mandarin speaker employs the sagittal axis to gesture about time (Chui, 2011), but that was an observation from one participant only. The present study will do quantitative research on a larger, more representative sample of Chinese speakers' sagittal temporal gestures.

Second, to corroborate the patterns of space–time mappings observed from spontaneous gestures, we will adopt a temporal performance task in Experiment 2, which has been used in several previous studies to explicitly test people's mental space–time mappings (e.g., de la Fuente et al., 2014; Li & Cao, 2018a, 2018b). Particularly, we are interested in whether these mappings are affected by different space–time metaphors. Third, with a survey on Chinese people's temporal focus of attention, we will investigate the influence of language on spatial-temporal mappings while controlling for Chinese attitude toward time (Experiment 3).

Finally, we will perform a cross-cultural comparison of Chinese, Moroccans, and Spaniards regarding their cultural temporal-focus of attention (comparing data we collected ourselves with data obtained in previous studies), and we will explore whether variation in temporal-focus may influence corresponding space–time mappings.

2. Experiment 1: Do Chinese people spontaneously gesture the past to the front?

As spontaneous gestures have been argued to provide a window into people's mental space–time mappings (e.g., Casasanto & Jasmin, 2012), in Experiment 1, we used a word definition task that has previously been used by Gu, Mol, et al. (2017) and Gu et al. (2019) to elicit Chinese people's speech accompanying gestures about time. This task also enabled us to study the possible effect of temporal language on co-speech temporal gestures. The goal of this experiment is twofold: (a) we will investigate whether Mandarin speakers systematically produce sagittal gestures and examine the temporal orientation of the sagittal temporal gestures (e.g., whether the past is gestured to the front or back); and (b) we will try to further explore the relationship between the temporal orientation of sagittal gestures and the accompanying temporal language.

2.1. Method

2.1.1. Participants

A total of 34 monolingual Mandarin speakers (M_{age} = 33.79 years, SD = 7.58, 12 males) participated as speakers in an experiment conducted in Rizhao, China. Three participants were excluded in later analyses as they did not produce any gestures. Participants' education level was about middle to senior high school (self-reported, M = 2.55, SD = 0.96, 1-primary school; 2-middle school; 3-high school; 4-college; 5-university).

2.1.2. Materials and procedure

We constructed 12 wordlists, each containing two to four expressions that were thematically related (e.g. “yesterday,” “today,” and “tomorrow”). Five wordlists were about time conceptions, which in total consisted of 13 temporal expressions (see Appendix); the rest were fillers. The experiment was ostensibly set up as a test of speakers’ short-term memory and addressees’ long-term memory. As speakers, participants were asked to remember each wordlist shortly after they had seen them twice; they had to tell and explain the words (i.e., give definitions) as explicitly as possible to addressees who could ask them clarification questions (Fig. 2; for more details, see Gu, Mol, et al., 2017 and Gu et al., 2019). The addressees were told to “remember as many descriptions of the speaker as possible for a later memory test” (the latter test, in fact, did not take place). Gestures were not mentioned at any moment. The experiment was audio-video recorded after participants had explicitly given their informed consent. Debriefing responses indicated that participants had not been aware that the study was about speakers’ gestures.

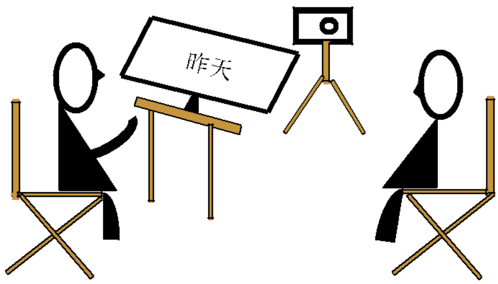


Fig. 2. Schematic illustration of the experimental set-up.

2.1.3. Coding of the data

Temporal gestures were annotated in ELAN (Lausberg & Sloetjes, 2009). A first coder performed an initial coding, viewing the entire video with the accompanying audio. The axes of gestures were coded as vertical, lateral, or sagittal, and the temporal orientation of each axis was indicated as well (Casasanto & Jasmin, 2012; Gu, Mol, et al., 2017; Gu et al., 2019). The time words accompanying temporal gestures were also transcribed.

The present study focused on sagittal temporal gestures; of course, people can also use the lateral and vertical axes to position time in space (e.g., Boroditsky, 2001; Fuhrman et al., 2011), also in Chinese, but these were not addressed here (see a more detailed discussion about Chinese people’s lateral and vertical temporal gestures in Gu et al., 2013; Gu, Mol, et al., 2017; Gu et al., 2019). Therefore, vertical or lateral gestures were all treated as “non-sagittal” in the later analyses of this study. Accordingly, the temporal expressions were coded as sagittal or non-sagittal. Sagittal words included temporal words explicitly having overt sagittal spatial references to “front” (前/qian) and “back” (后/hou) (e.g., “后年/hou-nian,” literally *back year*, the *year after next year*). All the other temporal words were coded as non-sagittal. Thus, we obtained binary scores for the axis of each temporal gesture (sagittal or non-sagittal), for the temporal orientation of each sagittal gesture (a future-in-front/past-at-back or past-in-front/future-at-back mapping), and for the lexically expressed references to time accompanying each temporal gesture (sagittal or non-sagittal words).

In total, we obtained 507 temporal word-gesture tokens that contained both a word and a gesture. The inter-coder reliability of the annotation was established by having a naïve second person code videos of 10 randomly chosen participants (37.7% of all temporal gesture data). The two coders agreed on the gesture axes judgement on 91.1% of the tokens (N = 191), *Cohen's Kappa* = 0.84 (referring to "Excellent" agreement). In cases of disagreement, the two coders discussed and reached agreement on the labels, which were then used for the final analysis.

2.2. Results and discussion

First, we found that Chinese people indeed spontaneously produced sagittal temporal gestures (N = 104), which accounted for 20.51% of all temporal gestures. Interestingly, as shown in Fig. 2.3, when participants were uttering sagittal temporal words, almost half of their co-speech temporal gestures (46.53%) were produced on the sagittal axis. However, the proportion of sagittal gestures decreased to 14.04% when participants were uttering non-sagittal temporal words.

The proportion of sagittal gestures was analyzed as a function of sagittal temporal words using a binary logistic regression for panel data, which considered multiple responses from the same participants and took individual differences, like age, education, and gender, into account. The results showed that participants were more likely to pro-duce sagittal temporal gestures when uttering sagittal temporal words than when uttering non-sagittal temporal words, $\chi^2(1) = 29.28$, N = 507, $p < .001$, $\beta = 1.96$, 95% CI = [1.25, 2.67], while controlling for age, education, and gender. This indicated that sagittal gestures are influenced by the accompanying temporal words.

Furthermore, when focusing on the temporal orientation of sagittal gestures, the results showed that apart from gesturing the past to the back and the future to the front (past-at-back/future-in-front gestures) (50.96%), Chinese people gestured the past to the front and the future to the back (past-in-front/future-at-back gestures) (49.04%). In comparison to previous studies with English speakers, the proportion of past-in-front/future-at-back gestures by Mandarin speakers is surprisingly high. English speakers instead predominately produce sagittal temporal gestures with past-at-back/future-in-front mappings (about 80%, Casasanto & Jasmin, 2012). Based on such gestural behaviors, and based on the claim that temporal gestures can reveal people's conceptualization of time (e.g., Casasanto & Jasmin, 2012; Cienki, 1998; Nunez & Sweetser, 2006), this finding suggests that Chinese sometimes can visualize time in space as the Aymara do (past-in-front/future-at-back).

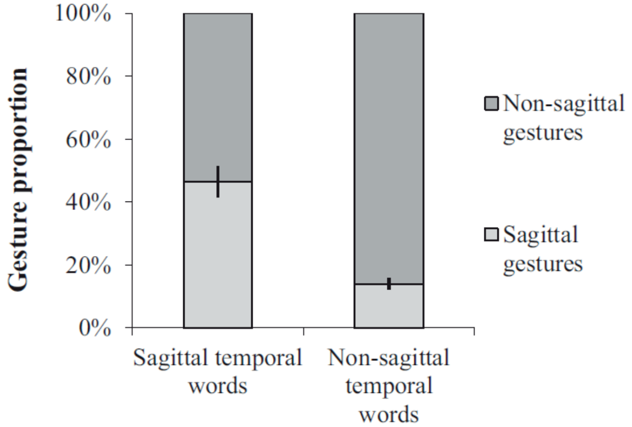


Fig. 3. The proportion of sagittal and non-sagittal temporal gestures (with SE error bars) when accompanying sagittal and non-sagittal temporal words.

Interestingly, the temporal orientation of sagittal temporal gestures appears to be associated with the accompanying temporal words. In our study, 72.34% of the sagittal gestures were past-in-front/future-at-back when participants were uttering overt sagittal temporal words, whereas the proportion dropped to only 29.82% when participants were speaking non-sagittal temporal words (Fig. 4).

This was born out by the analysis, because a regression (N = 104) of sagittal gesture orientation on sagittal temporal words showed that the temporal orientation of sagittal gestures was influenced by the accompanying temporal words. Specifically, at the sagittal axis, participants were more likely to perform past-in-front/future-at-back gestures when speaking sagittal temporal words than when speaking other temporal words, $\chi^2(1) = 6.64$, $p = .01$ (two-tailed), $\beta = 5.57$, 95% CI = [1.33, 9.80], while controlling for age, education, and gender.

This Chinese temporal gesture pattern was different from the pattern by English speakers from a previous study, in which there was no significant effect of the metaphorical spatial words on temporal gesture orientation (Casasanto & Jasmin, 2012). The result that Chinese people's past-in-front/future-at-back gestures were more often associated with sagittal temporal words may be due to the use of past-in-front/future-at-back space–time metaphors. Given that Mandarin sagittal words for spatial "front" (前/qian)" and "back" (后/hou) are also used as temporal conceptions of "before/past" and "after/future," the sagittal spatial metaphors for time can suggest past-in-front/future-at-back space–time mappings[1], and therefore can significantly influence the temporal orientation of sagittal temporal gestures.

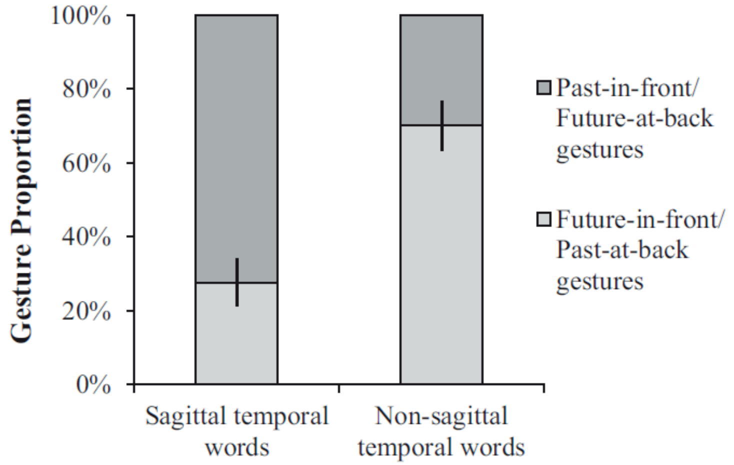


Fig. 4. The temporal orientation of sagittal temporal gestures (with SE error bars) and the corresponding accompanying temporal words.

However, as mentioned in the introduction (Example 2, Table 1), Mandarin does not exclusively use lexical cues to associate past with front, but also has the option to use words that suggest that the future is in front.

Additionally, some temporal expressions consist of words that do not contain spatial metaphors (neutral words, like "yesterday," "later"). If it is the case that there is an effect of sagittal temporal words on the temporal orientation of sagittal gestures (as shown above), then compared to when uttering past-in-front/future-at-back metaphors, Chinese people are expected to perform fewer past-in-front/future-at-back gestures when they are uttering future-in-front/past-at-back metaphors, or neutral temporal words.

To further confirm this assumption, we sorted sagittal gestures that co-occurred with temporal words of past-in-front/future-at-back, neutral words, and future-in-front/past-at-back metaphors (see Fig. 5) and ran a regression ($N = 97$) of sagittal gesture temporal orientation on sagittal temporal metaphors. (Note that we focused on the analysis of sagittal axis; the few cases of vertical temporal words (N = 7) were dropped rather than merged to any category because they were neither sagittal spatial metaphors for time nor neutral wordings. It is also inappropriate to create a new category that would cover a neglectable number of cases only.) As predicted, the proportion of past-in-front/future-at-back gestures uttered with past-in-front/future-at-back metaphors (72.34%) was significantly higher than when uttered with neutral words (31.25%, $\chi^2(1) = 5.59$, $\beta_{neutral} = 7.83$, $p = .018$, 95% CI = [14.32, 1.34]) and with future-in-front/past-at-back metaphors (22.22%, $\chi^2(1) = 8.20$, $\beta_{future\_front} = 12.64$, $p = .004$, 95% CI = [21.29, 3.99]), while controlling for age, gender, and education.

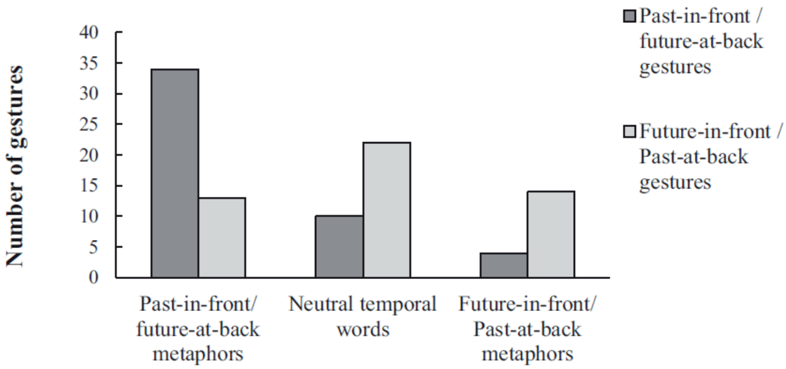


Fig. 5. The number of past-in-front/future-at-back gestures and future-in-front/past-at-back gestures in the past-in-front/future-at-back metaphors, neutral words, and future-in-front/past-at-back metaphors conditions.

In short, the results of this study showed that Chinese speakers can produce sagittal gestures not only directing the past to their back but also to their front. The extent to which they performed past-in-front/future-at-back gestures was influenced by the accompanying temporal words (i.e., past-in-front/future-at-back metaphors; neutral words; future-in-front/past-at-back metaphors). Nevertheless, in Experiment 1, due to the fact that co-speech gestures were spontaneously produced on the fly, the number of total gestures in each metaphor condition could be rather unbalanced (see Fig. 5). Therefore, in Experiment 2, we used a more controlled and explicit approach to corroborate this first set of findings.

3. Experiment 2: Do Chinese people place past events in front?

A temporal performance task, adapted from de la Fuente et al.'s (2014) temporal diagram task, was used to examine Chinese people's space–time mappings. This task has been shown to be an efficient and reliable paradigm to test people's sagittal mental space–time mappings in several cross-cultural studies (e.g., Casasanto, 2009; de la Fuente et al., 2014; Li & Cao, 2018a, 2018b), and it is more explicit than our gesture study in Experiment 1 about people's mental representations.

3.1. Method

3.1.1. Participants

A total of 114 Mandarin monolinguals (M_{age} = 23.64 years, *SD* = 7.98, 56 females) were assigned to three different (between-subject) temporal word conditions (cf. Experiment 1 had three within-subject conditions): 38 in neutral word condition, 37 in past-in-front metaphor/future-at back condition, and 39 in the future-in-front/past-at-back metaphor condition. Each participant was tested individually in Rizhao, China. The mean education level of participants was between senior high school to college (*M* = 3.58, *SD* = 0.83, 1-primary school; 2-middle school; 3-high school; 4-college; 5-university).

3.1.2. Materials and procedure

Participants sat at a table on which they viewed a toy doll (named Xiaoming) positioned between two boxes. The doll and boxes were positioned on a sagittal axis from the participants' perspective, whereby the participants and the character faced the same sagittal direction (Fig. 6). The instruction presented to the participants was the same across three conditions, except, as explained below, that the wordings of temporal expressions were manipulated with the use of (a) neutral words, (b) past-in-front/future-at-back metaphors, and (c) future-in-front/past-at-back metaphors. All materials were in Mandarin.

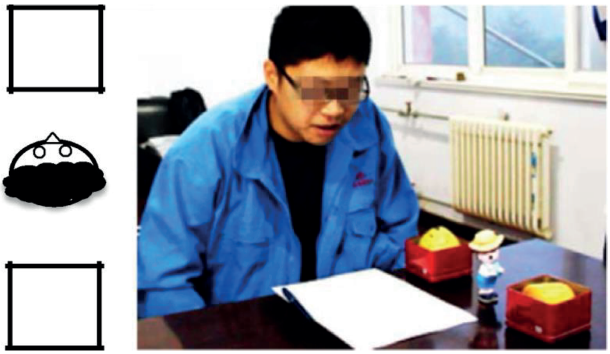


Fig. 6. Schematic illustration of de la Fuente et al. (2014)'s temporal diagram task (left); setup of Exp. 2 (right).

For the neutral word condition, participants read that *yesterday* (昨天, zuo-tian) Xiaoming went to visit a friend who liked eating apples, and *tomorrow* (明天, mıng-tian) he would be going to visit a friend who likes eating pears (or vice versa). Participants were given an apple and a pear and were instructed to put the *apple* in the box that corresponded to what happened at *an earlier time* and the *pear* in the box that corresponded to what would happen at *a later time*. The temporal expressions (e.g., yesterday, later) in the instructions consisted of neutral words that did not contain any lexical cues referring to space. The mentioning order of the apples and pears was counterbalanced (same for other conditions), as well as the way they were paired with temporal expressions *yesterday* and *tomorrow*.

For the past-in-front/future-at-back metaphor condition, however, the expressions about time in the instruction were changed from neutral words to explicit past-in-front/future-at-back spatial metaphors: *The day before yesterday* (前天/qian-tian, "front day") Xiaoming went to visit a friend who liked eating apples, and *the day after tomorrow* (后天/hou-tian, "back day") he would be going to visit a friend who likes eating pears. Participants were instructed to put the *apple* in the box that corresponded to the *past* (以前/yǐ-qian, *to front*, before) events and the *pear* in the box that corresponded to the *future* (今后/jın-hou, *now back*, from now on) events. Note that the new pair of temporal constructs (*the day before yesterday* and *the day after tomorrow*) had a similar period of time unit as the pair of *yesterday* and *tomorrow* in the neutral word condition, both being one or two days away from the *now* moment.

For the future-in-front/past-at-back metaphor condition, the instruction was the same as that in the neutral word condition except that the neutral wording of an earlier time and a later time in the instruction were replaced with future-in-front/past-at-back metaphors. Specifically, participants were instructed to put the *apple* in the box that corresponded to *past* (过去/guo-qu, *pass go*) events, and the *pear* in the box that corresponded to *future* (未来/wei-lai, *will/not yet come*) events.

We made two adjustments to de la Fuente et al.'s (2014) paradigm. First, de la Fuente et al. (2014) used the entities of "plant" and "animal" to represent the conceptions of "past" and "future," whereas we used "apple" and "pear" to reduce the possible temporal thinking of an evolutionary sequence (plants came earlier than animals). Second, as Chinese people can conceptualize time vertically with "up" as "early" and "down" as "late" (e.g., Boroditsky, 2001; Gu, Mol, et al., 2017; Gu et al., 2019), we had participants do the task with real entities rather than letting them write them down on paper, in this way minimizing the potential projection of vertical timelines into the sagittal dimension. After this temporal performance task, we had also a brief interview asking participants why they had such placements. These interview results are addressed in the general discussion.

3.2. Results and discussion

In the neutral word condition, 36.8% of participants placed the fruits representing the past in front of the character and the future behind it. Even though they were still a minority, the result suggests that some Chinese indeed conceptualize the past as in front of them.

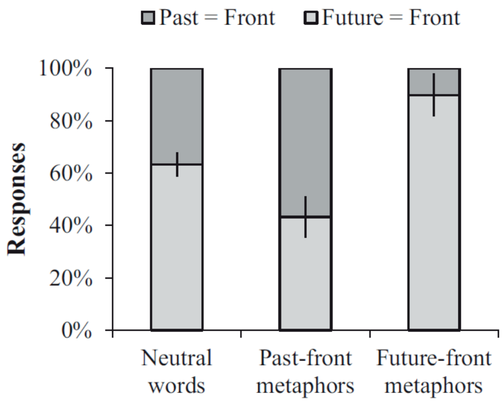


Fig. 7. Percentage of past-in-front and future-in-front responses with SE error bars: Chinese neutral word condition, past-in-front/future-at-back metaphor condition (PFMC), and future-in-front/past-at-back metaphor condition (FFMC).

Interestingly, the participants' responses toward space–time mappings were sensitive to the different lexical conditions (Fig. 7). Specifically, in the past-in-front/future-at-back metaphor condition (PFMC), the proportion of past-in-front responses was 20% higher than that of in the neutral word condition (56.8% vs. 36.8%, $\chi^2(1) = 2.84$, $N = 75$, $p = .0917$ (two tailed; but we had a directional hypothesis, so $p = .046$, one-tailed), $OR = 4.0$, 95% CI = [.80, 20.04]), while controlling for age[2] ($p = .39$) in a binary logistic regression. By contrast, in the future-in-front/past-at-back metaphor condition (FFMC), only 10.3% of participants performed past-in-front/future-at-back mappings, which was significantly lower than that of the 36.8% in the neutral condition ($\chi^2(1) = 6.80$, $p = .009$, $OR = 5.12$, 95% CI = [1.50, 17.45]), and the 56.8% in the PFMC ($\chi^2(1) = 10.76$, $p = .001$, $OR = 20.30$, 95% CI = [3.36, 112.46]), controlling for age ($p = .39$) in the regression ($N = 114$).

Furthermore, we recoded the temporal words of the three conditions according to the extent to which they hinted to past-in-front/future-at-back mappings (= 1 if FFMC; = 2 if neutral wording; = 3 if PFMC) and ran a regression ($N = 114$) of space–time mappings on temporal words. The results showed that temporal wording was a significant factor in predicting the probabilities that participants would perform past-in-front/future-at-back mappings ($\chi^2(1) = 12.20$, $p = .0005$, $OR = 4.64$, 95% CI = [1.96, 10.96]), controlling for age ($p = .226$). It indicated that the more temporal expressions conveyed past-in-front/future-at-back mappings, the more likely Chinese would conceptualize the past in front/future at back. This again demonstrated an effect of spatial metaphors on people's mental representation of time within the Chinese culture. The results are consistent with the findings of Experiment 1 on Mandarin speakers' spontaneous time gestures.

4. Experiment 3: Language vs. cultural attitudes toward time

In Experiment 2, we found that linguistic space–time metaphors have a direct influence on people's mental representation of time. However, as we have reviewed in the introduction, previous research claims that space–time mappings in people's minds are also conditioned by their cultural attitudes toward time, which are dependent on attentional focus (de la Fuente et al., 2014). In Experiment 3, we investigated the roles of cultural temporal-focus of attention and of the linguistic metaphors in shaping Chinese people's space–time mappings in a survey on Chinese people's temporal performances (a replication study of Experiment 2) and cultural attitudes toward time (temporal-focus of attention).

4.1. Method

4.1.1. Participants

Another 206 Mandarin speakers (M_{age} = 29.99, *SD* = 7.28; 61 males, 130 females and 15 gender unknown) were assigned to fulfil a 3D temporal diagram task (adapted from Experiment 2) combined with a survey of their cultural attitudes toward time (temporal-focus of attention), with all instructions and questions written in Mandarin Chinese. Participants' education level was about university bachelor's degree (*M* = 3.11, *SD* = 0.56; 1 = Junior; 2 = High School; 3 = Bachelor; 4 = Master).

We could not ensure that participants in this experiment were monolinguals as they were recruited via social networking and their personal backgrounds were less known than participants in other experiments. Therefore, we also collected participants' English proficiency levels (*M* = 2.97, *SD* = 0.87, 5-point-self-assessment), in order to be able to check whether Mandarin speakers' L2 English proficiency may influence their conceptualization of time (e.g., Lai & Boroditsky, 2013).

4.1.2. Materials and procedure

First, we conducted a replication study of Experiment 2. Participants saw a 3D animated clip of a character named Xiaoming with one box behind and one box in front of him (Supplement I). Participants were randomly assigned to one of the three instruction conditions (neutral, past-in-front, and future-in-front metaphor conditions, cf. Experiment 2) and were requested to put the *apple* and *pear* in the corresponding boxes. On the next webpage, there was a test question asking participants to recall the axis (sagittal; vertical; lateral) on which the boxes were positioned with respect to the character in the clip. Those who did not indicate a sagittal axis (24 participants) were excluded from the analysis related to space–time mappings.

Next, participants were asked to fill in a temporal-focus questionnaire to survey their cultural values toward time. Although there are alternative measurements of cultural temporal-focus of attention (see discussions in Stolarski, Fieulaine, & van Beek, 2015; Szpunar, Spreng, & Schacter, 2014), we used the same questionnaire as de la Fuente et al.'s (2014) Experiment 4 to facilitate making direct comparisons between our results and their results with Spanish and Moroccan participants. The questionnaire was translated to Chinese and was double-checked by a backward translation (Supplement II). It consisted of 21 statements denoting opinions about the past and the future (e.g., past-focused: Traditions and old customs are very important for me; future-focused: Social and cultural changes will make people happier). Participants indicated the extent to which they agreed with the statements on a 5-point Likert scale. Those participants who did not complete the questionnaire (10) or did not provide their age (5) were excluded from the analyses that required these data. The data were collected via the survey program Qualtrics.

4.2. Results and discussion

First, the results of the 3D temporal diagram task showed that the proportions of past-in-front/future-at-back responses in the past-in-front (PFMC), neutral, and future-in-front metaphor (FFMC) conditions displayed a descending order (52.1%, 39.7%, and 24.6%), so in that sense replicated the results from Experiment 2 (see the three bars for Chinese in Fig. 9).

Second, according to the results from the temporal-focus questionnaire, the Chinese participants tended to focus more on the future than on the past. On average, the past-focused statements (M = 2.92, SD = 0.42) were rated significantly lower than the future-focused statements (M = 3.16, SD = 0.34), $t(195) = 5.72$, $p < .001$, Cohen's d = 0.63, 95% CI = [0.32, 0.16]. Following de la Fuente et al.'s (2014) proposal, for each participant, we calculated a Temporal-focus Index [TFI = (mean of future-focused items mean of past-focused items)/(mean of future-focused items + mean of past-focused items)], which yielded a modest future-orientation TFI (M = 0.04, SD = 0.10) that was significantly different from 0 (p = .0001, Cohen's d = 0.4. The TFI has a scale from 1, strong past focus, to +1, strong future focus). Additionally, there were no significant differences between the TFI across three wording conditions, which also indicated that TFI was not influenced by the wording conditions.

We linked the participants' TFI to their responses toward space–time mappings (3D temporal diagram task) across three word conditions. A logistic regression (N = 167) of space–time mappings (dependent variable) on word conditions, keeping the TFI constant, showed that, compared to the participants in the future-in-front metaphor condition (FFMC), participants in the past-in-front metaphor condition (PFMC) ($\chi^2(1) = 8.30$, p = .004, OR = 3.55, 95% CI = [1.50, 8.39]), and participants in the neutral condition ($\chi^2(1) = 4.30$, p = .038, OR = 2.43, 95% CI = [1.05, 5.63]) responded significantly more with past-in-front/future-at-back mappings in the 3D temporal diagram task, while controlling for age, gender, education, English proficiency, and the instruction sequence (the order of mentioning "yesterday" first and then "tomorrow" or vice versa). However, the analysis of the influence of TFI on participants' performances in the 3D diagram task turned out not to be significant,[3] $\chi^2(1) = 0.47$, $p = .49$, $OR = 0.29$, 95% CI = [0.009, 9.67], keeping other control variables constant. Furthermore, no interaction between wording conditions and TFI was found.

The results replicated the findings in Experiment 2, showing that spatial metaphors of time have influences on Chinese people's space–time mappings, even after controlling for their cultural attitude toward time (temporal-focus of attention). Moreover, we did not find within-cultural evidence to support the claim that temporal-focus of attention influences Chinese participant's space-time mappings.

The results showed that the Chinese participants had a slightly stronger future than past orientation. Interestingly, previous studies have shown that Chinese are still more past-oriented than Canadians or Americans (e.g., Guo et al., 2012; Ji et al., 2009). If Chinese are indeed more past-focused than Westerners, and if the cross-cultural differences in temporal focus predict different space–time mappings (*temporal-focus hypothesis*, de la Fuente et al., 2014), we would expect that, at the cross-cultural level, Chinese people are more likely to have past-in-front/future-at-back mappings than Westerners, in line with the previous findings of Moroccans. In a post hoc analysis, we compare Chinese data with the data of Moroccans and Spaniards obtained in de la Fuente et al.'s (2014) study to further scrutinize the effects of the cultural attitudes toward time on space–time mappings in a cross-cultural context.

5. A post hoc analysis: A cross-cultural comparison

5.1. Method

5.1.1. Participants

For this analysis, we used data from 93 Moroccans (M_{age} = 28.57 years, SD = 5.72), 55 Spaniards[4] (M_{age} = 20.18 years, SD = 2.66) (de la Fuente et al., 2014), and the 206 Chinese participants in Experiment 3. All participants had some university education.

5.1.2. Procedure

All participants had followed a similar procedure to complete the temporal diagram task and the survey of cultural attitudes toward time (temporal-focus of attention questionnaire) as described in Experiments 2 and 3.

5.1.3. Comparisons and analysis

First, we used a linear regression to compare the cross-cultural differences in temporal-focus of attention between countries. Second, we used a logistic regression to study the cross-cultural differences in temporal diagram placements. And third, we added TFI (Temporal-focus Index) to the regression model to examine how cultural temporal-focus contributes to the differences in space–time mappings.

Given that data obtained from Moroccan and Spanish groups were conducted in a neutral wording condition which could be mainly explained by their cultural temporal focus, whereas our Chinese data had three wording conditions which may introduce an extra factor of linguistic influences on space–time mappings, we limited the second and third comparisons with Chinese data only from the neutral wording condition so that participants from all cultures had the same wording condition.

5.2. Results and discussion

First, according to the results of the temporal-focus questionnaire, we found that there were indeed cross-cultural differences in attitudes toward time (see Fig. 8). Using a regression (N = 339) of TFI on country, controlling for age, we found that, in comparisons to Chinese (M = 0.04, SD = 0.10), Moroccans (M = 0.17, SD = 0.22) had a significantly lower TFI ($F(1, 335) = 142.77$, $p < .001$, β = 0.22), and Spaniards (M = 0.17, SD = 0.13) had a significantly higher TFI ($F(1, 335) = 8.68$, $p = .003$, β = 0.07). Interestingly, the factor age, even when limiting to these younger students, was still significantly negative ($F(1, 335) = 17.62$, $p < .001$, β = 0.005), which was consistent with past research (Bylund et al., 2019; de la Fuente et al., 2014) that older participants were less future-oriented than younger participants. In short, the results suggest that Chinese are more past-focused than Spaniards but less past-focused than Moroccans in their cultural attitude toward time.

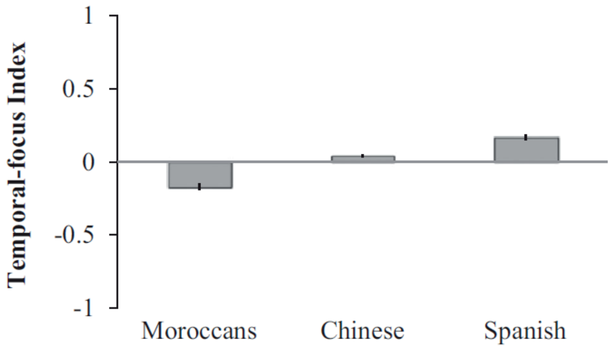


Fig. 8. Cross-cultural differences in normalized temporal-focus of attention (TFI) with SE error bars. The TFI has a scale from 1 (strong past focus) to +1 (strong future focus).

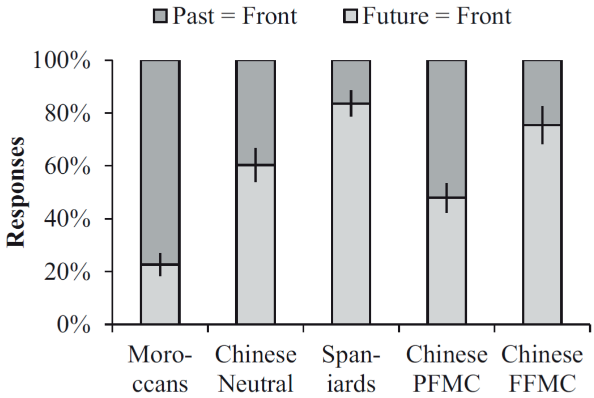


Fig. 9. Percentage of past-in-front and future-in-front responses with SE error bars: Separately for Moroccans, Spaniards (de la Fuente et al., 2014, Exp 4), Chinese neutral word condition, past-in-front metaphor condition (PFMC), and future-in-front metaphor condition (FFMC).

Second, as for the performances in the temporal diagram task across three country groups (neutral wording condition, see the three leftmost bars in Fig. 9), a logistic regression of space–time mappings on country group showed that there were also cross-cultural differences in responses toward space–time mappings ($\chi^2(2) = 59.28$, $p < .001$, $N = 206$). Specifically, in comparison to the Chinese in the neutral group (39.7%), Moroccans (77.4%) were more likely to place the past in front, $\chi^2(1) = 20.43$, $p < .001$, $OR = 5.22$, 95% CI = [2.55, 10.68], whereas Spaniards were less likely to do so (16.4%), $\chi^2(1) = 7.16$, $p = .0074$, $OR = 0.30$, 95% CI = [.12, .72].

Furthermore, we added TFI to the regression model to study how cultural temporal-focus contributes to the differences in space–time mappings. If temporal focus plays a role at the cross-cultural level, the TFI is expected to be significant. If the country differences in space–time mappings are mostly captured by the cultural temporal focus, the country dummies may not be significant any more after controlling for TFI. Indeed, the TFI was highly significant ($\chi^2(1) = 45.88$, $p < .0001$, $OR = 0.000002$, 95% CI = [4.73e08, 0.00009]). However, the country group differences were not significant any more after controlling for the TFI.[5] Specifically, Chinese in the neutral group no longer performed significantly different from Moroccans ($\chi^2(1) = 0.10$, $p = .75$, $OR = 1.23$, 95% CI = [0.34, 4.53]) or Spaniards ($\chi^2(1) = 0.04$, $p = .85$, $OR = 0.90$, 95% CI = [0.29, 2.78]). The significant TFI and these insignificant group differences indicated that the cross-cultural differences in space–time mappings were mostly affected by the cultural-specific temporal focus.

6. General discussion

In this study, we aimed to find out how linguistic expressions and cultural values toward time influence Mandarin speakers' sagittal space–time mappings by leveraging interesting properties of sagittal space–time metaphors in Mandarin Chinese. We first studied spontaneous co-speech gestures to investigate Chinese people's implicit sagittal space–time mappings. It was found that, in addition to future-in-front/past-at-back gestures, some Chinese people produced gestures to associate the past to the front and the future to the back of them, especially in cases where they also used spatial words that suggest the past in front and the future at back (Experiment 1).

Then we used a temporal performance task (Experiment 2) to more explicitly test Chinese people's mental space–time mappings. The results confirmed that some Chinese people conceptualize the past in front and the future as behind them, and such mappings are affected by the different words of Mandarin space–time metaphors, in that sense being consistent with the results of patterns in spontaneous gestures in Experiment 1.

Furthermore, we conducted a survey on Chinese people's cultural attitudes toward time (temporal-focus of attention) together with a 3D temporal diagram task to investigate the respective roles of the linguistic metaphors and of the Chinese cultural temporal-focus of attention in shaping Chinese people's space–time mappings. The survey showed that our Chinese participants tended to focus a little bit more on the future than on the past. In addition, we replicated the findings of Experiment 2 that some Chinese people conceptualize the past in front and the future as behind them, and the extent to which they have such mappings is affected by the different words of Mandarin space–time metaphors, even though factors such as temporal-focus of attention and age have been controlled for (Experiment 3). However, within the Chinese participants, we did not find evidence that the individual TFI has an influence on the sagittal space–time mappings.

Finally, with a cross-cultural comparison in space–time mappings between Chinese, Moroccans, and Spaniards, we found that Chinese more often had past-in-front/future-at-back mappings than Spaniards and less often than Moroccans, a result which is strongly in line with predictions based on the cultural temporal-focus of attention. In sum, we found that Chinese people's space–time mappings appeared to be the combined effect of lexical cues to space–time mappings and a culture-specific temporal attitude toward time. The findings have several important theoretical implications to be discussed below.

6.1. Implications for sagittal metaphorical temporal orientation in Chinese people

Our study reveals how Chinese people conceptualize time on the front-back axis. While some Chinese conceptualize the future as being ahead of them and the past behind them, others show the opposite pattern, and view the past as something ahead of them. More specifically, Chinese people reveal gestures and actions that reflect past-in-front/future-at-back mappings. Such mappings are peculiar, as pointing gestures referring the past to the front and the future to the back have so far only been reported in Aymara (Nunez & Sweetser, 2006).

One may argue that the Chinese past-in-front/future-at-back mappings are merely due to the lexical effect of Mandarin front/back sagittal words. That is, the explicit spatial language could simply be priming participants to make spatial responses in a way that matches the spatial expression, and thus without any space-time mapping conceptions being involved.

However, this is unlikely for the following reasons: First, the conceptions of "前天/ qian-tian" ("front day," the day before yesterday) and "后天/hou-tian" ("back day," the day after tomorrow) are unambiguous in Mandarin Chinese, as they can only be interpreted as time concepts. Second, from a previous study, we know that spatial priming may not activate congruent temporal gestures. For example, "prompting [English] participants with deictic space–time metaphors did not guarantee that they would spatialize time sagittally in their gestures—not even when the prompts strongly implied a particular direction on the sagittal axis" (Casasanto & Jasmin, 2012, p. 652). There is also evidence showing that this kind of priming does not work for Chinese people. Gu et al. (2019) found that Mandarin speakers who have knowledge of Chinese Sign language will predominately produce *past-at-back/future-in-front* spontaneous gestures even when they are verbally speaking overt *past-in-front/future-at-back* space–time metaphors in their native language Mandarin Chinese. Third, even when reading an instruction in which temporal expressions consisted of *future-in-front/past-at-back* metaphors, still about one-fifth (weighted average 19%, Experiment 2 [10.3%] and Experiment 3 [24.6%] combined) of the Chinese participants positioned the *past in front*.[6] Furthermore, according to post hoc interviews with 37 participants[7] who performed *past-in-front/future-at-back* mappings across three conditions in Experiment 2, the majority of them (29/37) explained that they had such placements because they indeed believed that the past should be in front, four of whom, similar to Aymara, argued that it was because that past is known and seen and the future yet unknown and unseen (cf. Nunez & Sweetser, 2006). The other eight participants considered that earlier events in time are in front of later events.

Thus, the results of this study contribute to the theory on Chinese people's mental orientation of time on the sagittal axis. According to Xiao et al.'s (2018) proposal, time in Chinese minds can be perceived as moving from the future to the past, where the ego faces the future (see Fig. 1). Both "early" events and "future" events are in "front," depending on whether the perspective is taken from a time-reference-point or an ego-reference-point. From the time-reference-point perspective, earlier events are in front of later events, and thus the past is in the front of the timeline; from the ego-reference-point perspective (stationary or moving), earlier events are behind the ego, and as such the past is at the back of the ego. Therefore, "early" is in front of "late" but is still *behind* the ego.

However, some of the empirical results in the present study may not fit into the temporal reference frames proposed by Xiao et al. (2018). For instance, some Mandarin speakers gestured the past events in front of the ego and future events behind the ego (Experiment 1), and also as mentioned above, in the post hoc interviews of Experiment 2, some explicitly explained that they felt the past to be in front of them, and the future behind them. All these results may suggest that the ego of some

Chinese people can be facing the past (Ahrens & Huang, 2002; Alverson, 1994). Therefore, the sagittal timeline can not only run from the front to back (Fig. 1), but also from back to front (Fig. 10). If time is analogous to a moving train with a number of carriages, it is possible that a Chinese observer is standing still and facing the past, and the moving train is passing from the back to the front of the observer. Taking the moment when the train passes the observer as the time reference point of "now," the carriages that have passed the observer (e.g., carriages 1 and 2) become the past, and the carriages that have not passed the person (e.g., carriages 4 and 5) are future events. There is also some linguistic evidence in Mandarin Chinese for this conjecture, such as in (1) and (2).

(1) 直视自己的过去(zhı-shı zı-jǐ de guo-qu)
straight forward look my past go
gaze forward toward my past

(2) 准备自己的后事(zhun-bei zı-jǐ de hou-shı)
prepare for own back event
prepare for one's own future funeral

In the above proposal, the ego is static while time is moving (Fig. 10). It shows that early/past events can be in front of an observer even when an ego is involved in the time sequence. However, despite the fact that some Mandarin speakers believe that "early" is *in front of* the ego, and "late" is *at back of* the ego, at the same time they may still conceptualize the "future" as *ahead* and the "past" as *behind* themselves. This seemingly contradictory observation regarding mental timelines cannot fully be explained by the assumptions shown in Fig. 1 or Fig. 10.

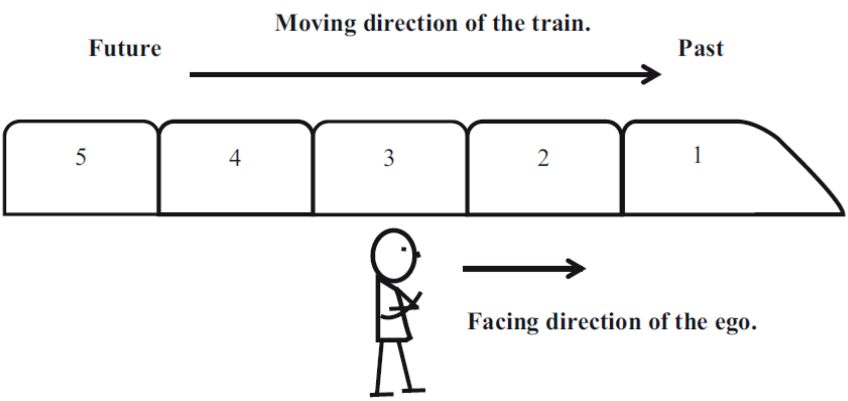


Fig. 10. Time moves from the future to the past, but the ego stands stationary and faces the past (carriage 3 is now): From the time-reference-point perspective, earlier events (e.g., carriages 1 and 2) are in front of later events (e.g., carriages 4 and 5), and thus the past is in the front of the timeline; however, different from Fig. 1, from the ego-reference-point perspective, earlier events are *in front of* the ego as well, and the past is *in front of* the ego.

For those Chinese people who have a mixed mental timeline, it is likely that there is both an internal human sequence timeline and an external ego-moving timeline (Ng et al., 2017; Xiao et al., 2018; Yu, 1998, 2012). Yu (1998, 2012) first proposes that the spatial conceptualization of temporal order of humans is similar to a human's queueing experience. In other words, it is consistent with the human's psychological reality of sequential time (Gauthier & van Wassenhove, 2016; Gentner et al., 2002; Moore, 2011). For instance, in a queue, people who are in or near the first position will be served earlier than those who are behind them (Nunez et al., 2006; Walker, Bergen, & Nunez, 2014, 2017). Specifically, suppose I am lining up in a queue (e.g., C), then within the line, the earlier people (e.g., A and B) are in front of me, and later people (e.g., D and E) are behind me (Fig. 11). However, for myself, as well as for all other people in the queue, the "future" is in front of me, as the path leading to the destination ahead, whereas the "past" is behind me, as the path I have taken to arrive at my current position ("now"). As such, both "earlier" and "future" can be in front of the ego, and both "late" and "past" can be behind the ego. Thus, the present study provides the first experimental evidence for this proposal that combines perspectives.

6.2. Implications for theoretical accounts of space–time mappings

This study extends our knowledge on cross-cultural differences in space–time mappings. The results that Chinese more often have past-in-front/future-at-back mappings than Spaniards and less often than Moroccans can largely be explained by the differences in culture-specific temporal-focus of attention (TFI). This provides strong evidence supporting the *temporal-focus hypothesis*, which proposes that space–time mappings in people's minds are conditioned by their cultural attitudes toward time (attentional focus) (de la Fuente et al., 2014).

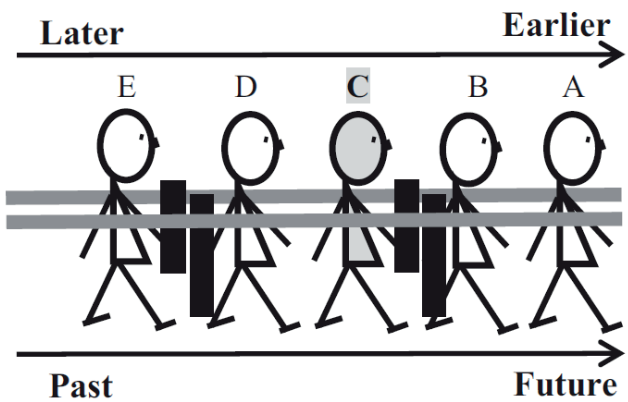


Fig. 11. In Yu's (1998, 2012) proposal, the ego faces the future: From the ego-reference-point perspective, earlier people (. . . A, B) are *in front of* the ego (C), later people (D, E . . .) are *behind* the ego. However, the destination/future is also *in front of* the ego, and the past is *behind* the ego.

Furthermore, de la Fuente et al. (2014) show that whether people conceptualize the past as behind and the future as ahead of them can vary independently from the way time is linguistically expressed in terms of spatial metaphors. By contrast, we show that, within the Chinese culture, the propensity of past-in-front/future-at-back mappings is sensitive to the linguistic variety of Mandarin space–time metaphors. For example, past-in-front/future-at-back sagittal temporal language (e.g., 前天/qian-tian, “front day,” the day before yesterday) will increase the probability of past-in-front/future-at-back space–time mappings while controlling for temporal-focus. Therefore, our study shows that, irrespective of cultural temporal-focus, sagittal space–time metaphors in language can indeed influence whether Chinese people map the past to the front or back.

Moreover, within the Chinese sample we did not find evidence supporting the *temporal-focus hypothesis* (de la Fuente et al, 2014). Another recent study, Bylund et al. (2019), even failed to find evidence at a cross-cultural level. Specifically, Afrikaners are found to be significantly more past-focused than English speakers but the two groups do not differ in their front-back mappings. Thus, it appears that the significant relationship between temporal-focus and sagittal space–time mappings may not be found in some cases. There may exist other factors, which may influence the effect of TFI on space– time mappings. Indeed, some recent studies have shown that individuals’ temporal focus and the corresponding space–time mappings are also affected by such factors, as whether one is pregnant, whether one’s religious belief is Buddhism or Taoism, and whether the temporal diagram task is conducted at the beginning of a new year or on the Tomb Sweeping Day, etc. (Li & Cao, 2018a, 2018b, 2018c).

Put together, the space–time mappings seem to be influenced by an increasing number of complex factors such as culture, language, bodily experience, religion, and individual attention to time; the weight of each factor and the interplay between different ones open up future research.

6.3. Implications for theories on the relation between language and thought

The findings of this study provide some new insights into the relation between language and thought, especially regarding the influence of linguistic context on thinking (e.g., Bylund, & Athanasopoulos, 2017; Lai & Boroditsky, 2013; Slobin, 1996). Results from our study of spontaneous gestures and of the temporal performance task show that there is a direct effect of linguistic metaphors on people’s reasoning about time. For example, past-in-front/future-at-back temporal language is more likely to activate past-in-front/future-at-back gestures/mappings. Such linguistic effect can be persistently significant even after controlling for factors of culture-specific temporal-focus of attention, age, education, and English proficiency (Experiment 3).

However, we need to note an important caveat that what is true about the influence of sagittal language in Mandarin on people’s space–time mappings may not generalize to other languages. Many other language groups may not have the linguistic variety of space–time metaphors that

Mandarin speakers have access to, and speakers of other language may not spatialize time consistent with linguistic metaphors the way Mandarin speakers do. For instance, in English sagittal space–time metaphors suggest that the future is ahead of the speaker and the past is behind, but English speakers often laterally gesture the past to the left and the future to the right even when speaking the overt sagittal temporal language,[8] and do not make any systematic use of the sagittal axis at all[9] (e.g., Casasanto & Jasmin, 2012; Walker & Cooperrider, 2016; Yap & Casasanto, 2018). Their mappings can mainly be explained by the left-to-right writing direction (Casasanto & Jasmin, 2012), but hardly explained by the sagittal future-in-front/past-at-back language in English.

Additionally, one may wonder why English speakers are also hardly influenced by the linguistic past-in-front/future-at-back mappings, given that in English the temporal "be-fore" and "after" can also be used as spatial "front" and "back." However, English "be-fore" and "after" are commonly used as temporal expressions, whereas "purely spatial uses of 'before' and 'after' are rare" (Casasanto, 2016, p. 70). In fact, to express the spatial concepts of *front* and *back* in English, it is more prevalent to use "front/back" or "ahead/behind" than to use "before" and "after."

By contrast, in Mandarin, "前/qian" and "后/hou" are often used to express temporal concepts of "before/past" and "after/future," while at the same time they are also the only words for the purely spatial use of "front" and "back." Given that in Mandarin, most words expressing temporal past and future consist of past-in-front/future-at-back metaphors (Chen, 2007; Peng, 2012), given the frequent spatial use of "前/qian" and "后/hou" (unlike the rarely spatial use of "before" and "after" in English), and given that people use space to conceptualize time, Mandarin speakers may well be more likely to establish the front-back space–time mappings than English speakers.

A further question is whether the past-in-front/future-at-back mappings in Mandarin have an effect of habitual thinking on speakers' conceptualization of time. According to Slobin's (1987) "thinking-for-speaking" hypothesis, habitual speech patterns may influence thinking online, during linguistic processing. When speakers use certain speech patterns repeatedly, they may form habitual language-specific conceptual schemas.

Given that in Mandarin most words expressing temporal past and future consist of past-in-front/future-at-back metaphors (Chen, 2007; Peng, 2012; Experiment 1), if habitual use of certain space–time metaphors can indeed influence one's time conceptions (Boroditsky, 2001; Hendricks, Bergen, & Marghetis, 2018; Hendricks & Boroditsky, 2017; Li, Casaponsa, Wu, & Thierry, 2019), one possibility is that, under the influence of past-in-front/future-at-back metaphors, some Mandarin speakers may form past-in-front/future-at-back space–time mappings in the long run. Especially, we did not find evidence for the effect of individual TFI (temporal focus index) on the temporal diagram placements within the Chinese participants in the neutral-wording condition. It appears like the proportion of past-in-front placements in this condition is due to the possible habitual thinking from Mandarin past-in-front space–time metaphors. If there is such a habitual thinking which is irrespective of TFI, given that Spanish and Arabic do not suggest any deictic past-in-front mappings, we expect that the Chinese group in the neutral wording condition may still be significantly different from Spanish and Moroccan groups after controlling for the TFI.

However, the cross-cultural post hoc analysis showed that the pattern of Chinese space–time mappings in the neutral wording condition can mainly be explained by the TFI. Notably, the country group differences were no longer significant after controlling for TFI, which did not indicate any significant additional influence such as the habitual past-in-front mappings from Mandarin language. Nevertheless, the non-significance does not necessarily mean that there is no influence from the general saliency of Mandarin past-in-front metaphors. Thus, in the neutral wording conditions, it remains unclear whether (or the extent to which) these mappings are also influenced from the habitual thinking via the saliency of past-in-front space–time metaphors.

7. Conclusion

In this study, we investigated how Mandarin linguistic space–time metaphors and cultural attitudes toward time can influence Chinese people's use of the sagittal space to conceptualize time. We studied Chinese people's spontaneous temporal gestures and action performances in space–time mappings, as well as surveyed their cultural temporal values. The results of cross-cultural (not within cultural) differences in spatial mappings of time provide strong evidence for the *temporal focus hypothesis* (de la Fuente et al., 2014), given that the extent to which people conceptualize the past as behind and the future as ahead of them depends on their cultural attitudes toward time. Moreover, the results of within-cultural differences show that linguistic expressions that refer to sagittal temporal metaphors can indeed influence Mandarin speakers' space–time mappings regardless of factors such as individual temporal focus and age. Thus, in Chinese, there are both long-term effects of cultural temporal-focus of attention (at least at the cross-cultural level) and immediate effects of the space–time metaphors used to probe people's mental representations. Such findings provide a better understanding of Chinese people's mental sagittal temporal orientation and of cross/within-cultural differences in spatial-temporal thinking, with additional implications for the theories on the relationship between language and thought.

Notes

1. By contrast, the use of "前/qian" (front) and "后/hou" (back) to convey "future" and "past" conceptions is rather rare. For instance, according to a corpus survey, only 2.75% of temporal use of "后/hou" refers to "early/before" (Peng, 2012). In this study, all sagittal temporal words produced by participants were the past-in-front/future-at-back spatial metaphors for time.

2. We controlled for age, as it may significantly influence individuals' mental space-time mappings; that is, older people are more likely to have past-in-front mappings than younger people (Bylund, Gygax, Samuel, & Athanasopoulos, 2019; de la Fuente et al., 2014), though the main

results of this analysis and other following analyses remained unchanged if age was dropped as a factor.

3. One reviewer mentioned that difference scores have typically a low signal-to-noise ratio, which may lead to the insignificance of temporal-focus. When we replaced the TFI with the raw past-focused score and future-focus score separately or jointly in the regression model, the results were unchanged. Another reviewer suggested that in the non-neutral wording conditions the TFI effect may be ruled out by the effect of past-in-front or future-in-front metaphors when we analyzed three conditions as a whole. Therefore, we ran an additional analysis of the TFI on space-time mappings only for the Chinese participants in the neutral wording condition, and the TFI was not significant. Despite this result, the overall pattern of TFI is consistent with that of space-time mappings for Chinese. Specifically, Chinese TFI turned out to be only a bit future-oriented (average TFI = 0.04, only moderately higher than the cutting point of 0). This pattern is matched with the proportion of future-in-front/past-at-back mappings in the neutral condition (60.3% vs. 50%), which is also slightly more likely to be future-in-front mappings than the cutting point of chance level.

4. There were two groups of Spaniards (younger group, Mage = 20 years, and older group, M_{age} = 74 years) in de la Fuente et al.'s (2014) study (Experiment 4). We used the data of the younger Spaniards group for cross-cultural comparisons, as they were more comparable to those of the Moroccan (M_{age} = 29 years) and Chinese (M_{age} = 30 years) samples.

5. To eliminate the potential multicollinearity between TFI and age, age was excluded in the model; the results were unchanged if age was additionally controlled for.

6. One may refer to de la Fuente et al.'s (2014) study, where in 31% of the cases, older Spaniards mapped the past to the front. However, this is not comparable to our data of the future-in-front metaphor condition for two reasons. First, according to that study, such a "high" proportion of past-in-front mapping by old Spaniards was driven by their age (*M* = 74 years), given that older people are more likely to have past-in-front mappings. Second, they were obtained from the neutral wording condition which was not comparable to our future-in-front wording condition. Ide-ally, we should compare our future-in-front data with the data of young Spaniards who are university students of a similar age and do the task in the Spanish future-in-front condition. Suppose Spaniards can have this future-in-front wording condition, one can speculate that the proportion of past-in-front mappings of Spanish future-in-front metaphors condition is unlikely to be higher (actually it can be even lower) than that of Spanish neutral wording condition (e.g., 12% Experiment 1, de la Fuente et al., 2014), which in turn can still be lower than that of the Chinese future-in-front condition.

7. In total there were 39 participants who responded towards past-in-front mappings across three conditions in Experiment 1 (*N* = 114). The experiment was run individually. We decided to add a post-hoc interview after we had already run several participants. Thus we had no interview with two participants who had performed past-in-front mappings (past-in-front condition), while we had the interview with all the rest who had past-in-front mappings in all conditions (37).

8. We also find such evidence in our Chinese participants, for example, past-in-front/ future-at-back temporal language does not always lead to past-in-front/future-at-back gestures or space-time mappings (e.g., see Experiments 1 and 3). However, the intriguing result from the current study is

that Mandarin speakers are more likely to perform past-in-front/future-at-back gestures/mappings when uttering lexical expressions that reflect past-in-front/ future-at-back sagittal concepts (e.g., 前天/qian tian, “front day,” the day before yesterday).

9. One may argue that English speakers may also gesture according to past = front mappings, as in Casasanto and Jasmin’s (2012) study in which English speakers’ sagittal spontaneous time gestures show a qualitative but statistically non-significant preference for a past = back mapping. However, that insignificance is “because there were so few gestures on this axis, in total” (*N* = 14) (Casasanto & Jasmin, 2012, pp. 655–656). Only three sagittal gestures of the whole sample were produced with past-in-front/future-at-back mappings (Fig. 1b, p. 651). A recent replication study with a larger sample size confirms that English speakers do not spontaneously produce such sagittal temporal gestures in any systematic manner (Yap & Casasanto, 2018).

References

Ahrens, K., & Huang, C. R. (2002). Time passing is motion. Language and Linguistics, 3(3), 491–519. Alibali, M. W. (2005). Gesture in spatial cognition: Expressing, communicating, and thinking about spatial information. *Spatial Cognition and Computation, 5*(4), 307–331. https://doi.org/10.1207/s15427633scc 0504_2

Alverson, H. (1994). *Semantics and experience: Universal metaphor of time in English, Mandarin, Hindi, and Sesotho*. Baltimore, MD: Johns Hopkins University Press.

Bender, A., & Beller, S. (2014). Mapping spatial frames of reference onto time: A review of theoretical accounts and empirical findings. *Cognition, 132*(3), 342–382. https://doi.org/10.1016/j.cognition.2014.03. 016

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition, 75*(1), 1–28. https://doi.org/10.1016/s0010-0277(99)00073-6

Boroditsky, L. (2001). Does language shape thought?: Mandarin and English speakers’ conceptions of time. *Cognitive Psychology, 43*(1), 1–22. https://doi.org/10.1006/cogp.2001.0748

Boroditsky, L., & Gaby, A. (2010). Remembrances of times East: Absolute spatial representations of time in an Australian aboriginal community. *Psychological Science, 21*(11), 1635–1639. https://doi.org/10.1177/ 0956797610386621

Bottini, R., Crepaldi, D., Casasanto, D., Crollen, V., & Collignon, O. (2015). Space and time in the sighted and blind. *Cognition, 141*, 67–72. https://doi.org/10.1016/j.cognition.2015.04.004

Brislin, R. W., & Kim, E. S. (2003). Cultural diversity in people’s understanding and uses of time. *Applied Psychology: An International Review, 52*(3), 363–382. https://doi.org/10.1111/1464-0597.00140

Bylund, E., & Athanasopoulos, P. (2017). The Whorfian time warp: Representing duration through the language hourglass. *Journal of Experimental Psychology: General, 146*(7), 911–916. https://doi.org/10. 1037/xge0000314

Bylund, E., Gygax, P., Samuel, S., & Athanasopoulos, P. (2019). Back to the future? The role of temporal focus for mapping time onto space. *Quarterly Journal of Experimental Psychology*, 1–9. https://doi.org/10. 1177/1747021819867624

Casasanto, D. (2009). Embodiment of abstract concepts: Good and bad in right- and left-handers. *Journal of Experimental Psychology: General*, 138(3), 351–367. https://doi.org/10.1037/a0015854

Casasanto, D. (2016). Temporal language and temporal thinking may not go hand in hand. In B. Lewandowska-Tomaszczyk (Ed.), *Conceptualizations of time* (pp. 169–186). Amsterdam: John Benjamins.

Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition, 106* (2), 579–593. https://doi.org/10.1016/j.cognition.2007.03.004

Casasanto, D., & Bottini, R. (2014). Mirror reading can reverse the flow of time. *Journal of Experimental Psychology: General, 143*(2), 473–479. https://doi.org/10.1037/a0033297

Casasanto, D., & Jasmin, K. (2012). The hands of time: Temporal gestures in English speakers. *Cognitive Linguistics, 23*(4), 643–674. https://doi.org/10.1515/cog-2012-0020

Chen, J. Y. (2007). Do Chinese and English speakers think about time differently? Failure of replicating Boroditsky (2001). *Cognition, 104*(2), 427–436. https://doi.org/10.1016/j.cognition.2006.09.012

Chui, K. (2011). Conceptual metaphors in gesture. *Cognitive Linguistics, 22*(3), 437–458. https://doi.org/10. 1515/cogl.2011.017

Cienki, A. (1998). Metaphoric gestures and some of their relations to verbal metaphorical expressions. In J. Koenig (Ed.), *Discourse and cognition: Bridging the gap* (pp. 189–204). Stanford, CA: CSLI Productions.

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

Cooperrider, K., & Gentner, D. & Goldin-Meadow, S. (2016). Spatial analogies pervade complex relational reasoning: Evidence from spontaneous gestures. *Cognitive Research: Principles and Implications, 1*, 1–17. https://doi.org/10.1186/s41235-016-0024-5.

Cooperrider, K., & Nu~nez, R. (2009). Across time, across the body: Transversal temporal gestures. *Gesture, 9*(2), 181–206. https://doi.org/10.1075/gest.9.2.02coo

de la Fuente, J., Santiago, J., Roman, A., Dumitrache, C., & Casasanto, D. (2014). When you think about it, your past is in front of you: How culture shapes spatial conceptions of time. *Psychological Science, 25*(9), 1682–1690. https://doi.org/10.1177/0956797614534695

Duffy, S. E., & Evans, V. (2017). The top trumps of time: Factors motivating the resolution of temporal ambiguity. *Language and Cognition, 9*(2), 293–315. https://doi.org/10.1017/langcog.2016.8

Duffy, S. E., Feist, M. I., & McCarthy, S. (2014). Moving through time: The role of personality in three real life contexts. *Cognitive Science, 38*(8), 1662–1674. https://doi.org/10.1111/cogs.12124

Floyd, S. (2016). Modally hybrid grammar?: Celestial pointing for time-of-day reference in Nheengatu. *Language, 92*(1), 31–64. https://doi.org/10.1353/lan.2016.0013

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. https://doi.org/10.1111/j.1551-6709.2010.01105.x

Fuhrman, O., McCormick, K., Chen, E., Jiang, H. D., Shu, D. F., Mao, S. M., & Boroditsky, L. (2011). How linguistic and cultural forces shape conceptions of time: English and Mandarin time in 3D. *Cognitive Science, 35*(7), 1305–1328. https://doi.org/10.1111/j.1551-6709.2011.01193.x

Gauthier, B., & van Wassenhove, V. (2016). Cognitive mapping in mental time travel and mental space navigation. *Cognition, 154*, 55–68. https://doi.org/10.1016/j.cognition.2016.05.015

Gentner, D., Imai, M., & Boroditsky, L. (2002). As time goes by: Evidence for two systems in processing space time metaphors. *Language and Cognitive Processes, 17*(5), 537–565. https://doi.org/10.1080/ 01690960143000317

Goldin-Meadow, S. (2003). *Hearing gesture: How our hands help us think*. Cambridge, MA: Harvard University Press.

Gu, Y., Mol, E. M. M., Hoetjes, M. W., & Swerts, M. (2013). What can Chinese speakers' temporal gestures reveal about their conception of time? *Proceedings of TiGeR 2013: The combined meeting of the10th international Gesture Workshop (GW) and the 3rd Gesture and Speech in Interaction (GESPIN) conference*, Tilburg, The Netherlands.

Gu, Y., Mol, L., Hoetjes, M., & Swerts, M. (2017). Conceptual and lexical effects on gestures: The case of vertical spatial metaphors for time in Chinese. *Language, Cognition and Neuroscience, 32*(8), 1048–1063. https://doi.org/10.1080/23273798.2017.1283425

Gu, Y., Zheng, Y., & Swerts, M. (2017). Does Mandarin spatial metaphor for time influence Chinese deaf signers' spatio-temporal reasoning? In G. Gunzelmann, A. Howes, T. Tenbrink, & E. J. Davelaar (Eds), *Proceedings of the 39th Annual Conference of the Cognitive Science Society* (pp. 445–450). Austin, TX: Cognitive Science Society.

Gu, Y., Zheng, Y., & Swerts, M. (2019). Having a different pointing of view about the future: The effect of signs on co-speech gestures about time in Mandarin-CSL bimodal bilinguals. *Bilingualism: Language and Cognition, 22*(4), 836–847. https://doi.org/10.1017/S1366728918000652

Guo, T., Ji, L., Spina, R., & Zhang, Z. (2012). Culture, temporal focus, and values of the past and future. *Personality and Social Psychology Bulletin, 38*(8), 1030–1040. https://doi.org/10.1177/0146167212443895

Hamdi, S. (2008). Conceptual metaphors of time in English and in Arabic: A comparative cognitive study. PhD dissertation, Universite Laval, Quebec.

Hendricks, R. K., Bergen, B. K., & Marghetis, T. (2018). Do metaphors move from mind to mouth? Evidence from a new system of linguistic metaphors for time. *Cognitive Science, 42*(8), 2950–2975.

Hendricks, R., & Boroditsky, L. (2017). New space-time metaphors foster new non-linguistic representations. *Topics in Cognitive Science, 9*(3), 800–818. https://doi.org/10.1111/tops.12279

Hostetter, A. B., & Alibali, M. W. (2008). Visible embodiment: Gestures as simulated action. *Psychonomic Bulletin & Review, 15*(3), 495–514. https://doi.org/10.3758/pbr.15.3.495

Ji, L., 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), 761–769. https://doi.org/10.1037/a0014498

Kita, S., Danziger, E., & Stolz, C. (2001). Cultural specificity of spatial schemas, as manifested in spontaneous gestures. In M. Gattis (Ed.), *Spatial schemas and abstract thought* (pp. 115–146). Cambridge, MA: MIT Press.

Lai, V. T., & Boroditsky, L. (2013). The immediate and chronic influence of spatio-temporal metaphors on the mental representations of time in English, Mandarin, and Mandarin-English speakers. *Frontiers in Psychology, 4*, 1–10. https://doi.org/10.3389/fpsyg.2013.00142

Lakoff, G., & Johnson, M. (1980). Metaphors we live by. Chicago, IL: University of Chicago Press.

Lausberg, H., & Sloetjes, H. (2009). Coding gestural behavior with the NEUROGES-ELAN system. *Behavior Research Methods, 41*(3), 841–849. https://doi.org/10.3758/brm.41.3.841

Le Guen, O., & Balam, L. I. P. (2012). No metaphorical timeline in gesture and cognition among Yucatec Mayas. *Frontiers in Psychology, 3*, 1–15. https://doi.org/10.3389/fpsyg.2012.00271

Li, H., & Cao, Y. (2018a). Time will tell: Temporal landmarks influence metaphorical associations between space and time. *Cognitive Linguistics, 29*(4), 677–701. https://doi.org/10.1515/cog-2017-0043

Li, H., & Cao, Y. (2018b). Karma or immortality: Can religion influence space-time mappings? *Cognitive* Science, 42, 1041–1056. https://doi.org/10.1111/cogs.12579

Li, H., & Cao, Y. (2018c). The hope of the future: The experience of pregnancy influences women's implicit space-time mappings. *The Journal of Social Psychology, 158*(2), 152–156. https://doi.org/10.1080/ 00224545.2017.1297289

Li, Y., Casaponsa, A., Wu, Y. J., & Thierry, G. (2019). Back to the future? How Chinese-English bilinguals switch between front and back orientation for time. *NeuroImage, 203*, 116180. https://doi.org/10.1016/j.ne uroimage.2019.116180

Miles, L. K., Nind, L. K., & Macrae, C. N. (2010). Moving through time. *Psychological Science, 21*(2), 222– 223. https://doi.org/10.1177/0956797609359333

Moore, K. E. (2011). Ego-perspective and field-based frames of reference: Temporal meanings of FRONT in Japanese, Wolof, and Aymara. *Journal of Pragmatics, 43*(3), 759–776. https://doi.org/10.1016/j.pragma. 2010.07.003

Ng, M. M., Goh, W. D., Yap, M. J., Tse, C. S., & So, W. C. (2017). How we think about temporal words: A gestural priming study in English and Chinese. *Frontiers in Psychology, 8*, 1–10. https://doi.org/10.3389/ fpsyg.2012.00271.

Nunez, R., & Cooperrider, K. (2013). The tangle of space and time in human cognition. *Trends in Cognitive Sciences, 17*(5), 220–229. https://doi.org/10.1016/j.tics.2013.03.008

Nunez, R., Cooperrider, K., Doan, D., & Wassmann, J. (2012). Contours of time: Topographic construals of past, present, and future in the Yupno valley of Papua New Guinea. *Cognition, 124*(1), 25–35. https://doi. org/10.1016/j.cognition.2012.03.007

Nunez, R., Motz, B., & Teuscher, U. (2006). Time after time: The psychological reality of the ego- and time-reference-point distinction in metaphorical construals of time. *Metaphor and Symbol, 21*(3), 133–146. https://doi.org/10.1207/s15327868ms2103_1

Nunez, 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. https://doi.org/10.1207/s15516709cog0000_62

Peng, Z. (2012). A cognitive study on time metaphor in Chinese: The Case of "qian" and "hou". *Journal of Shanxi Agricultural University (Social Science Edition), 11*, 1045–1051.

Saj, A., Fuhrman, O., Vuilleumier, P., & Boroditsky, L. (2014). Patients with left spatial neglect also neglect the "Left Side" of time. *Psychological Science, 25*(1), 207–214. https://doi.org/10.1177/0956797612475222

Santiago, J., Lupa~nez, J., Perez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin & Review, 14*(3), 512–516. https://doi.org/10.3758/bf03194099

Santiago, J., Roman, A., & Ouellet, M. (2011). Flexible foundations of abstract thought: A review and a theory. In A. Maass & T. W. Schubert (Eds.), *Spatial dimensions of social thought* (pp. 41–110). Berlin: Mouton de Gruyter.

Slobin, D. I. (1987). Thinking for speaking. In *Annual meeting of the Berkeley Linguistics Society* (vol. 13, pp. 435–445). Berkeley: CA: The Berkeley Linguistics Society. https://doi.org/10.3765/bls.v13i0.1826

Slobin, D. I. (1996). From "thought and language" to "thinking for speaking". In J. Gumperz, & S. C. Levinson (Eds.), *Rethinking linguistic relativity* (pp. 70–96). Cambridge: Cambridge University Press.

Stolarski, M., Fieulaine, N., & van Beek, W. (2015). *Time perspective theory: Review, research and application*. Cham: Springer International.

Szpunar, K. K., Spreng, R. N., & Schacter, D. L. (2014). A taxonomy of prospection: Introducing an organizational framework for future-oriented cognition. *Proceedings of the National Academy of Sciences*, 111(52), 18414–18421.

Torralbo, A., Santiago, J., & Lupa~nez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science, 30*(4), 745–757. https://doi.org/10.1207/s15516709cog0000_67

Ulrich, R., Eikmeier, V., de la Vega, I., Fernandez, 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 and Cognition, 40*(3), 483–495. https://doi.org/10.3758/s13421-011-0162-4

Walker, E. J., Bergen, B. K., & Nu~nez, R. (2014). Disentangling spatial metaphors for time using non-spatial responses and auditory stimuli. *Metaphor and Symbol, 29*(4), 316–327. https://doi.org/10.1080/10926488. 2014.948801

Walker, E. J., Bergen, B. K., & Nu~nez, R. (2017). The spatial alignment of time: Differences in alignment of deictic and sequence time along the sagittal and lateral axes. *Acta Psychologica, 175*, 13–20. https://doi. org/10.1016/j.actpsy.2017.02.001

Walker, E., & Cooperrider, K. (2016). The continuity of metaphor: Evidence from temporal gestures. *Cognitive Science, 40*(2), 481–495. https://doi.org/10.1111/cogs.12254

Wu, L., & Li, H. (2012). Time-space metaphors in Chinese Sign Language (中国手语中的时空隐喻). Chinese *Journal of Special Education, 150*(12), 25–29.

Xiao, C., Zhao, M., & Chen, L. (2018). Both earlier times and the future are “Front”: The distinction between time- and ego-reference-points in Mandarin speakers’ temporal representation. *Cognitive Science, 42*(3), 1026–1040. https://doi.org/10.1111/cogs.12552

Yap, D. & Casasanto, D. (2018). English speakers gesture laterally for time regardless of the input modality. *Poster presented at the 40th Annual Conference of the Cognitive Science Society*, Madison, WI. https://mindmodeling.org/cogsci2018/papers/0719/0719.pdf.

Yu, N. (1998). *The contemporary theory of metaphor: A perspective from Chinese*. Amsterdam: John Benjamins.

Yu, N. (2012). The metaphorical orientation of time in Chinese. *Journal of Pragmatics, 44*(10), 1335–1354. https://doi.org/10.1016/j.pragma.2012.06.002

Zheng, X. (2009). A study of signs for non-visual concepts in Shanghai Variety of Chinese Sign Language (上海手语非视觉概念表达研究). PhD dissertation, Fudan University, China.

Supplement I: 3D temporal diagram.
https://onlinelibrary.wiley.com/action/downloadSupplement?doi=10.1111%2Fcogs.12804&file=cogs12804-sup-0001-SupMat1.gif
Supplement II: Temporal—Focus questionnaire.
https://onlinelibrary.wiley.com/action/downloadSupplement?doi=10.1111%2Fcogs.12804&file=cogs12804-sup-0002-SupMat2.pdf

Appendix: Wordlists of targeted time referents in Experiment 1

	Chinese	Meaning
(1)	上周, 下周 shang zhou, xia zhou	Last week, next week
(2)	昨天, 今天, 明天 zuo tian, jın tian, mıng tian	Yesterday, today, tomorrow
(3)	早晨, 晌午, 傍晚, 深夜 zǎo chen, shǎng wǔ, bang wǎn, shen ye	Morning, noon, evening, late at night
(4)	上辈子, 下辈 子 shang bei zi, xia bei zi	Previous life, next life
(5)	前年, 后年 qian nian, hou nian	The year before last year, the year after next year

Chapter 3. Having a different *pointing* of view about the future: The effect of signs on co-speech gestures about time in Mandarin–CSL bimodal bilinguals

Abstract

Mandarin speakers often use gestures to represent time laterally, vertically, and sagittally. Chinese Sign Language (CSL) users also exploit signs for that purpose, and can differ from the gestures of Mandarin speakers in their choices of axes and direction of sagittal movements. The effects of sign language on co-speech gestures about time were investigated by comparing spontaneous temporal gestures of late bimodal bilinguals (Mandarin learners of CSL) and non-signing Mandarin speakers. Spontaneous gestures were elicited via a wordlist definition task. In addition to effects of temporal words on temporal gestures, results showed significant effects of sign. Compared with non-signers, late bimodal bilinguals (1) produced more sagittal but fewer lateral temporal gestures; and (2) exhibited a different temporal orientation of sagittal gestures, as they were more likely to gesture past events to their back. In conclusion, bodily experience of sign language can not only impact the nature of co-speech gestures, but also spatio-motoric thinking and abstract space-time mappings.

Acknowledgement: The work is supported by NWO Promoties in de Geesteswetenschappen (322-89-007) and NWO Research Talent (406-15-298), which are gratefully acknowledged. Preliminary results of this study have been presented at the 7th Conference of International Society for Gesture Studies in Paris (ISGS 2016), and "The role of gesture in cognitive and linguistic processes" workshop at the University of Warwick (July, 2017). We thank Yufen Chi, Weidong Zheng, and Qingshi Zhu who have assisted us in running experiments. We are grateful to Marieke Hoetjes and Rein Cozijn for their comments on the manuscript, and Arthur van Soest for his advice on statistics.

This chapter is based on:

Gu, Y., Zheng, Y. & Swerts, M. (2019). Having a different *pointing* of view about the future: The effect of signs on co-speech gestures about time in Mandarin–CSL bimodal bilinguals. *Bilingualism: Language and Cognition, 22*(4), 836–847. https://doi.org/10.1017/S1366728918000652

1 Introduction

People use space to represent the abstract concept of time (e.g., Casasanto & Boroditsky, 2008; see reviews Bender & Beller, 2014; Núñez & Cooperrider, 2013). For instance, we often talk about time in terms of space such as in phrases like: "The future is lying *ahead*; the past is *behind* us" (Calbris, 2008; Clark, 1973; Evans, 2004, 2013; Lakoff & Johnson, 1980; Traugott, 1978). In addition, humans also tend to gesture to visually express time in space. English people may refer to the future by pointing to the front of their body and indicate the past by pointing to their back (also left-right for past-future) (Casasanto & Jasmin, 2012; Cooperrider & Núñez, 2009; Walker & Cooperrider, 2016). Such *temporal gestures* with the future-in-front and the past-at-back mappings sound common for many Westerners.

However, across cultures and languages, people may gesture about time vastly differently. Take the temporal gestures of *future*: for instance, residents of Pormpuraaw (Australia) point the future to the front of them only when they are facing the west, because they always arrange temporal order according to cardinal directions from east to west (Boroditsky & Gaby, 2010). Interestingly, Aymara speakers point the future to their back as they believe that the future is unseen/unknown (Núñez & Sweetser, 2006). Moroccans also have a strong tendency to gesturally position the past in the front and the future at their back, which is claimed to be shaped by their cultural attitude towards time as Moroccans focus on past times and place high value on tradition (people who are past-focused metaphorically should have a tendency to place the past in front of them, "in the location where they could focus on the past literally with their eyes if past events were physical objects that could be seen" (de la Fuente *et al.*, 2014, p.1684). Additionally, some Chinese people spontaneously direct their gestures to their front when referring to past events, but the extent to which they perform past-in-front gestures is influenced by the accompanying temporal words (Chapter 2). Furthermore, people can even gesture about the future in some other space dimensions such as *downwards*, or *uphill*, etc. (Chapter 2; Núñez, Cooperrider, Doan, & Wassmann, 2012).

Despite the fact that there are an increasing number of studies on the relation between speakers' gestures and their spatialisation of time (e.g., Bostan, Börütecene, Özcan, & Göksun, 2016; Floyd, 2016; Kita, Danziger, & Stolz, 2001; Le Guen & Balam; 2012), we still have an incomplete understanding of why some communities gesture the future to the front whereas others gesture the past to the front. In the research reported here, we investigated this question by exploring the effect of temporal signs on temporal gestures in *bimodal bilinguals*, who know both a spoken language and a signed language (Emmorey, Boorin, Thompson, & Gollan, 2008). To the best of our knowledge, no study has researched the temporal gestures by people who have experience of sign language, which, in the case of Chinese, would represent an interesting group, as Mandarin Chinese-Chinese Sign Language (CSL)[2] bimodal bilinguals share a similar culture as non-signers, but have acquired CSL

[2] The sign languages used in mainland China are generally called Chinese Sign Language (CSL) (Fischer & Gong, 2010). CSL has different dialects such as the northern (Beijing) CSL and the southern (Shanghai) CSL, which sometimes can even be mutually unintelligible (Yang, 2005). The China Association of the Deaf has been making efforts to unify and standardise CSL since the late 1950s. An authorized dictionary, Chinese Sign Language (zhong-guo shou-yu) (China

which exploits different time-space mappings than Mandarin (see review below). Particularly, we are interested in whether Mandarin-CSL bimodal bilinguals gesture differently about time than Mandarin speakers who do not know CSL.

1.1 Background

Mandarin Speakers' Temporal Gestures

It has been shown that Mandarin speakers make gestures on different axes in space to represent time. First, similar to English speakers, Chinese people most often produce lateral temporal gestures, with the past on the left and the future on the right side. However, different from most Westerners, Chinese can exploit a vertical axis as well to gesture about time, as they tend to spontaneously point *upwards* for the time conception of "last week" and *downwards* for "next week" (Gu et al., 2017).

Table 1. Examples of future-in-front/past-at-back and past-in-front/future-at-back mappings in Mandarin.

Example (1)	展/zhǎn 望/wàng 未/wèi 来/lái unfold gaze-into-distance hasn't come Looking far ahead/into the future.	
	回/huí 首/shǒu 过/guò 去/qù turn-around head pass go Looking back to the past.	
Example (2)	前/qián 天/tiān, front day, the day before yesterday,	今/jīn 后/hòu today back from now on

Additionally, Mandarin speakers can perform sagittal gestures to express time. On the one hand, they can point the future to the front of their body and the past to the back, which is in line with the Mandarin future-in-front/past-at-back sagittal space-time metaphors (Table 1, Example 1). On the other hand, a Mandarin speaker can point to the front of his/her body to refer to the conception of temporal "before" (Chui, 2011). As revealed by the gesture study in Chapter 3 (Experiment 1), past-in-front/future-at-back gestures were more often associated with past-in-front/future-at-back space-time metaphors. As Example (2) shows, the sagittal words for spatial "front" (前/qián)" and "back" (后/hòu) are also used as temporal conceptions of "before/past" and "after/future". Such sagittal spatial metaphors for time suggest past-in-front/future-at-back space-time mappings, and, therefore, may significantly influence the direction of sagittal temporal gestures. Partially due to this lexical effect, some Mandarin speakers even explicitly report to believe the future to be positioned behind and the past in front of them (i.e., past-in-front/future-at-back space-time mappings) (Chapter 2).

Temporal Signs in CSL

Association of the Deaf and Hard of Hearing, 2003) is used in China to standardise CSL. The dictionary has collected the signed forms of more than 5,000 Chinese words that are common in use in both Beijing and Shanghai (representing the northern and the southern varieties). This standard variety is learned by users of both dialects and it is now widely used in education, on television and by interpreters (Yang, 2015). Note that we will deal with only one variety, namely the Standard CSL, which was the language taught to the hearing L2 learners in our study.

CSL users also make use of the lateral, vertical, and sagittal spatial representations to express the conception of time. In many sign languages, the lateral axis is often used to express a sequence timeline, which is parallel to the signers' body and extends from left to right, representing earlier to later time periods (e.g., Nilsson, 2016; Wilcox, 2002). It is used when signers refer to ordered events that are unrelated to the utterance time (Emmorey, 2001). Zheng (2009) finds that users of CSL are consistent in listing events that happened at a different time from the left to the right.

As for the vertical timeline, CSL signers make use of vertical spatial metaphors of "up" and "down" to represent time conceptions of "early" and "late", or the sequence of events. For instance, the temporal conception of "future" can be signed "downwards" (Wu & Li, 2012; Zheng, 2009).

Furthermore, the sagittal axis is often used for what could be termed a deictic timeline. Similar to other sign languages in the world (e.g., Cabeza Pereiro & Fernández Soneira, 2004; Maeder & Loncke, 1996; Schermer & Koolhof, 1990, see a review in Sinte, 2013), CSL signers' bodies are often referred to as a deictic reference point of the timeline, such that locations near the signers are often used for "now", and the future is signed more to their front and the past to their back (Wu & Li, 2012; Zheng, 2009).

Time in Hands: Gestures vs. Signs

Interestingly, there are dramatic *differences* in the deictic sagittal timelines between CSL and Mandarin Chinese. As stated above, Mandarin Chinese contains space-time metaphors that suggest both future-in-front/past-at-back and past-in-front/future-at-back space-time mappings. Accordingly, Mandarin speakers can not only produce future-in-front/past-at-back temporal gestures, but also past-in-front/future-at-back gestures. However, the sagittal lexical signs of CSL do not show this variation, as they represent *only* future-in-front/past-at-back space-time mappings, in this way being different from Mandarin Chinese. For instance, the time conceptions of "the day before yesterday" and "the day after tomorrow" in Mandarin are expressed in a completely reversed manner from what is the case in CSL (Wu & Li, 2012; Zheng, 2009). That is, in Mandarin the direction of "the day before yesterday (前天/qián-tiān, *front day*)" is literally to the front, and "the day after tomorrow (后天/hòu-tiān, *back day*)" is literally to the back, which is often reflected in the directionality of the co-speech sagittal temporal gestures by Mandarin speakers (Chapter 3). By contrast, in CSL the temporal sign of "the day before yesterday" is signed to the back, whereas the temporal sign of "the day after tomorrow" is signed to the front (Zheng, 2009).

Additionally, although Mandarin speakers and CSL signers both use 3D manual movements to indicate time, the relative proportion of the three time axes may be different, since Mandarin speakers predominantly produce temporal gestures on the lateral axis (see results presented in Chapter 2) whereas an empirical survey showed that CSL deaf signers mostly produce temporal signs on the sagittal and vertical axes (Zheng, 2009).

Do Speakers' Gestures Change after Learning a Spoken or Signed Language?

There has been a long interest on whether speakers gesture differently after learning an L2, even when the existing studies provide mixed results (e.g., Brown & Gullberg, 2008; Casey & Emmorey, 2009; Özçalişkan, 2016; Pika, Nicoladis, & Marentette, 2006). For unimodal (non-bimodal) bilinguals, Brown and Gullberg (2008) found that there were influences of an L2 on co-speech gestures of an L1. For instance, it was found that intermediate Japanese learners of English gestured slightly differently in their L1 Japanese than Japanese monolinguals when talking about motion events. Specifically, Japanese–English speakers (similar to English monolinguals) were less likely to perform a gesture that expressed manner of motion than monolingual Japanese, while their speech conveyed manner information. By contrast, Choi and Lantolf (2008) found that even advanced English learners of Korean as an L2 or Korean learners of an L2 English still retained their L1 co-speech gesture patterns when expressing manner of motion in their L1 language. Similarly, Özçalişkan (2016) found that Turkish-English bilinguals still followed L1 co-speech gesture patterns even when speaking L2.

As for bimodal bilinguals, the very few studies about their gestures reveal that there is probably an influence of a signed language on the co-speech gesture patterns in a first spoken language. For instance, an L2 sign language may affect the production of co-speech gestures or facial expressions when bimodal bilinguals speak in their L1 (Pyers & Emmorey, 2008). Additionally, two studies have shown that American Sign Language (ASL)-English bilinguals may have a higher co-speech iconic gesture rate than English non-signers (Casey & Emmorey, 2009; Casey, Emmorey, & Larrabee, 2012). These results seem to suggest that gestures and signs stem from the same manual articulation system, and that there is an interaction between a signed language production system and the co-speech gesture production system (Brentari, Nadolske, & Wolford, 2012; Emmorey *et al*., 2008).

However, the studies on gestures discussed above, regardless of whether they were dealing with unimodal or bimodal bilinguals, predominantly have focused on how gestures for motion events or gesture frequency and form can be affected by knowing a second spoken/signed language. No studies have looked into how the *content* of gestures (e.g., the abstract concept of space-time mappings represented in gestures) can be affected by the experience of a signed language.

1.2 The Current Study

The current study aims to investigate whether the experience of CSL influences the production of co-speech gestures about time in bimodal bilinguals. We will explore firstly whether Mandarin-CSL bimodal bilinguals perform different patterns of temporal gesture than Mandarin speakers, in terms of the relative proportion of three axes. Second, focusing on the temporal orientation on the sagittal axis, we aim to find out whether hearing people who have learned CSL have a different direction of sagittal temporal gestures than Mandarin non-signers.

If it is the case (in line with previous studies) that gesture production and sign production systems are interconnected (e.g., Emmorey *et al*., 2008) in a way that bimodal bilinguals are accustomed to perform manual movements in certain axes or directions, given the differences between temporal gestures and signs, we predict that bimodal bilinguals will have more sagittal and vertical temporal gestures but fewer lateral temporal gestures than Mandarin speakers who are non-signers. Additionally, Mandarin-CSL bilinguals are less likely to perform past-in-front/future-at-back gestural mappings than Mandarin speaking non-signers.

Furthermore, given that spontaneous gestures are a window into people's spatio-temporal thinking (e.g., Casasanto & Jasmin, 2012; Cienki, 1998; Núñez & Sweetser, 2006), providing a "vivid and naturalistic source of evidence for the use of space in abstract reasoning" (visualising thought) (Cooperrider, Gentner, & Goldin-Meadow, 2016; Tversky, 2011), the study of co-speech temporal gestures by late bimodal bilinguals may reveal the effect of cross-modal spatial metaphors of time on people's mental space-time mappings. Thus this study can show the cross-linguistic influence of an L2 on an L1 and may further help clarify the problem of the restructuring of temporal conceptualisation after learning an L2.

2 Method

Participants

Forty-four participants, including 10 hearing Mandarin-CSL late bimodal bilinguals (6 female; M_{age} = 39.2 yrs, *SD* = 7.7 yrs) and 34 Mandarin-speaking non-signers (22 females; M_{age} = 33.79 yrs, *SD* = 7.58 yrs), took part in the experiment in Rizhao, China. Three Mandarin-speaking non-signers were excluded from the analyses as they did not produce any gestures. The monolingual data were from a corpus collected in Chapter 3. We used part of the data to do different analyses so that they could be used as comparison materials in this study.

All late bimodal bilinguals were born into hearing families and acquired standard CSL as a second language later in their life (average age of acquisition = 20.6 yrs, *SD* = 3.3 yrs). They were fluent users of standard CSL with an average of 18.6 years of signing experience (*SD* = 9.2). Their CSL proficiency levels (*M* = 8.6, *SD* = 1.07, 10-point scales) were assessed by a CSL teacher from a school for special education. This assessment was done after all the participants had finished the experiment so that participants would not infer a focus on manual movements in the study. These bimodal bilinguals were teachers of deaf children, and none of them were interpreters.

Additionally, the English proficiency levels of participants of both groups were minimum (*M* = 1.36, *SD* = .66, 1 = hardly know any English; 2 = beginner to lower-intermediate), as reported on a 5-point-scales' self-assessment.

Materials and Procedure

A word definition task was used to elicit participants' spontaneous gestures, inspired by previous studies (e.g., Chapters 2 and 3; Núñez *et al*., 2012) that showed the effectiveness of this method. We constructed twelve wordlists, which consisted of five wordlists of time conceptions and seven of fillers. Each wordlist had two to four expressions that were thematically related (e.g., "yesterday", "today", and "tomorrow"). In total, there were thirteen Mandarin temporal expressions (see Chapter 2, Appendix).

The experiment was ostensibly set up as a study of speakers' short-term memory and addressees' long-term memory. All bimodal bilinguals and non-signers took the role of speakers to fulfil the word definition task in their native language, that is, spoken Mandarin (not in sign language). All participants were told that the task was in Mandarin and the addressees could only speak Mandarin Chinese. They were asked to remember each wordlist shortly after seeing it twice presented on screen. Then they had to tell and explain the words from each wordlist as explicitly as possible to Mandarin-speaking addressees who could ask them clarification questions (for more details see the same method in Chapter 2). The addressees were told to remember speakers' descriptions for a later memory test. However, the latter test actually did not take place as they were confederates. The experiment was videotaped after obtaining participants' written consent. Gestures or CSL were not mentioned at any moment and debriefing responses revealed that participants had not realised that the study was about speakers' gestures or manual movements.

Gesture Coding

Co-speech temporal gestures were annotated in ELAN (Lausberg & Sloetjes, 2009). A first coder did an initial coding, viewing the entire video with the audio. The axes of gestures were coded as vertical, lateral, or sagittal, with an indication of the directionality of each axis (Casasanto & Jasmin, 2012; Chapters 2 and 3). Additionally, although bimodal bilinguals were speaking to non-signers, they might still produce a small proportion of signs (e.g., about 3%, Casey & Emmorey, 2009). CSL temporal signs were noted when they were identifiable lexical signs, or hand movements that a non-signer would unlikely produce (Casey & Emmorey, 2009; Casey, Emmorey, & Larrabee, 2012). Six CSL temporal signs (about 2.8%) were detected and were excluded from the analyses (e.g., a temporal sign of "morning" was produced when the Mandarin word "morning" was uttered, that is, a movement of one hand starts with a palm down horizontally in front of the chest, with four fingers and thumb pinched, and the hand moves up slowly with fingers gradually opened, indicating the sky is lighting up).

Furthermore, the temporal words accompanying temporal gestures were transcribed. These could contain temporal words explicitly having vertical spatial references to "up" and "down" (e.g., 上周/shàng zhōu, *above week*, "last week"), sagittal spatial references to "front" (前/qián) and "back" (后/hòu) (e.g., 前年/qián-nián, *front year*, "the year before last year"), or words without having such lexical cues (e.g., 昨天/zuó-tiān, "yesterday"). These temporal words were coded in three categories (vertical; sagittal; neutral).

In total, we obtained 719 temporal word-gesture tokens, including 212 from late bimodal bilinguals, and 507 from Chinese non-signers. The average number of gestures by bimodal bilinguals (M = 21.2) tended to be significantly higher than that of non-signers (M = 14.9), t = 1.52, p = .067 (one-tailed with a directional hypothesis). The pattern of increased gesture production for bimodal bilinguals compared to non-signers is in line with previous results for ASL-English bilinguals (Casey & Emmorey, 2009; Casey, Emmorey, & Larrabee, 2012).

The reliability of the annotation of the gestures was established by having 53% of the data coded by a naïve second coder. The two coders agreed on the gesture axes judgement on 92.31% of the tokens (N = 380), Cohen's Kappa = 0.87 (referring to "Excellent" agreement). In cases of disagreement, the two coders discussed and reached agreement on the labels, and these consensus labels were used for the final analysis.

Statistical Analyses

A mixed multinomial logit model for panel data was used (Croissant, 2012) to compare the gesture proportion of three axes, with *group* (late bimodal bilinguals vs. Mandarin-speaking non-signers) as a main independent variable and *temporal gesture axis* (L; V; S) as a dependent variable. We started with the maximal random effect structure, including random intercepts and random slopes for the crucial independent variable *group*. However, the standard deviations of random slopes on *group* were insignificant, so the random slopes were not used in the final model. Given that previous research has shown that temporal words can have an influence on gestures (e.g., Chapter 2), we also controlled for the type of temporal words accompanying temporal gestures (vertical; sagittal; neutral). To compare the direction of sagittal temporal gestures, a binary logistic regression for panel data was used, with group as a main independent variable and the direction of sagittal gestures (past-in-front or future-in-front) as a dependent variable. Both models have taken individual differences into consideration and dealt with the repeated observations from the same individuals.

3 Results and Analyses

3.1 Temporal Gestures on the Lateral, Vertical, and Sagittal Axes

As Figure 1 shows, late bimodal bilinguals displayed a different distribution of temporal gestures on the three axes than the non-signers. Specifically, non-signers performed 48.72% of the temporal gestures on the lateral axis whereas late bimodal bilinguals performed only 29.72% of gestures on the lateral axis. Instead, late bimodal bilinguals performed 37.26% of the temporal gestures on the sagittal axis and 33.02% on the vertical axis, which, respectively, was 16.75% and 2.25% more than those of non-signers.

A mixed multinomial logit regression (N = 719) of gesture axes on group (baseline: vertical axis) showed that late bimodal bilinguals were significantly less likely to perform lateral temporal gestures (t = -2.42, p = .016, β = -0.74) but more likely to perform sagittal ones (t = 4.13, p < .001, β = 1.98) than the non-signers, controlling for the type of temporal words (vertical; sagittal; neutral) and age. The different distribution of axes between the two groups indicated that the production of temporal gestures can be influenced by the experience of learning temporal signs in CSL.

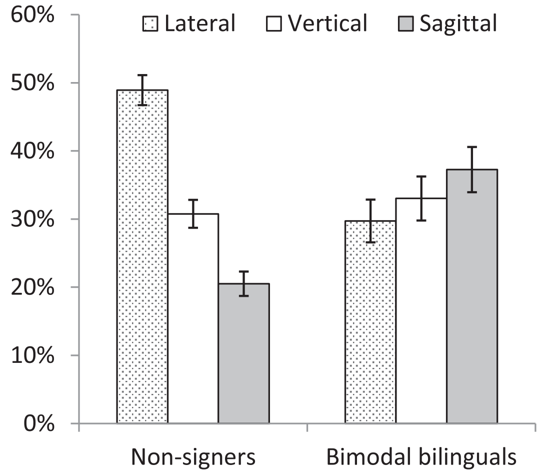


Figure 1. Distribution of temporal gestures on three axes by bimodal bilinguals and non-signers. Error bars show standard errors of the mean.

Additionally, as for the influence of the type of temporal words on temporal gestures, we found that participants were more likely to perform vertical temporal gestures when uttering vertical spatial metaphors for time than when uttering neutral temporal words, regardless of whether they were signers or non-signers, in that they would perform fewer lateral (t = -10.21, p < .001, β = -2.89) or sagittal temporal gestures (t = -9.66, p < .001, β = -4.97), controlling for group and age. Similarly, participants were more likely to produce sagittal temporal gestures when uttering sagittal spatial metaphors for time than when uttering neutral temporal words (t = 2.26, p = .024, β = .87). The results indicated that the concurrent temporal words also had an effect on the choice of temporal gesture axes.

3.2 Directionality of Sagittal Temporal Gestures

Focusing on the directionality of sagittal temporal gestures, non-signers performed about 49.04% of the sagittal temporal gestures with the past to the front and the future to their back (past-in-front/future-at-back gestures) and 50.96% with the future to the front and the past to the back (future-in-front/past-at-back gestures). However, the proportion of past-in-front/future-at-back gestures by late bimodal bilinguals was only 16.46%, and the proportion of future-in-front/past-at-back gestures was 83.54% (Figure 2).

A binary logistic regression (N = 183) of sagittal temporal gesture direction on group showed that late bimodal bilinguals performed a significantly lower proportion of past-in-front/ future-at-back temporal gestures than the non-signers, Wald χ^2 (1) = 5.12, p = .024, β = -6.85, 95% CI = [-12.78, -.92], even after controlling for the type of temporal words co-occurring with gestures (vertical; sagittal; neutral). This indicated that after learning CSL, late bimodal bilinguals were more likely to have a future-in-front/past-at-back temporal orientation as visible in their sagittal temporal gestures.

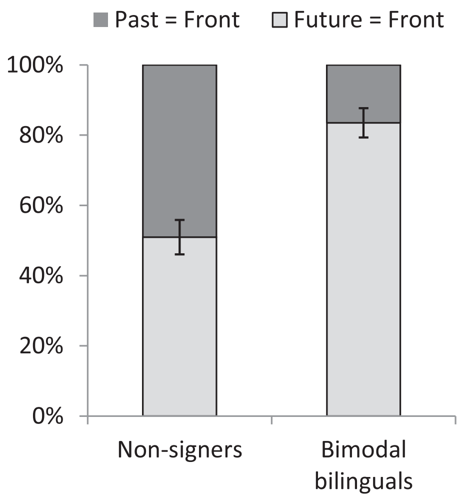


Figure 2. Orientation of sagittal temporal gestures by bimodal bilinguals and non-signers. Error bars show standard errors of the mean.

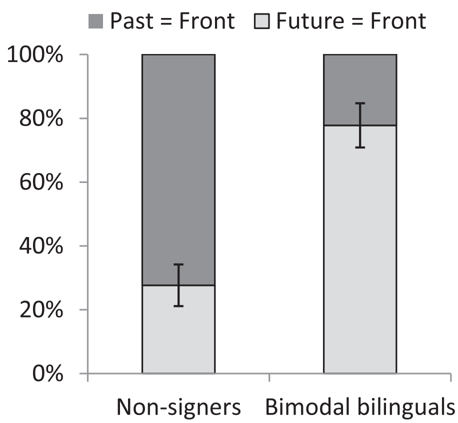
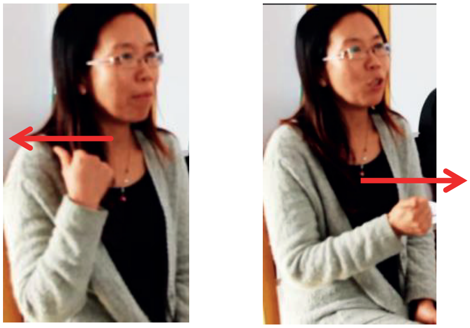


Figure 3. Orientation of sagittal temporal gestures accompanied by past-in-front temporal sagittal words. Error bars show standard errors of the mean.

今年/jīn-nián, this year 去年/qù-nián, last year 前年/qián-nián, *front year*, the year before last year

Figure 4. Gestures of "this year", "last year" and "the year before last year" in Chinese, by a Mandarin-speaking non-signer.



前年/qián-nián, *front year*, the year before last year 后年/hòu-nián, *back year*, the year after next year

Figure 5. Gestures of "the year before last year", and "the year after next year" in Chinese, by a late Mandarin-CSL bimodal bilingual.

Furthermore, it has been claimed that Mandarin speakers' past-in-front temporal gestures are predominantly produced when speakers utter sagittal temporal words with past-in-front metaphors (e.g., qián-tiān/前天, *front day*, "the day before yesterday") (Chapter 3; Lai & Boroditsky, 2013). For instance, in this study, when Mandarin-speaking non-signers uttered past-in-front metaphors, 72.34% of the sagittal temporal gestures were the past-in-front temporal gestures. However, in this case, the proportion by late bimodal bilinguals was only 22.22% (Figure 3), which was significantly smaller (Wald χ^2 (1) = 54.16, N = 83, p < .001, β = -19.75, 95% CI = [-25.01, -14.49]), and the majority of sagittal temporal gestures were instead produced according to the future-in-front mapping (77.78%). Thus, late bimodal bilinguals had a different direction of sagittal gestures than non-signers even when both groups were uttering the same overt past-in-front space-time metaphors (e.g., see Figure 4 and Figure 5). The results indicated that the experience of temporal signs influenced temporal gestures.

4 Discussion

This study is the first that explored temporal gestures by bimodal bilinguals, and the first to look into effects of temporal signs on temporal gestures. Our results have shown that both Mandarin-speaking non-signers and Mandarin-CSL late bimodal bilinguals could perform spontaneous temporal gestures on the lateral, vertical, and sagittal axes. However, the two groups were significantly different in their use of temporal gestures on the three axes, as well as in their direction of sagittal temporal gestures. Although the results of this study were admittedly obtained based on a relative small number of bimodal bilinguals, these findings have a number of important theoretical implications.

First, our findings support the claim that there is an interconnection between the co-speech gesture production system and a sign language production system (Emmorey *et al*., 2008). The few studies on this topic have mainly focused on the changes in gesture rate, character viewpoint, and handshape after learning American Sign Language (ASL). Although it has been observed in these studies that there was an increase of gesture rate in ASL learners, sometimes "these changes were not large enough to create significant group differences" in comparison to non-signers (Casey, Emmorey, & Larrabee, 2012) (Note in that study ASL learners had only one-year of ASL instruction). The present study, however, focusing on the study of temporal gestures, provides additional evidence that the knowledge and experience of an L2 sign language can indeed impact the content and form of L1 co-speech gestures.

Second, these results point out that there may be cross-linguistic influences of the L2 on the L1 (e.g., Brown & Gullberg, 2008, 2011; Zou, 2012). Studies have shown that languages are co-activated in a bilingual mind (e.g., Van Hell & Dijkstra, 2002). For instance, there is an unconscious access to the sound form of Chinese words when Chinese-English bilinguals read or listen to English words (Wu & Thierry, 2010). Such cross-language interactions can even occur across modalities (e.g., Emmorey *et al.*, 2005; Giezen & Emmorey, 2016; Ortega & Morgan, 2015). For example, Morford (2010) found that ASL– English bilingual deaf readers activate the ASL translations of written words in English even when the task does not explicitly require the use of ASL. Recent ERP research also reveals that there is an implicit co-activation of ASL in deaf readers (Meade et al., 2017). In our study, late bimodal bilinguals produced significantly more sagittal temporal gestures than non-signers. Given that CSL mostly makes use of the sagittal spatial metaphors for time (Zheng, 2009), a speculative explanation for the result can be that even when Mandarin is the target language for production, the detailed spatial information for temporal expressions in CSL is still activated, which may prime the action production system that generates temporal gestures (Casey & Emmorey, 2009).

One possible concern is that these manual movements produced by bimodal bilinguals were not co-speech gestures but CSL signs. This is quite unlikely because even native bimodal bilinguals only produce very few signs when interacting with non-signers (e.g., only 3%, Casey & Emmorey, 2009), and in our study participants were late bimodal bilinguals and their signs have been excluded in the analyses. Additionally, it was also visible by the number of fingers in the gestures. For example, the concept of "the day before yesterday" in CSL is expressed by the use of the index and middle fingers to point to the back once, whereas the gestures we obtained did not show such a pattern.

Furthermore, our results also suggest that the acquisition of a signed language may have an impact beyond the nature of gestures that accompany the native spoken language (cf. Casey, Emmorey & Larrabee, 2012; Emmorey, Giezen, & Gollan, 2016). For instance, an intriguing result is that Mandarin-CSL late bilinguals were highly unlikely to perform past-in-front/future-at-back temporal gestures as opposed to Chinese non-signers who would often do so. In other words, the future-in-front/past-at-back mappings were activated to a greater extent in bimodal bilinguals than in Mandarin non-signers. Strikingly, even when the sagittal temporal gestures were accompanied by the sagittal past-in-front words, a situation in which the gesture direction would most likely be influenced by the uttering of such overt words, late bimodal bilinguals still rarely directed the past to their front. If spontaneous gestures are a visible embodiment of cognition (Alibali, 2005; Hostetter & Alibali, 2008) which provide a window into people's mental space-time mapping (e.g., Casasanto & Jasmin, 2012; Cienki, 1998; Núñez & Sweetser, 2006; Walker & Cooperrider, 2016), it is likely that learning CSL changes Mandarin speakers' conceptualisations of space-time mappings.

Such differences in sagittal space-time mappings may be explained in terms of differences in time perspective-taking[3], related to two possible systems of space-time metaphor in language. There are two types of time perspectives, i.e., moving-ego and moving-time (e.g., Moore, 2011; Núñez, Motz, & Teuscher, 2006; Walker, Bergen, & Núñez, 2017). When a person takes an ego-moving perspective, s/he moves forward in the timeline, from past to future, e.g., "We look *forward* to the future *ahead*". When that person takes a time-moving perspective (e.g., "Christmas is coming"), s/he still faces the future, but time is conceived of as a river or conveyor belt on which events are moving from the future to the past (Gentner, Imai, & Boroditsky, 2002). In this perspective, the *front* of a timeline can be assigned to a past (earlier) event (e.g., in the timeline May is before (in front of) June).

According to previous studies, English speakers usually take an ego-moving perspective, whereas Mandarin speakers mostly take a time-moving perspective (e.g., Gentner, Imai, & Boroditsky, 2002; Xiao, Zhao, & Chen, 2017; Yu, 2012). For example, Mandarin-English speakers were influenced by the English time perspective even when they were speaking Mandarin, such that Mandarin-English speakers were less likely to take a time-moving perspective than Mandarin monolinguals (Lai & Boroditsky, 2013). Similarly, given that signers of CSL mainly take the ego-moving time perspective (the deictic of time in CSL is moving ego, Wu & Li, 2012), late bimodal bilinguals may be influenced by the CSL time perspective even in a non-signing context.

One may further ascribe such differences in spatio-temporal reasoning to the different uses of spatial metaphors for time between Mandarin Chinese and CSL, given that Mandarin Chinese contains both

[3] One reviewer pointed out that the cross-linguistic differences in time-space mappings are unlikely raised from the moving-ego vs. moving-time perspectives. When an ego is involved in the timeline, in both perspectives, the future is ahead and the past is behind; neither presents a scenario in which the past is ahead (because this would be characterised by a reverse moving time perspective, in which time moves from behind forward). More studies are needed to better understand the psychological realisation of Chinese sagittal space-time mappings.

lexicon words suggesting future-in-front/past-at-back and past-in-front/future-at-back space-time mappings, whereas the sagittal lexical signs of CSL do not show this variation as they represent only future-in-front/past-at-back space-time mappings (Wu & Li, 2012; Zheng, 2009). For instance, a recent study has shown that Chinese deaf signers display a different spatio-temporal reasoning than Mandarin speakers. Specifically, participants were asked to fulfil a Mandarin temporal performance task, in which they had to label the Mandarin past and the future concepts in front-back space. The results revealed that CSL deaf signers with higher Mandarin proficiency were more likely to perform past-in-front/future-at-back space-time mappings than signers with lower Mandarin proficiency (Gu, Zheng, & Swerts, 2017).

Given that a body of evidence has shown that space-time metaphors can influence people's mental representation of time (e.g., Boroditsky, 2000, 2001; Bylund & Athanasopoulos, 2017; Hendricks & Boroditsky, 2017), it is plausible that the learning of cross-modal spatio-temporal metaphors of CSL can also impact learners' time conceptualisations. For instance, Mandarin-CSL bilinguals "learn" to reconstruct the sagittal mental space-time mappings with the "past-at-back/future-in-front" as the dominant mappings.

Then the question is raised as to whether the differences in sagittal space-time mappings between Mandarin speakers and late bimodal bilinguals were merely due to bimodal bilinguals' learning of an L2 (having a different space-time metaphor than Mandarin). If this were the case, we would expect that Mandarin-English bilinguals may also have a similar change in space-time mappings as revealed by their co-speech gestures (since English, like CSL, usually also does not use past-in-front mappings). However, previous studies did not show such a pattern (e.g., Fuhrman *et al*., 2011; Gu, Hoetjes, & Swerts, in preparation), so that one can raise the question why Mandarin-English bilinguals still perform a large proportion of "past-in-front" temporal gestures while speaking Mandarin.

Apart from the possible influence of the L2 proficiency, this could be due to the fact that in English, these metaphoric gestures are not "learned" like CSL signs or emblematic gestures. Temporal conceptions are spatially more iconic in a signed language than a spoken language (e.g., CSL vs. English), as temporal signs are visually and physically salient in the signing movements. The acquisition of sign language requires the learner to linguistically make distinctions based on movement (Emmorey *et al*., 2009), and can enhance one's visual-spatial ability. For instance, habitual use of ASL may lead to enhanced memory for object orientation (Emmorey *et al.*, 1998). Therefore, if one learns a sign pointing to the back for the conception of past and keeps on signing like this on and on, day in and day out, it is imaginable that the person can form a habitual mapping of the past to the back. This is also in line with the *body-specificity hypothesis* (Casasanto, 2009) that particular patterns of bodily experience can give rise to corresponding habits of thinking, perceiving, and acting (Gibbs, 2003).

Furthermore, signs can be regarded as a special kind of action, representing the world linguistically by use of space whereas gestures are also claimed to generate from the same process that generates actions (Calbris, 2003; Chu & Kita, 2016; Kita & Özyürek, 2003; Streeck, 2009). Gestures can be regarded as *simulated actions* (Hostetter & Alibali, 2008), which have no physical consequence on the real world but share some properties with actions. Therefore, gesture and sign to some extent share the same action production system (e.g., Emmorey *et al*., 2008). The *Gesture-for-conceptualisation hypothesis* proposes that performing actions or gestures can activate and change one's spatial thinking (Kita, Alibali, & Chu, 2017). We believe that signing, a special kind of action in space, may also activate and change one's spatial thinking. For example, when bimodal bilinguals are signing about abstract ideas (e.g., time), the spatial movements of their hands may activate different spatio-motoric information from that of non-signers, which may affect bimodal bilinguals' spatial thinking in the long run. Given that people use space to think about time (e.g., Casasanto & Boroditsky, 2008), a different/new spatial thinking may consequently bring certain changes in space-time mappings, as shown in bimodal bilinguals' temporal gestures. Thus the results of this study appear to show an effect of (sign) language on thinking about time within a culture (Boroditsky, 2001; Chapter 4).

Alternatively, the results could be explained by the possibility that signing in a manner consistent with a past-at-back/future-in-front frame of reference primes bimodal bilinguals to gesture in a similar manner. This possibility is consistent with the proposal of *Gesture as Simulated Action* (Hostetter & Alibali, 2008): The activation of the motor system according to the spatio-temporal mapping via CSL may have primed the activation of the gesture system on a similar axis, which results in the effects observed in this study. This priming does not necessarily indicate that the bimodal bilingual's actual representations of time have changed, unlike the neo-Whorfian account that mentioned above (Nevertheless, this priming possibility is harder to reconcile with the findings concerning the relationship between the directionality of gesture and verbal expressions)[4].

Furthermore, one can even argue that co-speech temporal gestures do not necessarily reflect one's online conceptualisations of time, because they may only reveal speakers' implicit space-time mappings. Given all the above, future studies can use non-linguistic tasks (e.g., Fuhrman & Boroditsky, 2010; Fuhrman *et al.*, 2011) to further examine this in bimodal bilinguals of different signing proficiency.

Finally, the study provides a better understanding on the variation of the production of temporal gestures. Previous studies have shown that temporal gestures can be shaped by the reading and writing direction (e.g., Casasanto & Jasmin, 2012; Cooperrider & Núñez, 2009; Walker & Cooperrider, 2016), linguistic space-time metaphors (Chapters 2 and 3; Lai & Boroditsky, 2013), culture-specific belief (Núñez & Sweetser, 2006), use of cardinal frame of references (Boroditsky & Gaby, 2010), and geographical environments (Núñez *et al*., 2012).

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[4] We thank one anonymous reviewer for pointing out this alternative possibility.

This study, on the one hand, showed that temporal gestures can be shaped by the accompanying words that happen to be uttered, e.g., vertical/sagittal temporal words can lead to more vertical/sagittal temporal gestures. On the other hand, with a comparison between Mandarin-CSL late bilinguals and Mandarin-speaking non-signers, we discovered that temporal gestures can be affected by people's bodily experience of sign language which may influence CSL users' spatio-temporal thinking. Note that such differences in gesture production were unlikely due to the lexical effect of Mandarin temporal words, because both groups were speaking in the same L1 and the differences still existed even when the uttered words were identical. Therefore, the different temporal gestures may be due to their different thinking of using the body to interact with the physical environment (spatio-motoric thinking, Kita, 2000) to represent time in space. Overall, all this evidence suggests that the ultimate production of temporal gestures is a result of the linguistic words and the metaphoric spatio-motoric thinking (cf. Kita & Özyürek, 2003; Özçalişkan, 2016; Özçalişkan, Lucero, & Goldin-Meadow, 2016).

5 Conclusion

In this study we examined whether the experience of CSL influences the production of co-speech gestures about time in late bimodal bilinguals. The results showed that hearing people who have learned CSL performed differently in temporal gesture production than Mandarin speakers, both in terms of relative proportion of three time axes, and of the temporal orientation of sagittal gestures. Based on the mechanism of a shared production system between gestures and signs (Emmorey *et al*., 2008), and the *Gesture-for-conceptualisation hypothesis* (Kita, Alibali, & Chu, 2017), we believe that the learning of a signed language can not only have an impact on the nature of co-speech gestures but may also exert an influence on users' spatio-motoric thinking and their abstract reasoning such as space-time mappings. Although the study of space-time mappings in CSL has been somewhat neglected in the literature, this study could provide a first insight into a cross-modal influence of space-time metaphors on people's mental representations of time within a culture. Future research on this topic can adopt non-linguistic methods to corroborate our findings.

References:

Alibali, M. W. (2005). Gesture in spatial cognition: Expressing, communicating, and thinking about spatial information. *Spatial Cognition & Computation, 5*(4), 307- 331. doi:10.1207/s15427633scc0504_2

Bender, A., & Beller, S. (2014). Mapping spatial frames of reference onto time: A review of theoretical accounts and empirical findings. *Cognition, 132*, 342–382. doi:10.1016/j.cognition.2014.03.016

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition, 75*, 1–28. doi:10.1016/s0010-0277(99)00073-6

Boroditsky, L. (2001). Does language shape thought?: Mandarin and English speakers' conceptions of time. *Cognitive Psychology, 43*, 1–22. doi:10.1006/cogp.2001.0748

Boroditsky, L., & Gaby, A. (2010). Remembrances of times East: Absolute spatial representations of time in an Australian aboriginal community. *Psychological Science, 21*, 1635–1639. doi:10.1177/0956797610386621

Bostan, İ., Börütecene, A., Özcan, O., & Göksun, T., (2016). Temporal expressions in speech and gesture. In Papafragou, A., Grodner, D., Mirman, D., & Trueswell, J.C. (Eds.). *Proceedings of the 38th annual conference of the cognitive science society* (pp. 1871-1876). Austin, TX: Cognitive Science Society.

Brentari, D., Nadolske, M. A., & Wolford, G. (2012). Can experience with co-speech gesture influence the prosody of a sign language? Sign language prosodic cues in bimodal bilinguals. *Bilingualism: Language and Cognition, 15*(2), 402-412. doi:10.1017/S1366728911000587

Brown, A. & Gullberg, M. (2008). Bidirectional cross-linguistic influence in L1-L2 encoding of manner in speech and gesture. *Studies in Second Language Acquisition, 30*, 225-251. doi:10.1017/S0272263108080327

Brown, A. & Gullberg, M. (2011). Bidirectional cross-linguistic influence in event conceptualization? Expressions of Path among Japanese learners of English. *Bilingualism: Language and Cognition, 14*, 79-94. doi:10.1017/S1366728910000064

Bylund, E., & Athanasopoulos, P. (2017). The Whorfian time warp: Representing duration through the language hourglass. *Journal of Experimental Psychology: General*, *146*(7), 911–916. doi: 10.1037/xge0000314

Cabeza Pereiro, C., & Fernández Soneira, A. (2004). The expression of time in Spanish Sign Language (LSE). *Sign Language & Linguistics, 7*(1), 63-82. doi:10.1075/sll.7.1.06cab

Calbris, G. (2003). From cutting an object to a clear cut analysis: Gesture as the representation of a preconceptual schema linking concrete actions to abstract notions. *Gesture, 3*(1), 19-46.

Calbris, G. (2008). From left to right: Coverbal gestures and their symbolic use of space. In A. Cienki & C. Müller (Eds.), *Metaphor and gesture* (pp. 27–53). Amsterdam: John Benjamins.

Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition, 106*(2), 579–593. doi:10.1016/j.cognition.2007.03.004

Casasanto, D. (2009). Embodiment of abstract concepts: Good and bad in right- and left-handers. *Journal of Experimental Psychology: General, 138*(3), 351-367. doi:10.1037/a0015854

Casasanto, D., & Jasmin, K. (2012). The hands of time: temporal gestures in English speakers. *Cognitive Linguistics, 23*(4), 643-674. doi:10.1515/cog-2012-0020

Casey, S., & Emmorey, K. (2009). Co-speech gesture in bimodal bilinguals. *Language and Cognitive Process, 24*, 290–312. doi: 10.1080/01690960801916188

Casey, S., Emmorey, K., & Larrabee, H. (2012). The effects of learning American Sign Language on co-speech gesture. *Bilingualism: Language and Cognition*, *15*(4), 677-686. doi:10.1017/S1366728911000575P

China Association of the Deaf and Hard of Hearing (2003). *Chinese Sign Language* (中国手语). Beijing: Huaxia Publishing House.

Choi, S., & Lantolf, J. P. (2008). Representation and embodiment of meaning in L2 communication: Motion events in the speech and gesture of advanced L2 Korean and L2 English speakers. *Studies in Second Language Acquisition*, *30*(2), 191-224. doi:10.1017/S0272263108080315

Chu, M., & Kita, S. (2016). Co-thought and co-speech gestures are generated by the same action generation process. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42*(2), 257–270. doi:10.1037/xlm0000168

Chui, K. (2011). Conceptual metaphors in gesture. *Cognitive Linguistics, 22*(3), 437–458. doi:10.1515/cogl.2011.017

Cienki, A. (1998). Metaphoric gestures and some of their relations to verbal metaphorical expressions. In J. Koenig (Ed.), *Discourse and cognition: Bridging the gap* (pp. 189–204). Stanford, CA: CSLI Productions.

Cooperrider, K., & Núñez, R. (2009). Across time, across the body: Transversal temporal gestures. *Gesture, 9*(2), 181–206. doi:10.1075/gest.9.2.02coo

Cooperrider, K., D., Gentner, & S., Goldin-Meadow (2016). Spatial analogies pervade complex relational reasoning: Evidence from spontaneous gestures. *Cognitive Research: Principles and Implications*, *1*, 28. doi:10.1186/s41235-016-0024-5

Cooperrider, K., & Goldin-Meadow, S. (2017). When gesture becomes analogy. *Topics in Cognitive Science*, 1–19. doi: 10.1111/tops.12276,

Croissant, Y. (2012). Estimation of multinomial logit models in R: The mlogit Packages. *R package version 0.2-2. URL: http://cran.r-project.org/web/packages/mlogit/vignettes/mlogit. pdf.*

De la Fuente, J., Santiago, J., Román, A., Dumitrache, C., & Casasanto, D. (2014). When you think about it, your past is in front of you: How culture shapes spatial conceptions of time. *Psychological Science, 25*, 1682–1690. doi:10.1177/0956797614534695

Emmorey, K., Klima, E., & Hickok, G. (1998). Mental rotation within linguistic and non-linguistic domains in users of American Sign Language. *Cognition, 68*, 221-46.

Emmorey, K. (2001). Space on hand: The exploitation of signing space to illustrate abstract thought. In Merideth Gattis (ed.), *Spatial schemas and abstract thought* (pp. 147-174), Cambridge, MA, US: MIT Press.

Emmorey, K., Borinstein, H. B., Thompson, R., & Gollan, T. H. (2008). Bimodal bilingualism. *Bilingualism: Language and cognition, 11*(1), 43-61. doi:10.1017/S1366728907003203

Emmorey, K., Grabowski, T., McCullough, S., Ponto, L. L., Hichwa, R. D., & Damasio, H. (2005). The neural correlates of spatial language in English and American Sign Language: A PET study with hearing bilinguals. *Neuroimage, 24*(3), 832-840. doi: 10.1016/j.neuroimage.2004.10.008

Emmorey K., & McCullough S. (2009). The bimodal bilingual brain: effects of sign language experience. *Brain and Language, 109*, 124-32. doi:10.1016/j.bandl.2008.03.005

Emmorey, K., Giezen, M. R., & Gollan, T. H. (2016). Psycholinguistic, cognitive, and neural implications of bimodal bilingualism. *Bilingualism: Language and Cognition*, *19*(2), 223-242. doi:10.1017/S1366728915000085

Evans, V. (2004). *The structure of time: Language, meaning and temporal cognition*. Amsterdam: John Benjamins Publishing.

Evans V. (2013). *Language and time: a cognitive linguistics approach*. Cambridge: Cambridge University Press.

Fischer, S., & Gong, Q. (2010). Variation in East Asian sign language structures. In Diane Brentari (ed.), *Sign languages*, 502-521. Cambridge: Cambridge University Press.

Floyd, S. (2016). Modally hybrid grammar?: Celestial pointing for time-of-day reference in Nheengatú. *Language*, *92*(1), 31–64. doi:10.1353/lan.2016.0013

Fuhrman O., Boroditsky L. (2010). Cross-cultural differences in mental representations of time: Evidence from an implicit nonlinguistic task. *Cognitive Science*, *34*, 1430–1451. doi:10.1111/j.1551-6709.2010.01105.x

Fuhrman, O., McCormick, K., Chen, E., Jiang, H. D., Shu, D. F., Mao, S. M., & Boroditsky, L. (2011). How linguistic and cultural forces shape conceptions of time: English and Mandarin time in 3D. *Cognitive Science, 35*, 1305–1328. doi:10.1111/j.1551-6709.2011.01193.x

Gentner, D., Imai, M., & Boroditsky, L. (2002). As time goes by: Evidence for two systems in processing space time metaphors. *Language and Cognitive Processes*, *17*(5), 537–565. doi:10.1080/01690960143000317

Gibbs, R. W. (2003). Embodied experience and linguistic meaning. *Brain and Language, 84*(1), 1-15. doi:10.1016/s0093-934x(02)00517-5

Giezen, M., & Emmorey, K. (2016). Language co-activation and lexical selection in bimodal bilinguals: Evidence from picture–word interference. *Bilingualism: Language and Cognition, 19*(2), 264-276. doi:10.1017/S1366728915000097

Hendricks, R. & Boroditsky, L. (2017). New space-time metaphors foster new non-linguistic representations. *Topics in Cognitive Science.* doi:10.1111/tops.12279.

Hostetter, A. B., & Alibali, M. W. (2008). Visible embodiment: Gestures as simulated action. *Psychonomic Bulletin & Review*, *15*(3), 495–514. doi:10.3758/pbr.15.3.495

Kita, S. (2000). How representational gestures help speaking. In D. McNeill (Eds.), *Language and gesture* (pp. 162–185). Cambridge, MA: Cambridge University Press. doi:10.1017/cbo9780511620850.011

Kita, S., Danziger, E., & Stolz, C. (2001). Cultural specificity of spatial schemas, as manifested in spontaneous gestures. In M. Gattis (Ed.), *Spatial schemas and abstract thought* (pp. 115-146). Cambridge, MA: MIT Press.

Kita, S., Alibali, M. W., & Chu, M. (2017). How do gestures influence thinking and speaking? The Gesture-for-Conceptualization Hypothesis. *Psychological Review, 124*(3), 245-266. doi:10.1037/rev0000059

Kita, S., & Özyürek, A. (2003). What does cross-linguistic variation in semantic coordination of speech and gesture reveal? Evidence for an interface representation of spatial thinking and speaking. *Journal of Memory and Language, 48*(1), 16–32. doi:10.1016/s0749-596x(02)00505-3

Lai, V. T., & Boroditsky, L. (2013). The immediate and chronic influence of spatio-temporal metaphors on the mental representations of time in English, Mandarin, and Mandarin-English speakers. *Frontiers in Psychology, 4,* 1–10. doi:10.3389/fpsyg.2013.00142

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago, IL: University of Chicago Press.

Lausberg, H., & Sloetjes, H. (2009). Coding gestural behavior with the NEUROGES-ELAN system. *Behavior Research Methods*, *41*(3), 841–849. doi:10.3758/brm.41.3.841

Le Guen, O., & Balam, L. I. P. (2012). No metaphorical timeline in gesture and cognition among Yucatec Mayas. *Frontiers in Psychology, 3.* doi:10.3389/fpsyg.2012.00271

Maeder, C., & Loncke, F. (1996). Spatial, temporal and temporo-logical notions in French Sign Language: Comparative study of deaf and hearing subjects. *Sign Language Studies, 90*(1), 38-51. doi:10.1353/sls.1996.0006

Meade, G., Midgley, K., Sevcikova Sehyr, Z., Holcomb, P., & Emmorey, K. (2017). Implicit co-activation of American Sign Language in deaf readers: An ERP study. *Brain and Language*, *170*, 50-61. doi:10.1016/j.bandl.2017.03.004

Morford, J. P., Wilkinson, E., Villwock, A., Piñar, P. & Kroll, J. F. (2011). When deaf signers read English: Do written words activate their sign translations? *Cognition, 118* (2), 286-292. doi:10.1016/j.cognition.2010.11.006

Moore, K. E. (2011). Ego-perspective and field-based frames of reference: Temporal meanings of FRONT in Japanese, Wolof, and Aymara. *Journal of Pragmatics, 43*(3), 759-776. doi:10.1016/j.pragma.2010.07.003

Moore, K. (2014). *The spatial language of time. Metaphor, metonymy and frames of reference*. Amsterdam & Philadelphia: John Benjamins.

Nilsson, A. L. (2016). Embodying metaphors: Signed language interpreters at work. *Cognitive Linguistics*, *27*(1), 35-65. doi:10.1515/cog-2015-0029

Núñez, R., Cooperrider, K., Doan, D, Wassmann, J. (2012). Contours of time: Topographic construals of past, present, and future in the Yupno valley of Papua New Guinea. *Cognition*, *124*, 25–35. doi:10.1016/j.cognition.2012.03.007

Núñez, R., Cooperrider, K., (2013). The tangle of space and time in human cognition. *Trends in Cognitive Sciences*, *17*, 220–229. doi:10.1016/j.tics.2013.03.008

Núñez, R., Motz, B., & Teuscher, U. (2006). Time after time: The psychological reality of the ego- and time-reference-point distinction in metaphorical construals of time. *Metaphor and Symbol, 21*, 133–146. doi:10.1207/s15327868ms2103_1

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*, 401–450. doi:10.1207/s15516709cog0000_62

Ortega, G., & Morgan, G. (2015). The effect of sign iconicity in the mental lexicon of hearing non-signers and proficient signers: Evidence of cross-modal priming. *Language, Cognition and Neuroscience, 30*(5), 574-585. doi:10.1080/23273798.2014.959533.

Özçalışkan, Ş. (2016). Do gestures follow speech in bilinguals' description of motion? *Bilingualism: Language and Cognition*, *19(3)*, 644-653. doi:10.1017/s1366728915000796

Özçalışkan, Ş, Lucero, C., & Goldin-Meadow, S. (2016). Does language shape silent gesture? *Cognition, 148*, 10–18. doi:10.1016/j.cognition.2015.12.001

Pika, S., Nicoladis, E., & Marentette, P. F. (2006). A cross-cultural study on the use of gestures: Evidence for cross-linguistic transfer?. *Bilingualism: Language and Cognition*, *9*(3), 319–327. doi:10.1017/S1366728906002665

Pyers, J., & Emmorey, K. (2008). The face of bimodal bilingualism: Grammatical markers in American Sign Language are produced when bilinguals speak to English monolinguals. *Psychological Science*, 19, 531–536. doi:10.1111/j.1467-9280.2008.02119.x

Schermer, T., & Koolhof, C. (1990). The reality of time-lines: Aspects of tense in Sign Language of the Netherlands (SLN). In S. Prillwitz & T. Vollhaber (eds.), *Current trends in European sign language research*, pp. 295-305. Hamburg: Signum.

Sinte, A. (2013). Expression of time in French Belgian Sign Language (LSFB). In Meurant, L. Sinte, A., Van Herreweghe, M., & Vermeerbergen, M. (Eds.), *Sign language research, uses and practices: Crossing views on theoretical and applied sign language linguistics* (pp. 205-235). Berlin: De Gruyter Mouton and Ishara Press. doi: 10.1515/9781614511472.205

Streeck, J. (2009). *Gesturecraft: The manu-facture of meaning*. Amsterdam: John Benjamins

Traugott, E.C. 1978. On the expression of spatio-temporal relations in language. In *Universals of human language word structure*, Vol. 3, J. Greenberg (ed.), 369-400. Stanford CA: Stanford University Press.

Tversky, B. (2011). Visualizing Thought. *Topics in Cognitive Science, 3*(3), 499–535. doi:10.1111/j.1756-8765.2010.01113.x

Walker, E. J., Bergen, B. K., & Núñez, R. (2017). The spatial alignment of time: Differences in alignment of deictic and sequence time along the sagittal and lateral axes. *Acta Psychologica, 175*, 13–20. doi: 10.1016/j.actpsy.2017.02.001

Walker, E., & Cooperrider, K. (2016). The continuity of metaphor: Evidence from temporal gestures. *Cognitive Science, 40*(2), 481–495. doi:10.1111/cogs.12254

Wilcox, S. (2002). The iconic mapping of space and time in signed languages. In L. Albertazzi (ed.), *Unfolding perceptual continua*, 255-281. Amsterdam & Philadelphia: John Benjamins. doi:10.1075/aicr.41.12wil

Wu, L., & Li, H. (2012). Time-space metaphors in Chinese Sign Language (中国手语中的时间空间隐喻). *Chinese Journal of Special Education*, *150*(12), 25-29.

Wu, Y. J., & Thierry, G. (2010). Chinese–English bilinguals reading English hear Chinese. *Journal of Neuroscience, 30*(22), 7646-7651. doi:10.1523/jneurosci.1602-10.2010

Xiao, C., Zhao, M. & Chen, L. (2017). Both earlier times and the future are “Front”: The distinction between time- and ego-reference-points in Mandarin speakers’ temporal representation. *Cognitive Science*. doi:10.1111/cogs.12552

Yang, J. H. (2005). Expressing negation in Chinese sign language. *MA Thesis*. Rochester Institute of Technology. Accessed from http://scholarworks.rit.edu/theses/4010

Yang, J. H. (2015) Chinese Sign Language. In Jepsen, J.B., De Clerck, G., Lutalo-Kiingi, S., McGregor, W. B. (Eds), *Sign languages of the world: A comparative handbook* (pp. 177-194). Berlin: De Gruyter. doi:10.1515/9781614518174-012

Yu, N. (2012). The metaphorical orientation of time in Chinese. *Journal of Pragmatics, 44*, 1335–1354. doi:10.1016/j.pragma.2012.06.002

Zheng, X. (2009). *A study of signs for non-visual concepts in Shanghai Variety of Chinese Sign Language* (上海手语非视觉概念表达研究). PhD Dissertation. Fudan University, China.

Zou, L., Abutalebi, J., Zinszer, B., Yan, X., Shu, H., Peng, D., & Ding, G. (2012). Second language experience modulates functional brain network for the native language production in bimodal bilinguals. *NeuroImage, 62*, 1367–1375. doi:10.1016/j.neuroimage.2012.05.062

Chapter 4. Back to the future or the past? The effect of Chinese Sign Language (CSL) on deaf CSL-Mandarin bilinguals' spatial conceptualisation of time

Abstract: Chinese Sign Language (CSL) has past-at-back space-time metaphors whereas Mandarin additionally allows past-in-front metaphors. In this paper we focused on a previously unexplored population, deaf CSL-Mandarin bilinguals, and investigated (1) the effect of such cross-modal/linguistic differences on their sagittal space-time mappings and (2) whether they have a different spatial-temporal reasoning than Mandarin hearing speakers. In Experiment 1 we tested deaf bilinguals' (N=123) sagittal space-time mappings first in CSL and then in Mandarin. Particularly, the temporal expressions in the Mandarin test (but not in CSL) had overt past-in-front/future-at-back metaphors indicating past-in-front/future-at-back mappings. Results showed that deaf signers, irrespective of in CSL or Mandarin, were less likely to have past-in-front/future-at-back mappings than Mandarin speakers, even after controlling for related factors such as temporal-focus and age. In Experiment 2, we used real life questions to examine participants' understanding of time in Mandarin, related to the ego-moving and time-moving perspectives. Results showed that, Mandarin speakers mostly took the time-moving perspective whereas deaf signers, influenced by the CSL time perspective, were less likely to take the Mandarin time-moving perspective. Such results still held even when only limiting to deaf participants with higher education (highly proficient in Mandarin). Experiment 3 replicated Experiments 1 and 2 and further showed that deaf bilinguals (N=104) performed differently between CSL and Mandarin, and that age of acquisition of CSL and CSL proficiency affect signers' future-in-front/past-at-back mappings. Within the Chinese culture, signers persistently displayed a different spatial-temporal reasoning than Mandarin speakers. We conclude that bodily experience of sign language (especially at an earlier age) impacts signers' spatial and temporal thinking. This first study on deaf signers' spatial temporal reasoning not only has implications for theories on space-time mappings, but also for the relationship between signed language and thought.

Key words: Chinese Sign Language (CSL); bimodal bilingualism; cross-modal influences; conceptual metaphor; language and thought; space and time; temporal-focus hypothesis

Acknowledgements: This work is supported by grants from The Netherlands Organization for Scientific Research, via NWO Promoties in de Geesteswetenschappen (322-89-007) to YG, NWO Research Talent (406-15-298) to YQZ, and a grant from the Ministry of Education, China, via Humanities and Social Sciences Research (20YJC740027) to LH. We thank Eva (Huan) Sheng, Christy (Yingjie) Ni, Weiyu Cai and our deaf participants for their help with this study. Results have been orally presented at the UK cognitive linguistic conference (2020).

The chapter is based on:

Gu, Y., Lin, H. & Zheng, Y. (in revision) Back to the future or the past? The effect of Chinese Sign Language (CSL) on deaf CSL-Mandarin bilinguals' spatial conceptualisation of time. *Journal of Memory and Language*.

Introduction

People use spatial representations to conceptualise time (e.g., Boroditsky, 2000; Casasanto & Boroditsky, 2008, see reviews in Bender & Beller, 2014; Núñez & Cooperrider, 2013). Most Westerners feel that the past is behind, and the future is in front of them (e.g., Miles et al., 2010; Ulrich et al., 2012). Such an intuition matches the human's experience of walking in a certain direction, which is usually moving towards the front, so that the passed-by path is the past and the place ahead represents the future (e.g., Clark, 1973). The future-in-front and past-at-back mappings are also reflected in the way speakers talk about time linguistically, e.g., in English, 'We look forward to the New Year ahead, and look back to the hard times behind' (e.g., Lakoff & Johnson, 1980).

In some cultures people spatialize the future and the past in an opposite way (e.g., Sullivan & Bui, 2016). For example, Aymara speakers conceptualise past things as in front of them, and the future as yet unseen events behind them. Such mappings are consistent with their space-time metaphors, as 'front year' in Aymara has the meaning of 'last year' (Núñez & Sweetser, 2006).

Interestingly, in Arabic the metaphoric expression of front/back time closely matches that of most future-in-front languages such as English and Spanish, but Moroccans still tend to have past-in-front mappings. The reason for it is claimed to be related to the fact that, in their culture, tradition and old generations are more valued, and they are more past-focused (temporal-focus hypothesis, de la Fuente et al., 2014). According to this hypothesis, people who are past-focused metaphorically should have a tendency to place the past in front of them, 'in the location where they could focus on the past literally with their eyes if past events were physical objects that could be seen' (p.1684). Thus space-time mappings in people's minds are claimed to be conditioned by their cultural attitudes towards time, which could be independent from the space-time mappings expressed in language.

Nevertheless, a recent study on Mandarin speakers shows that there are not only long-term effects of cultural attitudes on the spatialisation of time, but also immediate effects of lexical cues to space-time metaphors which can probe people's mental representations. Gu, Zheng and Swerts (2019a) found that Chinese people are intermediate between Spaniards and Moroccans in cultural temporal-focus, and accordingly they are intermediate between Spaniards and Moroccans in their tendency to place the past in front. More importantly, the extent to which Mandarin speakers have past-in-front mappings is online affected by the different words of Mandarin space-time metaphors, even after controlling for participants' temporal-focus of attention.

Such an effect of spatial-temporal language on people's mental representation of time has also been observed between speakers of different languages (e.g., Boroditsky, 2001; Bylund & Athanasopoulos, 2017) or between two languages of bilinguals (Gu, Mol et al., 2017; Fuhrman et al., 2011). Somewhat surprisingly, so far all studies have focused on effects of spoken space-time metaphors on hearing people whereas no study has investigated the effect of a signed language on users' spatio-temporal reasoning.

Sign languages are structured quite differently from spoken languages, and they provide an excellent tool to study the possible impact of language (and language modality) on conceptual representations (Emmorey, 2019). Deaf signers also use linguistic space-time metaphors to represent time but in the manual modality by means of signs. Especially, in the case of Chinese, they represent a particular interesting group, as they share a similar culture to hearing Chinese, but use a manual language that encodes different sagittal time-space mappings (see more in background). However, Chinese Sign Language (CSL) is very understudied in the literature, let alone research on Chinese deaf signers' expressions of time and their spatial-temporal reasoning. Thus it is entirely unknown how deaf signers' bodily experience of CSL would interact with the different Mandarin space-time metaphors across modalities.

The present study aims to provide a first insight into the effect of such cross-modal and cross-linguistic influences on Chinese deaf signers' sagittal space-time mappings and find out whether deaf CSL-Mandarin signers have a different spatial-temporal reasoning than Mandarin speakers.

Background

Mandarin space-time metaphors and temporal gestures

Mandarin has different spatial metaphors for time. The most well-known one is the employment of vertical spatial metaphors to represent time conceptions of 'early' and 'late', e.g., '上周/shàng zhōu' (literally 'above week') means 'last week', while '下周/xià zhōu' (literally 'below week') refers to 'next week'. Interestingly, Mandarin speakers can also spontaneously point *upwards* for 'last week' and downwards for 'next week' (Gu, Mol et al., 2017), which is consistent with the vertical spatial-temporal language.

The vertical mapping only accounts for about 20%–30% of Mandarin space-time metaphors, whereas the majority are the sagittal temporal metaphors (67.2%–76.46%, Chen, 2007; Yang & Sun, 2016). Some Mandarin sagittal time metaphors can suggest past-at-back/future-in-front space-time mappings, with the past behind and future in front of the ego (an ego-reference-point metaphor, Example 1, Table 1). By contrast, some other sagittal time metaphors can linguistically represent the reverse, i.e., with past-in-front/future-at-back mappings (Example 2, Table 1, termed as a time-reference-point metaphor/earlier-times-in-front-of-later-times in Yu, 2012; Xiao, Zhao & Chen, 2018).

As for the spatial metaphors implying past-in-front and future-at-back mappings (Example 2), the expressions of the temporal conceptions of 'past' and 'future' are commonly consisted of sagittal space-time words, i.e., '前/qián' (literally 'front') and '后/hòu' (literally 'back'). Such a space-time word as '前/qián' can indicate both the spatial concept of 'forward/front' and the temporal concept of ‘early/before’, whereas ‘后/hòu’ indicates both the spatial concept of ‘back/behind’ and the temporal concept of ‘late/after’[1]. In this way the space-time words suggest past-in-front/future-at-back space-time mappings. Importantly, these temporal expressions (Example 2) are not ambiguous as they can by no means refer to others but time. In Mandarin such past-in-front/future-at-back space-time mappings are much more frequent than the past-at-back/future-in-front mappings[2] (Chen, 2007).

Table 1. *Examples of future-in-front (1) and past-in-front (2) mappings in Mandarin.*

Example (1)	展/zhǎn 望/wàng	未/wèi 来/lái
	unfold gaze-into-distance	hasn’t come
	Looking far ahead/into the future.	
	回/huí 首/shǒu	过/guò 去/qù
	turn-around head	pass go
	Looking back to the past.	
Example (2)	前/qián 天/tiān,	今/jīn 后/hòu
	front day,	today back
	the day before yesterday,	from now on

Mandarin speakers also perform sagittal gestures to express time. In addition to the ‘common’ temporal gestures that point the past to the back (Casasanto & Jasmin, 2012; Cooperrider & Núñez, 2009; Walker & Cooperrider, 2016), Mandarin speakers can point to the front of the body to indicate the concept of temporal ‘before’ (Chui, 2011, 2018). Recent quantitative research further reveals that about half of sagittal temporal gestures (49%) were produced with the future behind and the past in front of the speakers. There was an effect of temporal wordings on the production of sagittal time gestures, e.g., the proportion of past-in-front/future-at-back gestures uttered with Mandarin past-in-front/future-at-back metaphors (72.34%) was higher than when uttered with future-in-front/past-at-back metaphors (22.22%) (Gu et al., 2019a).

Finally, in Mandarin there is no left-right space-time metaphor, but Mandarin speakers do frequently use the lateral axis (past-to-left/future-to-right) to gesture about time (Gu et al., 2019b).

Time, space and signs in Chinese Sign Language (CSL)

[1] It is rare to use ‘前/qián’ (front) to indicate ‘late/after’ and ‘后/hòu’ (back) to indicate ‘early/before’, e.g., only 2.75% of temporal use of “后/hòu” refers to “early/before” according to a corpus survey (Peng, 2012). In ancient Chinese (before Late Middle Chinese), “前/qián” (front) was only used to express the concept of past and “后/hòu” (back) was only used to express the concept of future (Xu, 2016).

[2] According to a search in a modern Mandarin corpus (http://corpus.zhonghuayuwen.org/, 20 million words, Jin, Xiao, Fu & Zhang, 2005), we found that there were 32,542 times of the past-in-front/future-at-back space-time mappings (using ‘前/qián’(front, past) and ‘后/hòu’ (back, future) whereas there were only 5,820 times of past-at-back/future-in-front mappings (using ‘过去’ (pass go, past); ‘未来/将来’ (will come, future).

It is visible that sign languages make use of space to express time (e.g., Nilsson, 2016, 2018; Wilcox, 2002). Although various elements such as lexical items, specific markers (e.g., not yet, finished), pointings, hand holds, or non-manual behavior (e.g., facial expressions and body movements) can be used to express time in sign languages, the metaphorical representation of time as timelines is an unavoidable starting point in any description of temporal marking (Sinte, 2013).

There are many timelines in most sign languages (e.g., Danish Sign Language has four timelines, Engberg-Pedersen, 1999; Dutch Sign Language has five timelines, Schermer & Koolhof, 1990). The sequence and deictic timelines are some of the concepts suggested for certain directions in space used to convey time in signed languages. In American Sign Language (ASL), for instance, the sequential timeline can be parallel to signers' body and extends laterally, representing earlier to later time periods, and it can also be used when signers refer to a sequence of ordered events (Emmorey, 2001). The deictic use of the 'back-to-front-timeline' to refer to past, present and future was first found in ASL and has also been described for many other sign languages such as British Sign Language (Brennan, 1983), French Sign Language (Maeder & Loncke, 1996), and Spanish Sign language (Cabeza Pereiro & Fernández Soneira, 2004) (see a review in Sinte, 2013).

Studies on temporal expressions in Chinese Sign Language (CSL), however, is very limited. Zheng (2009) did a case study by interviewing four deaf signers about temporal signs, based on which she described that CSL deaf signers could employ the sagittal (future-in-front/past-at-back), vertical (future-to-down/ past-to-up) and lateral (earlier-to-left/later-to-right) timelines. Wu and Li (2012) surveyed temporal expressions in a CSL dictionary, and also identified these three timelines.

Recently, based on a naturalistic CSL corpus, Lin and Gu (submitted) did the first systematic study of CSL temporal expressions produced by 72 deaf signers. They found that time in CSL can be expressed through the use of part of the body, iconicity, number incorporation and timeline-based signs. Especially, the sagittal, vertical and lateral timelines account for the largest part of temporal expressions in CSL[1].

Interestingly, they discovered that there are mainly two types of sagittal temporal signs to express the conception of 'past' in CSL. First, it is most often signed toward the back of the right shoulder (Fig. 1a), thus indicating past-at-back mappings. The second type is a variation of the first one: a sign of a person-classifier ('A' handshape formed by both hands) is located in neutral space near a signer as a time reference point, and then the dominant hand is drawn back (Fig. 1b). The back of the person-classifier is symbolized as the past. Despite that this type of sign for past is located in front of a signer, the concept of early or before is still signed behind the time reference point. Crucially, such a past-to-backwards mapping for the timeline of time reference point metaphor is remarkably different

[1] CSL signers most often use the vertical axis for future concepts whereas they most often use the sagittal axis for past concepts. The horizontal axis is used the least (Lin & Gu, submitted).

from the Mandarin earlier-times-in-front-of-later-times metaphor (past-in-front mappings) as their timeline orientations are completely reversed.

1a **1b**

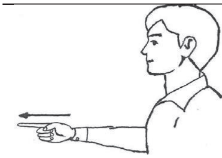
Figure 1. Two types of temporal signs to express the conception of 'past' in CSL

Space-time mappings: Mandarin vs. CSL

With a comparison between CSL and Mandarin space-time mappings, the most notable differences seem to lie on the sagittal timelines. Mandarin has metaphors that can suggest both past-at-back/future-in-front and past-in-front/future-at-back space-time mappings, whereas the CSL sagittal lexical signs do not have any past (early)-in-front/future-at-back space-time mappings (Lin & Gu, submitted).

Take the time conceptions of 'the day before yesterday' and 'the day after tomorrow' for instance (Table 2): in Mandarin the direction of 'the day before yesterday (前天/qián-tiān, front day)' is literally to the front while 'the day after tomorrow (后天/hòu-tiān, back day)' is literally to the back. By contrast, in CSL these time concepts are expressed in a completely reversed direction, i.e., the temporal sign of 'the day before yesterday' is directed to the back whereas 'the day after tomorrow' is signed to the front (China Association of the Deaf and Hard of Hearing, 2003; Zheng, 2009).

Table 2. *Differences between Mandarin Chinese and CSL in sagittal space-time metaphors*.

	Mandarin Chinese	CSL
Space: Front	**前面 (*front* surface)**	 One hand, with the index finger extended*, points to the very front*.
Time: The day before yesterday	**前天 (*front* day)**	 The index and middle fingers *point to the back* once.
Space: Back	**后面 (*back* surface)**	 One hand, with the index finger extended, points to the *back* of shoulder.
Time: The day after tomorrow	**后天 (back day)**	 The index and middle fingers point *forward*.

The differences in sagittal space-time mappings between CSL and Mandarin may be related to the different use of sagittal space-time metaphors. In Mandarin '前/qián' and '后/hòu' are the only words expressing the purely spatial concept of 'front' and 'back', but they also actively have the temporal concepts of 'before/past' and 'after/future', thus indicating past-in-front mappings (e.g., Mandarin earlier-times-in-front-of-later-times metaphor, Example 2, Table 1). However, in CSL, there are no such past-in-front mappings, because the spatial 'front' and the temporal 'before' are signed to different directions (also for 'back' and 'after'). In other words, the sign representing spatial 'front' cannot be used to indicate the past, and the sign representing spatial 'back' cannot be used to indicate the future[1].

[1] The CSL signs indicating 'past' and 'future' cannot be directly used to indicate spatial 'back' and 'front' and the sagittal lexical spatial signs themselves usually do not have temporal uses. However, both the temporal and spatial signs can make use of the space near signers' body along a same axis, e.g., the phonology of the signs indicating 'past' and spatial

Do bilinguals think about time differently in each language?

There has been a growing number of studies showing that speakers of different languages may have different ways of thinking about time (e.g., Boroditsky, 2001; Bylund & Athanasopoulos, 2017), but only several studies have compared whether bilinguals conceptualise time differently between their L1 and L2. These studies revealed that there is an effect of immediate linguistic context on bilinguals' conceptualisation of time (Fuhrman et al., 2011; Gu, Mol et al., 2017; Li et al., 2019). For example, a spontaneous gesture study showed that Mandarin-English bilinguals produced vertical temporal gestures when talking about Mandarin time conceptions with vertical spatial metaphors whereas they produced lateral gestures when talking about same time conceptions in English. Similarly, Mandarin-English speakers preferred vertical gestures to lateral gestures when perceiving time references expressed by Mandarin vertical spatial metaphors. This bias towards vertical gestures still existed when they perceived them in L2 English, but to a significantly lesser extent (Gu, Mol et al., 2017). Such results seem to suggest that when bilinguals operate time in the L2, they unconsciously access irrelevant native language representations that shape time conceptualisation in real time (Li et al., 2019), and the cognitive processing of time is also quite flexible and can be driven by the language of operation (cf. motion events, Athanasopoulos et al., 2015; Bylund & Athanasopoulos, 2017).

However, Gu, Mol et al. (2017) found that Mandarin-English bilinguals did not gesture or perceive time differently between L1 and L2 when the time expressions were expressed with neutral words (words without any spatial indicator). Thus, the differences between bilinguals' L1 and L2 space-time mappings are usually found only in the instances where there are cross-linguistic differences in space-time metaphors.

As for sign bilingualism, two studies have revealed that there is an implicit co-activation of signs in deaf readers. It is clear that deaf readers of English print would activate the sign translations of written words even the signs are not contextually required to perform the task (Meade et al., 2017; Morford et al., 2011). What remains controversial is as to whether sign bilinguals think differently in each language. One recent study on sign–speech bilinguals has found that neural representations of semantic categories, such as fruit, animals, transportation are shared across British Sign Language and English, but individual items, such as apple, mouse, bicycle are not (Evans et al., 2019). It appears that the neural representation of high-level semantic categories is not impacted by language or modality whereas neutral patterns differed for individual signs and words that conveying the same concepts (translation equivalents) (see more discussion in Emmorey, 2019). However, no study so far has investigated whether bimodal bilinguals or deaf sign–print bilinguals think differently about abstract concept such as time in each language. It is also unknown whether deaf CSL-Mandarin bilinguals have a different spatial temporal reasoning than Mandarin speakers.

'back' are different in terms of handshapes and location while they share a similar sagittal movement towards the back of the signer. Additionally, verbs in CSL do not conjugate.

The current study

This study aims to investigate whether the experience of cross-modal and cross-linguistic differences in space-time metaphors would influence deaf signers' spatial conceptualisation of time. Specifically, we first study how deaf CSL-Mandarin bilinguals use the front-back space to conceptualise time in both CSL and Mandarin and the possible differences between two languages. Secondly, we examine in the context of Chinese culture, whether deaf CSL-Mandarin bilinguals have a different sagittal spatio-temporal reasoning than Mandarin hearing speakers.

In addition to a test on deaf CSL-Mandarin bilinguals' sagittal mental space-time mappings in CSL, we would investigate how they spatialize time in Mandarin. Given that a written form of a spoken language and a signed language are co-activated in a deaf signer's mind (e.g., Morford et al., 2011), and given that unimodal bilinguals may unconsciously retrieve irrelevant L1 time representation when processing L2 time (Gu, Mol et al., 2017; Li et al., 2019), when deaf CSL-Mandarin bilinguals read Mandarin past-in-front/future-at-back metaphors for time, the CSL signs for 'past/before' and 'future/after' will also be activated, but the sagittal temporal direction suggested by the CSL timeline can be *reversed* in comparison to the Mandarin timeline orientation (as shown in Table 2).

Such an 'inconsistency' raises an interesting point as to how CSL deaf signers conceptualise Mandarin sagittal space-time metaphors, which provides a unique opportunity to examine the cross-modal and cross-linguistic influences on space-time mappings. Sign language itself relies heavily on space, and the signing of time in space is visually iconic. If they view these Mandarin past-in-front time metaphors (e.g., '前天/qián-tiān', front day, the day before yesterday) mainly in a timeline that is consistent with their CSL, their conceptions of the past are likely to be at their back and those of the future in front.

By contrast, if there is an effect of immediate linguistic context on bilinguals' conceptualisation of time (Fuhrman et al., 2011; Gu, Mol et al., 2017; Li et al., 2019), and if the acquisition of new past-in-front space-time metaphors can change one's conceptualisation of time (e.g., Boroditsky, 2001; Hendricks, Bergen & Marghetis, 2018), deaf signers may think in a timeline that is consistent with what suggested by these Mandarin metaphors, thus having the possibility of mapping the past as in front. However, the extent to which such a change occurs may be affected by their sign language proficiency or age of acquisition of sign language.

Furthermore, given that unimodal (spoken) bilinguals may conceptualise same time concepts differently between two languages when such concepts have different space-time metaphors in L1 than in L2 (Gu, Mol et al., 2017), if the similar case applies to the sign-print bilinguals, deaf CSL-Mandarin bilinguals are expected to have more past-at-back space-time mappings in CSL than in Mandarin (with past-in-front metaphors).

To examine all this, we have conducted three experiments: In Experiment 1 we used a CSL and Mandarin versions of 3D temporal diagram task to test CSL-Mandarin deaf readers' sagittal space-time mappings and compared their performances with those of Mandarin hearing speakers. In Experiment 2, we used two classic real-life questions about time to explicitly test whether deaf CSL-Mandarin bilinguals have a different understanding of time than hearing speakers. In Experiment 3, we did a replication study of Experiment 1 and 2 to examine the generalisation of the findings.

Experiment 1

In this experiment, a temporal diagram task (e.g., de la Fuente et al., 2014; Gu et al., 2019a; Li & Cao, 2018a, b) was used to assess participants' mental space-time mappings. To examine deaf signers' time conceptualisation, as well as to make a comparison with the hearing speakers, deaf participants were asked to do the task where the instruction was in CSL; to study the cross-linguistic influences, deaf signers were also asked to do the task that was instructed in Mandarin print, where temporal expressions were expressed with overt past-in-front/future-at-back metaphors. The latter would not only allow for an additional comparison with Chinese hearing speakers who did the identical task that was instructed in Mandarin print, but also provide an opportunity to look into whether CSL deaf signers had different space-time mappings when the task instruction was in Mandarin as opposed to CSL.

Furthermore, given that previous research suggests that people's sagittal space-time mappings are also influenced by their cultural values toward time (de la Fuente et al., 2014; Li & Cao, 2018a, b), a temporal-focus questionnaire was used to survey participants' time attitudes. Altogether, this experiment allowed us to examine the respective role of a spoken language, CSL bodily experience, and cultural temporal values on space–time mappings.

Method

Participants

184 participants, including 123 CSL-Mandarin deaf signers (M_{age} = 32.53 years, 68 females and 55 males) and 61 Mandarin-speaking non-signers (M_{age} = 31.58 years, 36 females and 25 males), took part in the experiment in China. The 61 non-signers had no hearing deficits or CSL experience. These non-signers were participants in Gu et al. (2019a)'s study (Experiment 3), whose data were used as comparison materials in Experiment 1 of the present study. The deaf participants were individually recruited by three deaf research assistants.

On average, the deaf participants had some college education (M = 4.11), and the hearing participants had some university undergraduate education (M = 5.02, college = 4, university bachelor = 5, master = 6). The deaf CSL-Mandarin bilinguals became deaf at an early age (M = 2.46 years, SD = 5.04). Their hearing loss was between severe and profound (M = 3.18, slight = 1, moderate = 2, severe = 3, profound = 4). As shown by a self-assessment (1-5), their average CSL proficiency was between intermediate to good (M = 3.29, SD = .93), and their Mandarin proficiency was at the same level (M = 3.22, SD = .85, t = 0.96, p = .34). 35 deaf participants reported to have at least one parent who was deaf.

Materials and procedure

We used exactly the same 3D temporal diagram task (right, Fig. 2) as that in Gu et al. (2019a)'s study (Experiment 3), which was adapted from de la Fuente et al. (2014)'s version (left, Fig.2). This 3D paradigm has been used to study Mandarin speakers' space-time mappings. All deaf participants did the task once in CSL and once in Mandarin print.

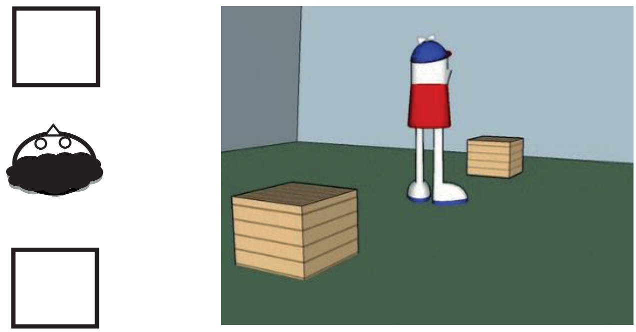


Figure 2. Schematic illustration of de la Fuente et al. (2014)'s temporal diagram task (left); a still picture from the 3D animated video of Experiment 1 (right).

Specifically, following Gu et al. (2019a)'s procedure, participants received an online link in which they saw a 3D animated clip of a character named Xiaoming with one box behind and one box in front of him. In the Mandarin version of the task, signers were provided with an instruction of Mandarin print in which they could read that the day before yesterday (前天/qián-tiān, 'front day') Xiaoming went to visit a friend who liked eating apples, and the day after tomorrow (后天/hòu-tiān, 'back day') he would be going to visit a friend who likes eating pears (or vice versa). Participants were instructed to put the apple in the box that corresponded to the past (以前/yǐ-qián, 'to front') and the pear in the box that corresponded to the future (今后/jīn-hòu, 'today back'). The mentioning order of the 'apple' and 'pear' and the way they were paired with 'the day before yesterday' and 'the day after tomorrow' were counterbalanced. Note that the phrases such as '以前/yǐ-qián' and '今后/jīn-hòu' in the instruction can only be used to refer to time concepts and cannot be used for spatial front/back.

In the sign language version of the task, the CSL instruction took about 42 seconds and participants could watch it as many times as they wanted. Deaf participants always first began with the CSL version of the temporal diagram task to obtain their authentic sagittal space-time mappings.

Afterwards, they continued with a background survey in Mandarin print, followed by the Mandarin version of the temporal diagram task. Given that both Mandarin and CSL have vertical space-time mappings and participants may mix the vertical and sagittal timelines, there was a test question asking participants to recall the axis on which the boxes were positioned with respect to the character in the clip on the next webpage right after the CSL/Mandarin temporal diagram task.

After finishing all these tasks, deaf signers were given a temporal-focus questionnaire to survey their values toward time. We used the same questionnaire as that was used in Gu et al. (2019a)'s Experiment 3 to facilitate making direct comparisons between our results and their results with Chinese hearing participants. The questionnaire consisted of 21 statements denoting opinions about the past and the future (e.g., past-focused: Traditions and old customs are very important for me; future-focused: Social and cultural changes will make people happier) (see the original English version in de la Fuente et al. (2014)'s Experiment 4). Each statement was translated to a video clip in CSL (about 6 seconds) and was double-checked by a Mandarin-CSL bimodal bilingual. Participants watched the video and indicated the extent to which they agreed with the statements on a 5-point Likert scale. On average, deaf people took about ten minutes to complete the whole experiment. The data was collected via the online survey programme Qualtrics or the Tencent Questionnaire.

The study followed the local ethical regulations of the university. All participants signed a consent form to participate in the study, and after all the tasks they were given a small amount of monetary reward.

Data and analysis

Given that the experiment was conducted online, and given that videos of the CSL instruction and temporal focus questions required considerable attention and sign language knowledge to understand, we cleaned up our data in following ways. First, those deaf signers who did not fulfil the task carefully (e.g., finishing the tasks less than 300 seconds, choosing the same answers for the 21 statements in temporal-focus questionnaire, giving random answers to background information or indicating a vertical axis in the test question) were excluded from the analyses (29 ppts). Second, three signers who had cochlear implants were not included.

Furthermore, to ensure that signers have understood the sign language version and Mandarin version of tasks, we dropped 11 participants who rated their CSL/Mandarin proficiency level as '1-very beginner' or '2-bad'), and only used the remaining deaf participants whose CSL and Mandarin proficiency were rated as at least at an intermediate level (a self-assessed score of 3; 4; 5). As for the hearing participants, those who failed to complete the questionnaire (6) or did not choose the sagittal axis (7) were excluded.

Hence there remained 80 deaf signers (M_{age} = 31.13 years; M_{age} to become deaf at 1.5 years old; Mean hearing loss = 3.28 (severe = 3, profound = 4), 22 participants had deaf parents), and 48 hearing participants (M_{age} = 30.48 years). These deaf participants' CSL (*M* = 3.59, *SD* = .67) and Mandarin proficiency (*M* = 3.51, *SD* = .62) levels did not differ significantly (t (79) = 1.0, p = .32). Their education level was between college and university (*M* = 4.45), and the hearing control group's education level was about university (*M* = 5.04, college = 4, university bachelor = 5, master = 6). Finally, data of these 128 participants were submitted to the analyses of space-time mappings.

As for the analysis, the dependent variable was a binary variable of participants' responses towards space-time mappings, i.e., the placement of the two fruit in the boxes (if a participant put the fruit representing the past in front of the toy doll and the fruit representing the future behind it, this past-in-front/future-at-back response was coded as '1'; the reversed placement of the two fruit with future-in-front/past-at-back response was coded as '0'). We used a logistic regression for binary dependent variable (the command *logit* in Stata), with clustering at individual level to deal with repeated observations on signers.

We included two predictors in the regression model: a group dummy called *Hearing* (coded as '1' if a participant was a hearing person; '0' if deaf), and a language dummy called *CSL* (coded as '1' if the task instruction was in CSL; '0' if in Mandarin print). These two predictors characterized a 3-level factor (deaf Mandarin, deaf CSL, hearing Mandarin), coded as '0, 0, 1' for the predictor *Hearing* and as '0, 1, 0' for the predictor CSL. Deaf Mandarin (coded as '0' in both predictors) was treated as the reference level against which the other two levels were compared.

Furthermore, we controlled for factors that may moderate people's responses towards space-time mappings. First, we measured and controlled for participants' temporal-focus of attention given people's cultural values toward time may influence their space-time mappings (de la Fuente et al., 2014). Second, we controlled for age because Bylund et al. (2020) suggest that older people are more likely to have past-in-front mappings. Additionally, we controlled for participants' education level and the order in which time words were mentioned (mentioning first 'the day before yesterday' and then 'the day after tomorrow' or vice versa in the instruction).

Results and discussion

First, for the 3D temporal diagram task, 52.08% of the Mandarin hearing control group responded according to the past-in-front/future-at-back mappings, placing the fruit representing the past event in front of the character and the fruit representing the future event behind it. However, this was not the case for deaf signers: when the instruction was in CSL, only 27.50% of deaf participants responded according to the past-in-front/future-at-back mappings; even when the instruction was in Mandarin print where temporal expressions were expressed with overt past-in-front/future-at-back metaphors, still only 28.75% of deaf participants responded towards past-in-front/future-at-back mappings (Fig. 3). The results of regression analyses (reference level: deaf Mandarin) showed that deaf signers did not perform differently when the language of the tasks was in Mandarin print versus in CSL (β = -.06, z = -1.0, p = .32, 95% CI = [-1.83, .059]), but they were significantly more likely to have future-in-front/past-at-back mappings than hearing speakers, independently from whether the task was in Mandarin (β = .99, z = 2.60, p = .009, 95% CI = [.243, 1.74] or in CSL (β = 1.05, z = 2.74, p = .006, 95% CI = [.305, 1.805]).

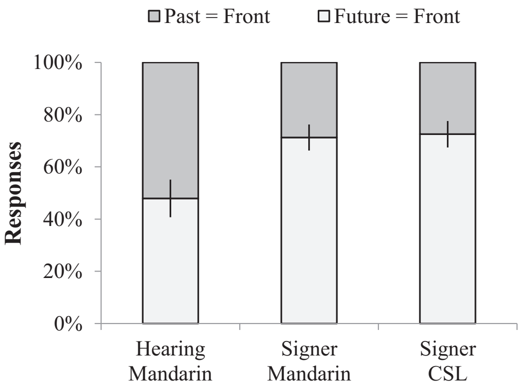


Figure 3. Percentage of past-in-front and future-in-front responses with SE error bars: Separately for hearing Mandarin speakers (Gu et al., 2019a, Exp. 3), deaf signers in Mandarin, and deaf signers in CSL.

Second, according to the results from the temporal-focus questionnaire, both Chinese deaf and hearing participants tended to focus more on the future than on the past. Specifically, the future-focused statements were rated significantly higher than the past-focused statements (for deaf signers, M_{future}= 3.58, SD = .47 vs. M_{past} = 3.11, SD = .52, t (79) = 7.42, p < 0.001, Cohen's d = .83; for hearing participants, M_{future}= 3.12, SD = .37 vs. M_{past} = 2.84, SD = .52, t (47) = 7.42, p = 0.014, Cohen's d = .37).

To normalize the rating across groups, we followed de la Fuente et al. (2014)'s proposal, and calculated a Temporal-focus Index for each participant in the deaf and hearing groups [TFI = (mean of future-focused items – mean of past-focused items) / (mean of future-focused items + mean of past-focused items)]. The TFI has a scale from –1, strong past focus, to +1, strong future focus. Both deaf and hearing participants yielded a moderate future orientation that was significantly higher than 0 (signers' TFI: M = .07, SD = .09, p = .0001, Cohen's d = .82; hearing speakers' TFI: M = .05, SD = .13, p = .012, Cohen's d = .38). However, there was no significant difference in the TFI between the two groups (t (126) = 1.25, p = .21).

Furthermore, we linked participants' TFI to their responses toward space-time mappings. The results of a logistic regression model showed that even after controlling for TFI, deaf signers still responded significantly more with future-in-front/past-at-back mappings in both Mandarin (β = 1.04, z = 2.46, p = .014, 95% CI = [.211, 1.88]) and CSL (β = 1.11, z = 2.63, p = .009, 95% CI = [.282, 1.94]) than the hearing Mandarin speakers, while keeping age (p = .817), education (p = .815), and the mentioning order of time words (p = .010)[1] constant. However, the analysis of the influence of TFI on participants' space-time mappings turned out not to be significant (β = .29, z = .14, p = .886, 95% CI = [-3.66, 4.24]). There was also no interaction between group and TFI. The factor of age and education were not significant either. Thus the group differences were indeed shaped by the deaf participants' CSL experience rather than the TFI.

In short, Experiment 1 provides strong evidence showing that CSL-Mandarin deaf signers have different space-time mappings than hearing Mandarin speakers. In Experiment 2 we would further corroborate our findings by examining how the CSL experience can influence deaf signer's understanding of time in real life situations.

Experiment 2

We used a meeting and a clock question to explicitly investigate deaf signers' understanding of time. These classic questions (McGlone & Harding, 1998) have been used in many previous studies to assess people's perspective-taking in time (e.g., Boroditsky & Ramscar, 2002; Duffy & Feist, 2014; Gentner, Imai & Boroditsky, 2002; Núñez, Motz & Teuscher, 2006; Stickles & Lewis, 2018), and are shown to be sensitive to the effect of participants' language background (e.g., Bennardo, Beller & Bender, 2010; Lai & Boroditsky, 2013; Stocker & Hartmann, 2019).

Table 3 summarizes the English and Mandarin versions of the meeting and clock questions, which were used in Lai and Boroditsky (2013)'s study. In Mandarin, possible correct answers for the meeting question are Monday or Friday, and for the clock question are 12 PM or 2 PM (Lai & Boroditsky, 2013). The sagittal space-time word '前/qián' ('forward' or 'before') in these questions can be interpreted in two ways, depending on which time-perspective one takes. When taking a time-moving perspective, the answer will be Monday and 12 PM respectively. Specifically, a person stands still facing the future, and time is conceived of as a river or conveyor belt on which events are moving from the future to the past towards the observer (Gentner et al., 2002; Núñez et al., 2006). In the perspective of time (without including the ego), the front of a timeline can be assigned to a past (earlier) event, thus in the timeline Monday or 12 PM is before (in front of) Wednesday or 1 PM (front as past). However, when taking an ego-moving perspective, a person moves forward in the timeline, from past to future, and then two days from Wednesday towards the future is Friday and one hour from 1PM towards the future is 2 PM (front to future).

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[1] The order of mentioning first 'the day before yesterday' and then 'the day after tomorrow' (not vice versa) in the instruction was consistent with the psychological realisation of sequence (earlier events are in front of late events, Núñez et al., 2006; Walker, Bergen & Núñez, 2017; Xiao et al., 2018), so this order of mentioning time expressions elicited more past-in-front mappings than that of mentioning them in a reversed order.

Table 3. *Possible correct answers to the meeting question (Q1) and clock question (Q2) and corresponding time perspectives.*

Questions	Time-moving perspective	Ego-moving perspective
Q1.下周三的会议要往**前(forward/before)**挪两天。请问这个意思是下周几开会？ Next Wednesday's meeting has been moved **forward** two days. What day is the meeting now that it has been rescheduled?	周一 Monday	周五 Friday
Q2. 假设这个时钟显示现在是下午一点，请你把它往**前(forward/before)**调一个小时。请问调好应该是几点？ Suppose now it is 1 PM, what time is it if I would ask you to move the clock time one hour **forward**?	12 点 12 PM	2 点 2PM

Lai and Boroditsky (2013) found that Mandarin monolinguals mostly took the time-moving perspective (front as past/before, answering Monday and 12 PM) when responding to the Mandarin meeting and clock questions, whereas English speakers mostly took the ego-moving perspective (front to future, answering Friday and 2 PM) when responding to the English meeting and clock questions. This is because in Mandarin the word of spatial 'front' can have a meaning of 'before/past' (thus past-in-front mappings), but in English the word of spatial 'front' usually does not have a meaning of temporal 'before'. Interestingly, when Mandarin learners of English and Mandarin monolinguals were both asked to answer the same Mandarin questions, Mandarin learners of English were significantly more likely to take an ego-moving perspective (front to future, answering Friday and 2 PM) (affected by the L2 English). Therefore, Lai and Boroditsky (2013) claim that there is an effect of space-time metaphors on speakers' spatial-temporal reasoning.

Similar as in English, in CSL the sign of spatial 'front' does not have a meaning of temporal 'before/past', and the two types of sagittal temporal signs (regardless of the deictic or the time reference point of time) always have earlier/past-at-back mappings, hence having no earlier/past-in-front mappings. Thus similar to the Mandarin learners of English, the CSL signers may get an impact of time-perspective taking from both CSL and Mandarin. If CSL signers habitually take the time perspective in CSL, they are likely to be influenced by the CSL ego-moving time perspective when answering the meeting and clock questions in Mandarin (front to future, answering Friday and 2 PM). Alternatively, it is possible that they may take the time-moving perspective after learning Mandarin (front as before/past, answering Monday and 12 PM).

Method

Participants

All 123 deaf signers who initially participated in Experiment 1 participated in Experiment 2.

82 Mandarin speakers (68 females, M_{age} = 19.64 years) from a university in China were recruited as a control group.

Materials and procedure

After finishing the CSL version of the 3D temporal diagram task, deaf participants continued with a Mandarin questionnaire to fill in their personal information. The meeting and clock questions, also in the written form of Mandarin, were respectively inserted near the beginning and end of the Mandarin questionnaire. The order of these two time questions was counterbalanced. The reason why the time questions were in Mandarin print was to avoid the visual spatial priming from signs, e.g., in the clock question, the movement of clock hand in CSL would give away the answer directly.

Data and analysis

We coded participants' responses to the time questions as a binary dependent variable. Specifically, an answer that indicated a time-moving perspective (i.e., 12 PM or Monday) was coded as '1', whereas an answer that indicated an ego-moving time perspective (i.e., 2 PM or Friday) was coded as '0'. Each participant should have two data points for two answers. However, those participants who did not give correct answers to both questions were excluded (10 deaf and 2 hearing participants). If only one of two answers was correct, the wrong one would be coded as a missing data. In total, there were data of 104 deaf signers and 80 hearing participants for the meeting question and 109 deaf signers and 78 hearing participants for the clock question, which were submitted for analysis.

We defined a binary independent variable of signer (signer = 1; hearing control = 0) and included education, age, question items (meeting or clock questions), and the sequence of questions as additional control variables. To deal with repeated data points from same participants we run a random effects logistic regression for panel data with the command of *xtlogit* in Stata.

Results and discussion

Fig. 4 presents the answers to both questions combined and separately by hearing and deaf participants. In general, 94.94% of the answers (150/158) by the hearing Mandarin speakers were according to a time-moving perspective (Monday/12PM), whereas this proportion was only 71.36% (152/213) by the deaf participants. Specifically, for the meeting question, 98.75% (79/80) of hearing participants responded according to a time-moving perspective (Monday) whereas only 1.25% of them took an ego-moving perspective (Friday). By contrast, only 69.23% (72/104) of signers took a time-moving perspective whereas 30.77% of them instead took an ego-moving perspective. Similarly, for the clock question, 91.02% (71/78) of the hearing Mandarin participants responded according to a time-moving perspective (12 PM), whereas this proportion for deaf signers was only 73.39% (80/109).

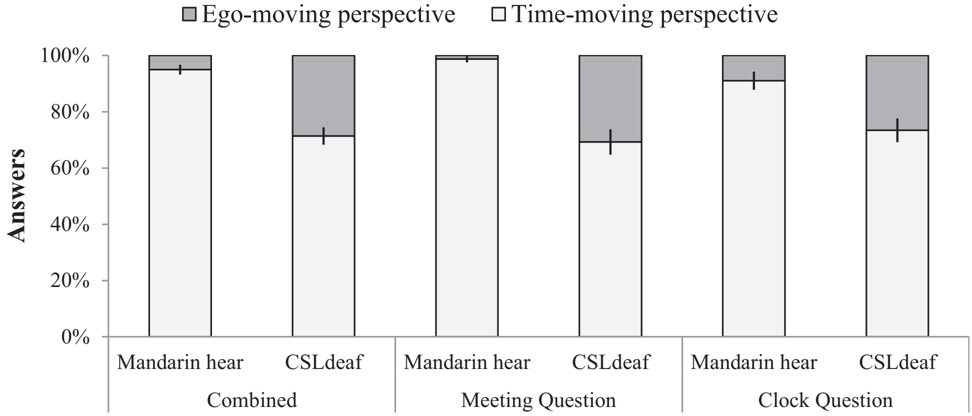


Figure 4. Percentage of answers indicating ego- and time-moving perspectives for hearing Mandarin speakers and deaf CSL signers with SE error bars: two questions combined, the meeting question and the clock question respectively.

The results of a logistic regression showed that deaf participants were significantly less likely to take a time-moving perspective than Mandarin speakers did (β = -4.0, z = - 3.67, p < .0001, 95% CI = [-6.13, -1.86]). The group differences were still highly significant (β = -3.91, z = - 2.89, p = .004, 95% CI = [-6.57, -1.26]) even when other variables such as education, age, question sequence, and question items were controlled for (all ps > .16).

One may argue that the differences between deaf and hearing participants in Experiment 2 cannot be explained by the influences of CSL timeline, but by signer's poor comprehension ability of Mandarin texts. That is, deaf participants may not understand the spatial-temporal metaphor as time conceptions at all. This alternative account, however, is quite unlikely: first, we have only included those who provided correct answers, and all incorrect answers were excluded in the analysis. Second, unlike in English, these questions in Mandarin are unambiguous in terms of expressing time (Li, 2020), and pilot research showed that even deaf participants from primary school can already understand this kind of question quite well (Gu, Zheng et al., 2017), let alone adult deaf participants who are much more proficient in Mandarin. This was also indicated by the insignificance of education in the regression model (β = -.63, z = -1.42, p = .16, 95% CI = [-1.49, .24]). To provide further evidence for this, we sorted deaf participants who had higher education and ran a regression based on this subsample (57 deaf participants). These participants were highly proficient in Mandarin and had obtained their bachelor or master degree from typical Chinese universities where all courses materials and exams were fully in Mandarin. As expected, there were still significant differences between the deaf (65.49%) and hearing participants (94.94%) in the choice of time-moving perspective, β = -4.40, z = - 2.93, p = .003, 95% CI = [-7.36, -1.46], while controlling for age, questions items, and question sequence. The results of Experiment 2 indeed showed that deaf signers may have a different time perspective than hearing Mandarin speakers.

However, these two questions used in in Experiment 2 address the forward/before perspective (前/qian), and not backward/behind (后/hou). The few items used in both Experiment 1 and Experiment 2 may limit generalization of our findings beyond the tested items. Furthermore, current data do not allow us to explore effects of age-of-acquisition versus proficiency on bilingual performance (e.g., Hernandez & Li, 2007), including whether bimodal CSL-Mandarin bilinguals' preference for future-in-front/past-at-back mappings relates to their proficiency in sign language and their current frequency of use of sign language. Finally, deaf signers in Experiment 1 did not display different space-time mappings in CSL and Mandarin print, which could be due to that participants were asked to do the task where the instruction was in CSL and the task that was instructed in Mandarin print together without a testing interval and results were affected by a learning effect. Thus in Experiment 3 we did a conceptual replication of Experiments 1-2 using multiple items to examine deaf signers' mental space-time mappings while considering their language background and setting a testing interval.

Experiment 3

Method

Participants

Another 106 CSL-Mandarin deaf signers (M_{age} = 34.44 years, SD = 8.65, 42 males and 64 females) participated in the experiment in China. Participants' average education level was between college (= 4) and university bachelor's degree (= 5) (M = 4.24, SD = 1.13). The deaf CSL-Mandarin bilinguals became deaf at an early age (M = 1.65 years, SD = 1.96), with an average hearing loss between severe (= 3) and profound (= 4) (M = 3.10, SD =.79). As shown by a self-assessment (1-7), their average CSL proficiency (M = 5.68, SD = 1.37) not significantly different than their Mandarin proficiency (M = 5.78, SD = 1.26, $t = 0.92$, $p = .36$). The mean age of acquisition (AoA) of Mandarin (M= 5.46 years, SD = 2.53) was smaller than the AoA of CSL (M = 7.55 years, SD = 4.80, $t = -3.92$, $p < .001$).

Materials and procedure

We constructed eight temporal diagram tasks in different contexts and varied the temporal units of Mandarin sagittal space-time words (e.g., qian-tian/front day; qian-nian/front year). An equivalent CSL version was also made, thus making 16 temporal diagram tasks in total. In addition, we created 32 real life questions in Mandarin related to time perspectives, counterbalancing the use of space-time words of "前/qian (front)" and "后/hou (back)" (Appendix).

Participants followed similar procedure as described in Experiments 1-2 took part twice in the experiment with an interval of one week. Ultimately, they should complete eight temporal diagram tasks and 16 time-perspective questions. In week 1, participants were assigned to four of the temporal diagram tasks in one language and eight of the 32 time-perspective questions. In week 2 participants completed the same four temporal diagram tasks in the other language and answered eight new time perspective questions. The testing order of the languages of temporal diagrams was counterbalanced. We also collected participants linguistic background (Li, Zhang, & Yu, 2020) and demographic information, etc.

Data and analysis

Analyses were similar to Experiment 1 and 2 except that now we use logistic regression for panel data to deal with multiple observations. Furthermore, we generated the following control variables: age of acquisition (AoA) and language proficiency of both CSL and Mandarin, task language, education, sequence of temporal words, age, etc.

Results and discussion

Temporal diagram tasks

Deaf signers performed significantly differently when the language of the tasks was in CSL versus in Mandarin print (β = -.59, p = .0053, 95% CI = [-1.02, -.18]), showing that they were less likely to have past-in-front mappings in CSL (32%) than in Mandarin (39%). Furthermore, there was a negative effect of CSL proficiency on past-in-front mappings (β = -.61, p = .011, 95% CI = [-1.11, -.15]), indicating that deaf signers with higher CSL proficiency were more likely to have future-in-front/past-at-back mappings, controlling for significant factors of task language, sequence of time words, and education (all p's < .05). The CSL effect remained highly significant (β = -.95, p = .0013, 95% CI = [-1.57, -.39] when a positive effect of Mandarin proficiency (β = .66, p = .041, 95% CI = [.03, 1.33]) on past-in-front mappings was additionally controlled for. In addition, as a robustness check, we replaced the language proficiency variables with AoA of CSL and Mandarin. We found a significant effect of CSL AoA (β = .17, p = .006, 95% CI = [.05, .29]), indicating that a later acquisition of CSL predicts more past-in-front mappings. (Fig. 5)

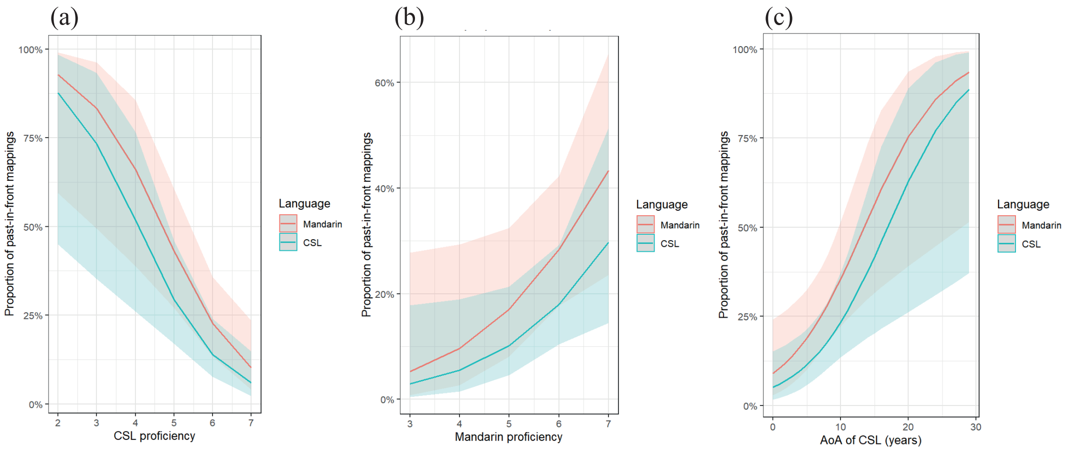


Figure 5. Predicted effects of (a) CSL proficiency, (b) Mandarin proficiency, and (c) age of acquisition (AoA) of CSL on past-in-front mappings in Mandarin print and CSL by CSL-Mandarin deaf bilinguals.

Time perspective questions

In general, deaf signers had 86.59% (1356/1566) of answers according to a time-moving perspective (what Mandarin speakers prefer). The proportions were not different between “前/qian” (front, before) (86.18%, 655/760) and “后/hou”(back, after) (86.55%, 663/766) questions (β = -0.03, p = .86). There appeared no effect of CSL proficiency (β = -0.15, p = .43) on choices of time perspective. However, the self-assessed proficiency may not be sensitive to this task. We catergorised those who rated their CSL proficiency “native level (=7)” into a relatively higher proficient group (N = 43) and the rest as relatively lower proficient group (N = 60). Indeed, there was a negative effect of CSL proficiency on time-moving perspective (β = -1.0, p = .041, 95% CI = [-.04, -1.95]), while controlling for front/back space-time words (p=.76) and education (p =.86). The effect was robust (β = -1.1, p =.035, 95% CI = [-.08, -2.15]), even additionally controlling for signers' Mandarin proficiency (β = -.039, p =.88), whether having a deaf parent (β = -.50, p =.136), or ever attended a deaf school (β = 1.74, p =.142). This indicated that deaf signers with higher CSL proficiency were less likely to take time-moving perspective (Fig. 6). In addition, when replacing the language proficiency variables with the AoA of CSL and Mandarin, we found a significant effect of Mandarin AoA (β = -.21, p = .038, 95% CI = [-.01, -.41]), indicating that a later acquisition of Mandarin predicts less moving-time perspective (Fig. 7).

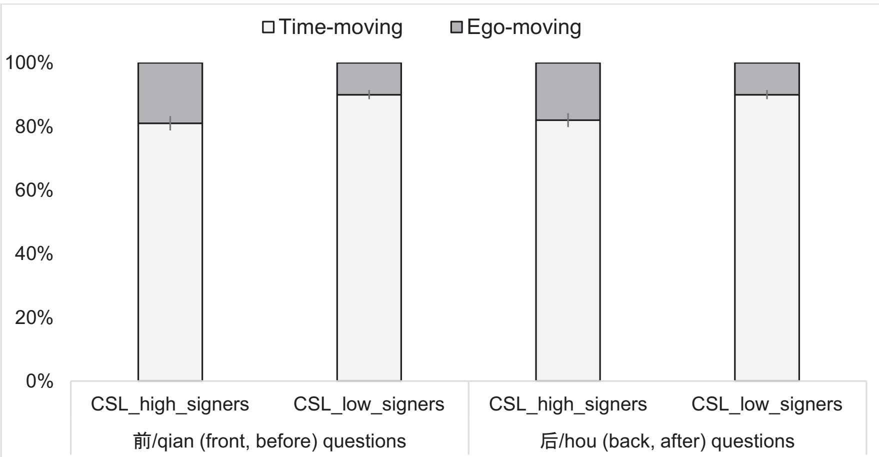


Figure 6. Percentage of answers indicating ego- and time-moving perspectives for higher proficient CSL signers and lower proficient CSL signers with SE error bars: “前/qian” (front, before) and “后/hou” (back, after) questions respectively.

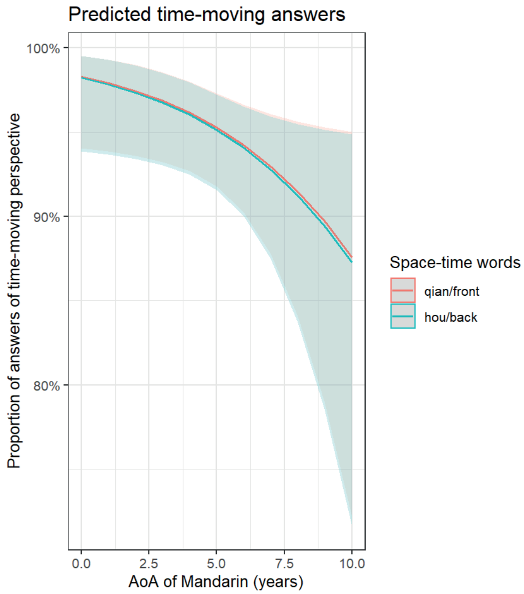


Figure 7. The predicted effect of age of acquisition (AoA) of Mandarin on time perspective-taking in answering Mandarin real life questions by CSL-Mandarin deaf bilinguals.

General discussion

This study is the first that scrutinized the spatial-temporal reasoning in signers, and has focused on previously unexplored differences between a deaf and hearing Chinese population. In experiment 1 we found that the majority of Chinese deaf participants performed future-in-front / past-at-back space-time mappings, irrespective of instruction language of the task (CSL or Mandarin). Signers were also significantly more likely to have future-in-front mappings than hearing Mandarin speakers, even after controlling for their cultural values about time (TFI), age and education. In experiment 2, we used two traditional questions about the flow of time to explicitly examine whether Chinese deaf signers and Mandarin speakers understand time differently, related to two kinds of temporal perspectives, i.e., the ego-moving perspective (front to future) and the time-moving perspective (front as before/past). We found that Mandarin participants mostly took the time-moving perspective whereas the CSL deaf participants were significantly less likely to do so, even when only limiting to deaf participants with higher education. In Experiment 3, apart from a generalization of our findings, we further showed that there are effects of language in operation, CSL proficiency, and AoA on deaf signers' performances. Our findings have several important theoretical contributions, which will be discussed below.

Space-time mappings

This study is one of the few studies related to CSL, and documents how Chinese deaf people conceptualize time on the front-back axis. The comparison between Chinese hearing and deaf signers extends our knowledge on within-cultural differences in space–time mappings. Past studies have shown that whether people conceptualise the past as behind and the future as ahead of them are conditioned by their attentional focus toward time (*temporal-focus hypothesis*) (de la Fuente et al., 2014). According to that hypothesis, 'Participants' TFIs were a highly significant predictor of their responses on the temporal diagram task […]' (p.1687). People who are past-focused are more likely to have past-in-front mappings than people who are future-focused.

Despite there being some evidence supporting the *temporal-focus hypothesis* (e.g., Gu et al., 2019a; Li & Cao, 2018a, b), two recent studies reported a failure to find a significant relationship between the temporal-focus and sagittal space–time mappings. For instance, Bylund et al. (2020) did not find such a significant relationship at the cross-cultural level, i.e., Afrikaners were significantly more past-focused than English speakers but the two groups did not differ in their front-back temporal mappings. While Gu et al. (2019a) did find a cross-cultural effect of TFI on space-time mappings between Chinese, Moroccans and Spaniards, they did not find a significant correlation between participants' TFI and their sagittal space–time mappings within the hearing Mandarin sample.

In the current study, the differences in the front-back space-time mappings between the deaf and hearing groups can hardly be explained by the TFI, as signers were still significantly less likely to have past-in-front mappings than hearing Mandarin speakers even when TFI was controlled for. The influence of individual TFI on deaf signers' space-time mappings was not statistically significant either. Both results seem to suggest that the relationship between temporal-focus and sagittal space-time mappings may not be found in some cases. The *temporal-focus hypothesis* was proposed based on hearing people, which might not be fully applicable to our deaf sample.

Furthermore, de la Fuente et al. (2014) found that older Spaniards are more past-focused and more likely to have past-in-front mappings than younger Spaniards. Bylund et al. (2020) found that age is a significant predictor of participants' sagittal space-time mappings. However, in our study deaf participants' age was not significantly correlated to their space-time mappings (it was found to be insignificant in Mandarin speakers as well, see Gu et al., 2019a). This could be due to the fact that within our deaf sample the variation of age was very limited as most of our deaf participants were quite young (mean age = 31.13 years, *SD* = 6.2 years, range 20-47 years), whereas in both de la Fuente et al.'s (2014) and Bylund et al.'s (2020) studies the age range was very large (e.g., Spaniards' mean age = 50.45 years, SD = 27 years, range18-89 years, de la Fuente et al., 2014, Experiment 4).

Instead, we found that deaf participants' bodily experience of CSL can shape their sagittal space-time mappings. One may argue that CSL signers' future-in-front mappings are not necessarily caused by their CSL modality experience, but because it is the mostly cognitively available one across cultures (then past-in-front mappings in hearing speakers should be influenced by the Mandarin language). However, this can be ruled out by the results of a positive effect of CSL proficiency and a negative effect of AoA of CSL. These two effects reveal a causal influence on mental space-time mappings. The finding is also consistent with another study showing that Mandarin speakers who have learned CSL were significantly more likely to spontaneously gesture past events to their back than Mandarin-speaking non-signers, when both speaking their native Mandarin (see more discussions below in section *Language and thought* and in Fig. 8) Thus, the experience of cross-modal CSL space-time metaphors can indeed influence CSL users' spatio-temporal reasoning (Gu et al., 2019b). Our findings contribute to a better understanding of the growing complexity of space-time mappings in human minds.

Additionally, studies have shown that space-time mappings can change, depending on contextual influences and personal experience (e.g., Santiago et al., 2007; Saj et al., 2014; Torralbo, Santiago & Lupáñez, 2006). For instance, individuals' mental timelines can be reversed after brief exposure to mirror-reversed orthography (Casasanto & Bottini, 2014), and people's conceptions of time may vary as a function of temporal landmarks (calendar time of a year, Li & Cao, 2018a), or of individual differences such as age (Bylund et al., 2020), religious beliefs (Li & Cao, 2018b), personality (Duffy, Feist & McCarthy, 2014) etc. In our study we found that if we tested the Mandarin temporal diagram task immediately after a CSL one, the mental space-time mappings can simply be affected by the sign language. However, if the tasks in two languages were completed with an interval, there was an effect of language. It is interesting to research which factors are relatively more 'stable' and which are more 'dynamic'. Future study can also look into the weight of and interplay between different factors on space-time mappings.

Cross modal language co-activation

Our results are consistent with a growing number of studies showing that there is an unconscious access to contextually non-selective language in bilinguals (e.g., Van Hell & Dijkstra, 2002; Emmorey et al., 2008; Villamerie et al., 2016), and particularly in Chinese people. For instance, there is a co-activation of the sound form of Chinese words when advanced Chinese-English bilinguals read or listen to English words (Wu & Thierry, 2010). Additionally, such cross-language interactions can occur across modalities, i.e., between a spoken language and gestures (Brown & Gullberg, 2008), or between a written form/gesture of spoken language and a signed language (e.g., Casey & Emmorey, 2009; Emmorey et al., 2005; Morford et al., 2014). For example, Morford et al. (2011) found that ASL–English bilingual deaf readers activate the ASL translations of written form of English words even when the task does not explicitly require the use of ASL. An ERP study also shows that there is an implicit co-activation of ASL in deaf readers of English print (Meade et al., 2017).

Instead of viewing bilinguals' languages are unconsciously co-activated, recently researchers have proposed an alternative account for the mechanism: the influences of L1 on L2 only appear at a much earlier stage during the L2 learning process, and such influences would be less obvious as L2 proficiency increases (Costa et al., 2017; Oppenheim et al., 2018). However, deaf CSL-Mandarin bilinguals in our study, including those who had a higher education of bachelor and master (see Experiment 2), appeared to automatically access their CSL timeline when processing input in

Mandarin print in the non-signing contexts, which seemed to suggest that there were still interference effects from their L1 even after the L2 concept was fully acquired. The results thus expand our understanding of language non-selective lexical activation mechanisms in bilinguals of different scripts (e.g., Li et al., 2019; Wu & Thierry, 2010), as well as different modalities by showing unconscious activation of representations of CSL time when deaf signers read Mandarin print.

Language and thought

The findings of the current study provide new insights into the relation between language and thought, especially regarding the influence of cross-modal linguistic context on thinking (cf. Bylund, & Athanasopoulos, 2017; Lai & Boroditsky, 2013; Slobin, 1996). Previous research has shown that there is a direct effect of linguistic metaphors on people's reasoning about time. For example, using the same 3D temporal diagram task as that of Experiment 1, it was found that Mandarin hearing non-signers were more likely to perform past-in-front/future-at-back mappings when reading the task instruction that contained past-in-front/future-at-back space-time metaphors than when reading the instruction that had future-in-front/past-at-back space-time metaphors (Gu et al., 2019a). Such a linguistic effect has also been found in a between-language comparison of bilinguals' gesture about time. Mandarin-English speakers gesture more vertically when talking about time conceptions with vertical space-time metaphors in Mandarin than in English. Similarly, they preferred vertical gestures more when perceiving vertical time references in Mandarin than the English translation of the same concepts (Gu, Mol et al., 2017).

By contrast, the deaf signers in the present study did not display significantly different space-time mappings between fulfilling the temporal diagram task in CSL and Mandarin print in Experiment 1 (only 1.2% differences), while the space-time metaphors in Mandarin print were explicitly suggesting past-in-front/future-at-back mappings. Even though in Experiment 3 we found a difference between CSL and Mandarin space-time mappings, the effect size (7%) was much smaller compared to results from similar studies on Chinese spoken languages (e.g., 20%, Gu et al., 2019a; Lai & Boroditsky, 2013). However, within the Chinese culture, deaf signers were more likely to perform future-in-front/past-at-back mappings compared to the hearing participants. Our findings for the first time show that experience with cross-modal spatial metaphors for time can affect deaf signers' spatio-temporal reasoning.

Then a question arises as to why the language of operation affects late Mandarin-English speakers' conceptualisation of time, but to a much lesser extent on deaf CSL-Mandarin signers'. In additional to the possible influence of CSL priming, this could be due to the fact that in Mandarin/English, these metaphoric space-time metaphors are not 'learned' like CSL signs. In other words, temporal conceptions are spatially more iconic in a signed language than a spoken language (e.g., CSL vs. Mandarin), because temporal signs are visually and physically salient in the signing movements. Evidence supporting this proposal has also been found in the co-speech gestures of time by late Mandarin-CSL bimodal bilinguals. Gu et al. (2019b) have found that Mandarin non-signers can spontaneously gesture the past to front (top in Fig. 8), but the late bimodal bilinguals (hearing Mandarin learners of CSL) rarely gesture in this manner after learning L2 CSL. Instead, they would mainly produce past-at-back gestures, even when verbally uttering the overt Mandarin past-in-front words (bottom in Fig. 8).

A further question is whether the CSL sagittal space-time mappings have an effect of habitual thinking on signers' conceptualization of time. According to Slobin's (1996) 'thinking-for-speaking' hypothesis, habitual speech patterns may influence thinking online, during linguistic processing. When speakers use certain speech patterns repeatedly, they may form habitual language-specific conceptual schemes. It is then interesting to ask whether signers may also form such habitual schemes when they use certain sign patterns repeatedly.

Figure 8. Spontaneous gestures of 'this year', 'last year' and 'the year before last year' in Mandarin by a Mandarin-speaking non-signer (top), and gestures of 'the year before last year', and 'the year after next year' in Mandarin by a late Mandarin-CSL bimodal bilingual (bottom) (Pictures are made based on participants in Gu et al., 2019b's study).

Given that a signed language requires the user to linguistically make distinctions based on movement (Emmorey & McCullough, 2009), and can enhance one's visual-spatial ability and memory for object orientation (Emmorey et al., 1998; Navarrete et al., 2020), we propose that signing is a special kind of action in space that may also activate and change one's spatial thinking (Pyers et al., 2010; cf. *gesture-for-conceptualisation hypothesis*, Kita, Chu, & Alibali, 2017). When signing, the spatial movements of CSL signers' hands may activate different spatio-motoric information from that of Mandarin-speaking non-signers. Such sign patterns may influence spatial thinking online during linguistic processing ('thinking-for-signing'); and the repeated use of language-specific sign patterns may have a long-term influence on signers' spatial thinking. This is also in line with the body-specific hypothesis that particular patterns of bodily experience can give rise to corresponding habits of thinking, perceiving, and acting (Casasanto, 2009; Gibbs, 2003).

Given that people use space to think about time (e.g., Casasanto & Boroditsky, 2008), a different/marked spatial thinking may consequently bring certain differences in spatial conceptualization of time. Take the sagittal space-time metaphors as an example: if signers always sign to the back for the conception of past, then signers likely form habitual mappings of the past to the back, especially for those who have acquired CSL at an earlier age and with a high CSL proficiency level. Thus the results of this study seem to show an effect of (sign) language on thinking about time within a culture (cf. Boroditsky, 2001; Fuhrman et al., 2011; Gu et al., 2019b).

Nevertheless, although there were significant differences both in the space-time mappings and understanding of real life questions about time between deaf and hearing Chinese, the tasks above all involved some linguistic instructions. In the future study, it would also be interesting to examine the extent to which Chinese deaf signers would conceptualise time differently than Mandarin speakers in non/less-linguistic tasks.

Conclusion

In this study we investigated whether CSL deaf signers would conceptualise time differently from hearing Mandarin speakers due to cross-modal and cross-linguistic differences in space-time metaphors between CSL and Mandarin. The results show that deaf signers are more likely to have future-in-front/past-at-back mappings and take an ego-moving temporal perspective than Mandarin speakers do. The results also show a cross-modal (CSL vs. Mandarin print) unconscious activation of CSL space-time metaphors when they read Mandarin print. Additionally, rather than deaf signers' temporal-focus of attention (de la Fuente et al., 2014) or age (Bylund et al., 2020) being the key influence on their conceptualisation of time, we found that deaf participants' bodily experience of CSL shapes their sagittal space-time mappings. Given that habitual use of certain sign patterns may affect signers' spatial thinking, we conclude that experience of sign language may have an impact on signers' spatio-motoric thinking and spatial-temporal reasoning, and such an impact is enhanced by a higher CSL proficiency level or an early AoA of CSL. Despite that research on CSL generally has been somewhat neglected in the literature, this study could provide a first insight into a cross-modal influence of space-time metaphors on deaf people's mental representations of time within a culture, with additional implications for the theories on space-time mappings and the relationship between language and thought.

Stimuli, data and analysis scripts can be found in
https://osf.io/y937u/?view_only=36f5136946b842f480bfb6e565034c7e

Appendix: **Materials used in Experiment 3**

Task 1: **Temporal diagram task with multiple trials: Mandarin version**

1A 题目：前天小明拜访了一个朋友，这个朋友喜欢梨子；后天小明将要去拜访另一个朋友，这个朋友喜欢苹果。在上面的图里，您可以看到小明和两个盒子。问题：请将"梨子"放进代表"前天"的那个盒子里，表示以前发生的事情；请把"苹果"放进代表"后天"的另一个盒子里，表示今后要发生的事情。

1B 题目：后天小明将要去拜访一个朋友，这个朋友喜欢苹果；前天小明拜访了一个朋友，这个朋友喜欢梨子。在上面的图里，您可以看到小明和两个盒子。问题：请将 "苹果"放进代表"后天"的那个盒子里，表示今后要发生的事情；请把"梨子"放进代表"前天"的另一个盒子里，表示以前发生的事情。

2A 题目：前天小明拜访了一个朋友，这个朋友喜欢植物；后天小明将要去拜访另一个朋友，这个朋友喜欢动物。在上面的图里，您可以看到小明和两个盒子。问题：请将"植物"放进代表"前天"的那个盒子里，表示以前发生的事情；请把"动物"放进代表"后天"的另一个盒子里，表示今后要发生的事情。

2B. 题目：后天小明将要去拜访一个朋友，这个朋友喜欢动物；前天小明拜访了一个朋友，这个朋友喜欢植物。在上面的图里，您可以看到小明和两个盒子。问题：请将 "动物"放进代表"后天"的那个盒子里，表示今后要发生的事情；请把"植物"放进代表"前天"的另一个盒子里，表示以前发生的事情。

3A. 题目：前年小明的阿姨结婚了；后年小明的叔叔将要结婚。在上面的图里，您可以看到小明和两个盒子。问题：请在代表"前年"的那个盒子里写 "阿姨"，表示以前发生的事情；请在代表"后年"的那个盒子里写"叔叔"，表示今后要发生的事情。

3B. 题目：后年小明的叔叔将要结婚；前年小明的阿姨结婚了。在上面的图里，您可以看到小明和两个盒子。问题：请在代表"后年"的那个盒子里写"叔叔"，表示今后要发生的事情。请在代表"前年"的那个盒子里写 "阿姨"，表示以前发生的事情。

4A. 题目：前年小明去美国旅游了；后年小明将要去英国旅游。在上面的图里，您可以看到小明和两个盒子。问题： 请在代表"前年"的那个盒子里写"美国"，表示以前发生的事情；请在代表"后年"的那个盒子里写"英国"，表示今后要发生的事情。

4B. 题目：后年小明将要去英国旅游；前年小明去美国旅游了。在上面的图里，您可以看到小明和两个盒子。问题：请在代表"后年"的那个盒子里写"英国"，表示今后要发生的事情；请在代表"前年"的那个盒子里写"美国"，表示以前发生的事情。

Task 2: Time perspective questions

Version 1

Week1

1. 假设时钟显示现在是 3 点，请你把它往前调一个小时。请问调好应该是几点？___点
2. 某个周三的会议要往前挪一天，请问这个意思是周几开会？周___
3. 9 月 15 日的活动要往前挪一天，请问改日期后活动几号举行？9 月____日
4. 有个项目 2022 年开工，现把开工时间往前挪一年，请问这个意思是项目哪年开工？202____年
5. 假设时钟显示现在是 4 点，请你把它往后调一个小时。请问调好应该是几点？____点
6. 某个周三的会议要往后挪 2 天。请问这个意思是周几开会？周___
7. 11 月份的活动要往后挪一个月，请问改期后活动几月份举行？___月
8. 明天早晨 10 点的预约见面要往后挪一小时。请问这个意思是明天几点见面？____点

Week 2

1. 假设时钟显示现在是 6 点，请你把它往后调一个小时。请问调好应该是几点？___点
2. 周三的会议往后挪一天，请问这个意思是周几开会？周____
3. 历史的车轮定格在 1840 年，从那往后 40 年是哪年？18____年
4. 有个项目 2022 年开工，现把开工时间往后挪一年，请问这个意思是项目哪年开工？202____年
5. 假设时钟显示现在是 1 点，请你把它往前调一个小时。请问调好应该是几点？____点
6. 周三的会议往前挪两天。请问这个意思是周几开会？ 周____
7. 历史的车轮定格在 1840 年，从那往前 40 年是哪年？18__年
8. 11 月份的活动要往前挪一个月，请问改期后活动几月份举行? ____月

Version 2

Week 1

1. 假设时钟显示现在是 3 点，请你把它往后调一个小时。请问调好应该是几点？___点
2. 某个周三的会议要往后挪一天，请问这个意思是周几开会？周____
3. 9 月 15 日的活动要往后挪一天，请问改日期后活动几号举行？9 月____日
4. 有个项目 2022 年开工，现把开工时间往后挪一年，请问这个意思是项目哪年开工？202____年
5. 假设时钟显示现在是 4 点，请你把它往前调一个小时。请问调好应该是几点？____点
6. 某个周三的会议要往前挪 2 天。请问这个意思是周几开会？ 周____
7. 11 月份的活动要往前挪一个月，请问改期后活动几月份举行? ____月
8. 明天早晨 10 点的预约见面要往前挪一小时。请问这个意思是明天几点见面？____点

Week 2:

1. 假设时钟显示现在是 1 点，请你把它往前调一个小时。请问调好应该是几点？___点
2. 周三的会议往前挪一天，请问这个意思是周几开会？周___
3. 历史的车轮定格在 1840 年，从那往前 40 年是哪年？18__年
4. 有个项目 2022 年开工，现把开工时间往前挪一年，请问这个意思是项目哪年开工？202____年
5. 假设时钟显示现在是 6 点，请你把它往后调一个小时。请问调好应该是几点？____点
6. 周三的会议往后挪 2 天。请问这个意思是周几开会？周___
7. 历史的车轮定格在 1840 年，从那往后 40 年是哪年？18__年
8. 11 月份的活动往后挪一个月，请问改期后活动几月份举行？___月

References:

Athanasopoulos, P., Bylund, E., Montero-Melis, G., Damjanovic, L., Schartner, A., Kibbe, A., ... & Thierry, G. (2015). Two languages, two minds: Flexible cognitive processing driven by language of operation. *Psychological Science*, *26*(4), 518-526. doi:10.1177/0956797614567509

Bender, A., & Beller, S. (2014). Mapping spatial frames of reference onto time: A review of theoretical accounts and empirical findings. *Cognition, 132*(3), 342-382. doi:10.1016/j.cognition.2014.03.016

Bennardo, G., Beller, S., & Bender, A. (2010). Temporal frames of reference: Conceptual analysis and empirical evidence from German, English, Mandarin Chinese and Tongan. *Journal of Cognition and Culture*, *10*(3-4), 283-307. doi:10.1163/156853710X531195

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition, 75*(1), 1-28. doi:10.1016/s0010-0277(99)00073-6

Boroditsky, L. (2001). Does language shape thought?: Mandarin and English speakers' conceptions of time. *Cognitive Psychology, 43*(1), 1-22. doi:10.1006/cogp.2001.0748

Boroditsky, L., & Ramscar, M. (2002). The Roles of Body and Mind in Abstract Thought. *Psychological Science*, *13*(2), 185–189. doi:10.1111/1467-9280.00434

Brown, A. & Gullberg, M. (2008). Bidirectional cross-linguistic influence in L1-L2 encoding of manner in speech and gesture. *Studies in Second Language Acquisition, 30*, 225-251. doi:10.1017/S0272263108080327

Brennan, M., (1983) Marking time in British sign language. In *Language in Sign*, Jim Kyle, & Bencie Woll (eds.), *10–31*. London: Croom Helm.

Burns, P., McCormack, T., Jaroslawska, A. J., O'Connor, P. A., & Caruso, E. M. (2019). Time Points: A Gestural Study of the Development of Space–Time Mappings. *Cognitive Science*, *43*(12), e12801. doi: 10.1111/cogs.12801

Bylund, E., & Athanasopoulos, P. (2017). The Whorfian time warp: Representing duration through the language hourglass. *Journal of Experimental Psychology: General*, *146*(7), 911-916. doi:10.1037/xge0000314

Bylund, E., Gygax, P., Samuel, S., & Athanasopoulos, P. (2020). Back to the future? The role of temporal focus for mapping time onto space. *Quarterly Journal of Experimental Psychology, 73*(2), 174-182.

Cabeza Pereiro, C. & Fernández Soneira, A. (2004). The expression of time in Spanish Sign Language (LSE). *Sign Language and Linguistics, 7*(1), 63-82. doi:10.1075/sll.7.1.06cab

Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition, 106*(2), 579-593. doi:10.1016/j.cognition.2007.03.004

Casasanto, D.. 'Embodiment of abstract concepts: good and bad in right-and left-handers.' *Journal of Experimental Psychology: General, 138*(3), 351-67. doi:10.1037/a0015854.

Casasanto, D., & Bottini, R. (2014). Mirror reading can reverse the flow of time. *Journal of Experimental Psychology: General, 143*(2), 473-479. doi:10.1037/a0033297

Casasanto, D., & Jasmin, K. (2012). The hands of time: Temporal gestures in English speakers. *Cognitive Linguistics, 23*, 643-674. doi:10.1515/cog-2012-0020

Casey, S., & Emmorey, K. (2009). Co-speech gesture in bimodal bilinguals. *Language and Cognitive Processes, 24* (2), 290-312. doi: 10.1080/01690960801916188

Chen, J.-Y. (2007). Do Chinese and English speakers think about time differently? Failure of replicating Boroditsky (2001). *Cognition*, *104*(2), 427–436. doi:10.1016/j.cognition.2006.09.012

China Association of the Deaf and Hard of Hearing (2003). *Chinese Sign Language* (中国手语). Beijing: Huaxia Publishing House.

Chui, K. (2011). Conceptual metaphors in gesture. *Cognitive Linguistics, 22*(3), 437-458. doi:10.1515/cogl.2011.017

Chui, K. (2018). Spatial conceptualization of sequence time in language and gesture. *Gesture*, *17*(1), 176-195. doi:10.1075/gest.00015.chu

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

Cooperrider, K., & Núñez, R. (2009). Across time, across the body: Transversal temporal gestures. *Gesture, 9*(2), 181-206. doi:10.1075/gest.9.2.02coo

Costa, A., Pannunzi, M., Deco, G., & Pickering, M. J. (2017). Do bilinguals automatically activate their native language when they are not using it?. *Cognitive Science, 41*(6), 1629-1644. doi: 10.1111/cogs.12434

De la Fuente, J., Santiago, J., Román, A., Dumitrache, C., & Casasanto, D. (2014). When you think about it, your past is in front of you: How culture shapes spatial conceptions of time. *Psychological Science, 25*(9), 1682-1690. doi:10.1177/0956797614534695

Duffy, S. E., & Feist, M. I. (2014). Individual differences in the interpretation of ambiguous statements about time. *Cognitive Linguistics, 25*(1), 29-54. doi.10.1515/cog-2013-0030

Duffy, S. E., Feist, M. I., & McCarthy, S. (2014). Moving through time: The role of personality in three real life contexts. *Cognitive Science*, *38*(8), 1662-1674. doi:10.1111/cogs.12124

Duffy, S. E., & Evans, V. (2017). The top trumps of time: Factors motivating the resolution of temporal ambiguity. *Language and Cognition, 9*(2), 293-315. doi:10.1017/langcog.2016.8

Emmorey, K., Klima, E., & Hickok, G (1998). Mental rotation within linguistic and non-linguistic domains in users of American Sign Language. *Cognition, 68*, 221-46. doi: 10.1016/s0010-0277(98)00054-7.

Emmorey, K., & McCullough, S. (2009). The bimodal bilingual brain: effects of sign language experience. *Brain and language*, *109*(2-3), 124-132.

Emmorey, K. (2001). Space on hand: The exploitation of signing space to illustrate abstract thought. In Merideth Gattis (ed.), *Spatial schemas and abstract thought* (pp. 147-174), Cambridge, MA, US: MIT Press.

Emmorey, K., Borinstein, H. B., Thompson, R., & Gollan, T. H. (2008). Bimodal bilingualism. *Bilingualism: Language and Cognition, 11*(1), 43-61. doi: 10.1017/S1366728907003203

Emmorey, K., Grabowski, T., McCullough, S., Ponto, L. L., Hichwa, R. D., & Damasio, H. (2005). The neural correlates of spatial language in English and American Sign Language: A PET study with hearing bilinguals. *Neuroimage, 24*(3), 832-840. doi: 10.1016/j.neuroimage.2004.10.008

Emmorey, K. (2019). Language: Do bilinguals think differently in each language?. *Current Biology, 29*(21), R1133-R1135.

Engberg-Pedersen, E. (1999). Space and Time. In J. Allwood & P. Gärdenfors (Eds.), *Cognitive semantics: Meaning and cognition* (pp. 131-152). Amsterdam/Philadelphia: John Benjamins Publishing Company.

Evans S, Price CJ, Diedrichsen J, Gutierrez-Sigut E, & MacSweeney M. (2019) Sign and speech share partially overlapping conceptual representations. *Current Biology,29*(21), 3739-3747.e5.

Fischer, S., & Gong, Q. (2010). Variation in East Asian sign language structures. In Diane Brentari (ed.), *Sign languages*, 502-521. Cambridge: Cambridge University Press.

Fuhrman, O., McCormick, K., Chen, E., Jiang, H. D., Shu, D. F., Mao, S. M., & Boroditsky, L. (2011). How linguistic and cultural forces shape conceptions of time: English and Mandarin time in 3D. *Cognitive Science, 35*, 1305-1328. doi:10.1111/j.1551-6709.2011.01193.x

Gentner, D., Imai, M., & Boroditsky, L. (2002). As time goes by: Evidence for two systems in processing space time metaphors. *Language and Cognitive Processes*, *17* (5), 537–565. doi: 10.1080/01690960143000317

Gibbs, R. W. (2003). Embodied experience and linguistic meaning. *Brain and Language, 84*(1), 1-15. doi:10.1016/S0093-934X(02)00517-5

Gu, Y., Zheng Y., Swerts, M. (2017). Does Mandarin spatial metaphor for time influence Chinese deaf signers' spatio-temporal reasoning? In G. Gunzelmann, A. Howes, T. Tenbrink, E. J. Davelaar (Eds). *Proceedings of the 39th Annual Conference of the Cognitive Science Society* (pp.445-450). Austin, TX: Cognitive Science Society.

Gu, Y., Mol, L., Hoetjes, M., & Swerts, M. (2017). Conceptual and lexical effects on gestures: the case of vertical spatial metaphors for time in Chinese. *Language, Cognition and Neuroscience*, *32* (8), 1048-1063. doi:10.1080/23273798.2017.1283425

Gu, Y., Zheng, Y., & Swerts, M. (2019a). Which is in front of Chinese people, Past or Future? The effect of language and culture on spatial conceptions of time. *Cognitive Science*, *43*(12), e12804. doi:10.1111/cogs.12804

Gu, Y., Zheng, Y., & Swerts, M. (2019b). Having a different *pointing* of view about the future: The effect of signs on co-speech gestures about time in Mandarin-CSL bimodal bilinguals. *Bilingualism: Language and Cognition, 22* (4), 836-847. doi:10.1017/S1366728918000652

Hendricks, R. & Boroditsky, L. (2017). New space-time metaphors foster new non-linguistic representations. *Topics in Cognitive Science*, *9* (3), 800–818. doi: 10.1111/tops.12279.

Hendricks, R. K., Bergen, B. K., & Marghetis, T. (2018). Do metaphors move from mind to mouth? Evidence from a new system of linguistic metaphors for time. *Cognitive Science, 42*(8), 2950-2975. doi: 10.1111/cogs.12693

Kita, S., Alibali, M. W., & Chu, M. (2017). How do gestures influence thinking and speaking? The gesture-for-conceptualization hypothesis. *Psychological Review, 124*(3), 245-266. doi: 10.1037/rev0000059

Jin, G.J., Xiao, H., Fu, L., & Zhang, Y.F. (2005). An introduction to the Modern Chinese Corpus (现代汉语语料库建设及深加工). *Applied Linguistics,* 2, 111-120.

Lai, V. T., & Boroditsky, L. (2013). The immediate and chronic influence of spatio-temporal metaphors on the mental representations of time in English, Mandarin, and Mandarin-English speakers. *Frontiers in Psychology, 4,* 1-10. doi:10.3389/fpsyg.2013.00142

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago, IL: University of Chicago Press.

Li, H., & Cao, Y. (2018a) Time will tell: Temporal landmarks influence metaphorical associations between space and time. *Cognitive Linguistics, 29* (4), 677-701.

Li, H., & Cao, Y. (2018b). Karma or immortality: Can religion influence space-time mappings? *Cognitive Science, 42*, 1041-1056. doi: 10.1111/cogs.12579

Li, H. (2020). Will it really happen? Disambiguating of the hypothetical and real "Next Wednesday's meeting" question in Mandarin speakers. *Lingua,237*(102806), 1-12.

Li, Y., Casaponsa, A., Wu, Y.J., & Thierry, G. (2019) Back to the future? How Chinese-English bilinguals switch between front and back orientation for time. *NeuroImage*, *203*, 116180. doi: 10.1016/j.neuroimage.2019.116180

Lin, H., & Gu, Y. (submitted) Back to the past and down to the future: Temporal expressions in Chinese Sign Language based on naturalistic data.

McGlone, M. S., & Harding, J. L. (1998). Back (or forward?) to the future: The role of perspective in temporal language comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*(5), 1211–1223. doi: 10.1037/0278-7393.24.5.1211

Meade, G., Midgley, K., Sevcikova Sehyr, Z., Holcomb, P., & Emmorey, K. (2017). Implicit coactivation of American Sign Language in deaf readers: An ERP study. *Brain and Language, 170*, 50-61. doi: 10.1016/j.bandl.2017.03.004

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

Morford, J. P., Wilkinson, E., Villwock, A., Piñar, P. & Kroll, J. F. (2011) When deaf signers read English: Do written words activate their sign translations? *Cognition, 118* (2), 286-292. doi: 10.1016/j.cognition.2010.11.006

Morford, J. P., Kroll, J. F., Piñar, P. & Wilkinson, E. (2014) Bilingual word recognition in deaf and hearing signers: Effects of proficiency and language dominance on cross-language activation. *Second Language Research, 30*(2), 251-271. doi.10.1177/0267658313503467

National Bureau of Statistics China (2006) Second China National Sample Survey on Disability (first report) (2006 年第二次全国残疾人抽样调查主要数据公报（第一号), http://www.cdpf.org.cn/special/dlzt/cydc/sjfb-3.htm

Navarrete, E., Miozzo, M. & Peressotti, F. (2020) Language can shape the perception of oriented objects. *Scientific Report, 10*, 8409.

Nilsson, A. L. (2016). Embodying metaphors: Signed language interpreters at work. *Cognitive Linguistics, 27*(1), 35-65. doi:10.1515/cog-2015-0029

Nilsson, A. L. (2018). Expressing time through space: Embodying conceptual metaphors in an L1 vs. an L2 signed language. *Translation and Interpreting Studies*,*13*(1), 6-26.

Núñez, R., Cooperrider, K., Doan, D., & Wassmann, J. (2012). Contours of time: Topographic construals of past, present, and future in the Yupno valley of Papua New Guinea. *Cognition, 124*(1), 25-35. doi: 10.1016/j.cognition.2012.03.007

Núñez, R., Cooperrider, K., (2013). The tangle of space and time in human cognition. *Trends in Cognitive Sciences*, *17*(5), 220–229. doi:10.1016/j.tics.2013.03.008

Núñez, R., Motz, B., & Teuscher, U. (2006). Time after time: The psychological reality of the ego- and time-reference-point distinction in metaphorical construals of time. *Metaphor and Symbol, 21* (3), 133–146. doi.org/10.1207/s15327868ms2103_1

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.

Oppenheim, G., Wu, Y. J., & Thierry, G. (2018). Found in translation: Late bilinguals do automatically activate their native language when they are not using it. *Cognitive Science*, *42*(5), 1700-1713. doi:10.1111/cogs.12618

Pyers, J. E., Shusterman, A., Senghas, A., Spelke, E. S., & Emmorey, K. (2010). Evidence from an emerging sign language reveals that language supports spatial cognition. *Proceedings of the National Academy of Sciences*, *107*(27), 12116-12120.

Peng, Z. (2012). A cognitive study on time metaphor in Chinese: The Case of “qián” and “hòu” (汉语时间隐喻的认知研究—以‘前’、‘后’为例). *Journal of Shanxi Agricultural University (Social Science Edition)*, *11*, 1045–1051.

Saj, A., Fuhrman, O., Vuilleumier, P., & Boroditsky, L. (2014). Patients with left spatial neglect also neglect the “Left Side” of time. *Psychological Science, 25* (1), 207–214. doi:10.1177/0956797612475222

Santiago, J., Lupáñez, J., Pérez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin & Review, 14*(3), 512-516.

Schermer, T., & Koolhof, C. (1990). The reality of timelines: Aspects of tense in Sign Language of the Netherlands (SLN). In S. Prillwitz & T. Vollhaber (Eds.), *Current trends in European sign language research* (pp. 295-305). Hamburg: Signum.

Sinte, A. (2013). Expression of time in French Belgian Sign Language (LSFB). In Meurant, L. Sinte, A., Van Herreweghe, M., & Vermeerbergen, M. (Eds.), *Sign language research, uses and practices: Crossing views on theoretical and applied sign language linguistics* (pp. 205-235). Berlin: De Gruyter Mouton and Ishara Press.

Slobin, D. I. (1996). From ‘thought and language’ to ‘thinking for speaking.’ In J. J. Gumperz & S. C. Levinson (Eds.), *Studies in the social and cultural foundations of language, No. 17. Rethinking linguistic relativity* (p. 70–96). Cambridge University Press.

Stickles, E., & Lewis, T. N. (2018). Wednesday's Meeting Really Is on Friday: A Meta‐Analysis and Evaluation of Ambiguous Spatiotemporal Language. *Cognitive Science*, *42*(3), 1015-1025. doi:10.1111/cogs.12559

Stocker, K., & Hartmann, M. (2019). ‘Next Wednesday’s meeting has been moved forward two days’: The time-perspective question is ambiguous in Swiss German, but not in standard German. *Swiss Journal of Psychology*, *78*(1-2), 61-67. doi:10.1024/1421-0185/a000220

Sullivan, K., & Bui, L.T. (2016). With the future coming up behind them: Evidence that time approaches from behind in Vietnamese. *Cognitive Linguistics, 27*(2), 205-233.

Torralbo, A., Santiago, J., & Lupáñez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science, 30*, 745-757. doi: 10.1207/s15516709cog0000_67

Ulrich, R., Eikmeier, V., de la Vega, I., Fernandez, 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 and Cognition, 40* (3), 483–495. doi: 10.3758/s13421-011-0162-4

Van Hell, J. G., & Dijkstra, T. (2002). Foreign language knowledge can influence native language performance in exclusively native contexts. *Psychonomic Bulletin & Review, 9*(4), 780-789. doi:10.3758/BF03196335

Van Hell, J. G., & Tanner, D. (2012). Second language proficiency and cross-language lexical activation. *Language Learning*, *62*, 148-171. doi.10.1111/j.1467-9922.2012.00710.x

Villameriel, S., Dias, P., Costello, B., & Carreiras, M. (2016). Cross-language and cross-modal activation in hearing bimodal bilinguals. *Journal of Memory and Language, 87*, 59-70.

Walker, E., & Cooperrider, K. (2016). The continuity of metaphor: Evidence from temporal gestures. *Cognitive Science, 40*(2), 481-495. doi:10.1111/cogs.12254

Walker, E. J., Bergen, B. K., & Núñez, R. (2017). The spatial alignment of time: Differences in alignment of deictic and sequence time along the sagittal and lateral axes. *Acta Psychologica, 175*, 13-20.

Wilcox, S. (2002). The iconic mapping of space and time in signed languages. In L. Albertazzi (Ed.), *Unfolding perceptual continua* (pp. 255-281). Amsterdam & Philadelphia: John Benjamins.

Wu, L., & Li, H. (2012). Time-space metaphors in Chinese Sign Language (中国手语中的时间空间隐喻). *Chinese Journal of Special Education*, *150*(12), 25-29.

Wu, Y. J., & Thierry, G. (2010). Chinese-English bilinguals reading English hear Chinese. *Journal of Neuroscience, 30*(22), 7646-7651. doi:10.1523/JNEUROSCI.1602-10.2010

Xiao, C., Zhao, M. & Chen, L. (2018). Both earlier times and the future are “Front”: The distinction between time- and ego-reference-points in Mandarin speakers’ temporal representation. *Cognitive Science, 42* (3), 1-26-1040. doi:10.1111/cogs.12552

Xu, D. (2016). Vertical time expressions in ancient Chinese (古汉语里的纵向时间表达). *Linguistic Science, 15*(1), 1-9. https://hal.archives-ouvertes.fr/hal-01386252

Yu, N. (2012). The metaphorical orientation of time in Chinese. *Journal of Pragmatics, 44* (10), 1335–1354. doi.org/10.1016/j.pragma.2012.06.002

Yang, J. H. (2015) Chinese Sign Language. In Jepsen, J.B., De Clerck, G., Lutalo-Kiingi, S., McGregor, W. B. (Eds), *Sign languages of the world: A comparative handbook* (pp. 177-194). Berlin: De Gruyter.

Yang, W., & Sun, Y. (2017). English and Mandarin speakers’ mental representations of time: Some new evidence about the language-thought relationship. *Review of Cognitive Linguistics*, *14*(2), 385–415. doi:10.1075/rcl.14.2.05yan

Zheng, X. (2009). *A study of signs for non-visual concepts in Shanghai Variety of Chinese Sign Language* (上海手语非视觉概念表达研究). PhD Dissertation. Fudan University, China.

Chapter 5. Beyond financial knowledge and IQ: The effect of temporal values on pension planning, homeownership and financial wealth of natives and immigrants in the Netherlands

Abstract

We study pension planning and financial wealth of natives and immigrants (*N*=1177) in the Netherlands, in relation to their temporal values (past/future-focused), financial knowledge, IQ, and other individual characteristics. We find that, compared to natives, immigrants are less financially literate and rely more on the government for their retirement income, but are more future-focused and think more about their retirement. Second, controlling for financial knowledge, IQ, saving intention, health, self-control and demographic factors, temporal values help to predict many aspects of pension planning: how much people think about retirement, their desired retirement age, whether they develop a plan to save for retirement, perceived saving adequacy, and home ownership. Furthermore, temporal values predict savings and financial wealth in 2016 and 2020, even after controlling for the financial situation in 2016. In conclusion, habitually attending to the past leads people to give less priority to the future compared to the past, which has consequences for people's planning and behaviour such as retirement planning and financial well-being. Our results have strong implications for policies related to pension communication and contribute to the theory on relationships between economic decisions, time and cognition.

Keywords: temporal focus; time; well-being; pension planning; retirement; IQ; savings; financial wealth

Acknowledgements: This work is supported by a grant from The Netherlands Organization for Scientific Research, via NWO Research Talent (406-15-298) to YQZ.

An abstract of the chapter has been published as:

Zheng, Y., Gu, Y., & van Soest, A. (2022). Beyond financial knowledge and IQ: The effect of temporal values on pension planning and financial wealth of natives and immigrants in the Netherlands. *Proceedings of the Annual Meeting of the Cognitive Science Society, 44*. Retrieved from https://escholarship.org/uc/item/4gj9r21c

Introduction

Pension reforms in many countries have shifted a large part of the responsibility for an adequate standard of living after retirement from the government, employers, or pension providers to individuals and their households. Individuals increasingly must make their own decisions, while on the other hand many people do not think about their future and do not have the interest or the knowledge to make such decisions in a conscious or optimal way.

Immigrants are potentially a vulnerable group that has not gained much attention in pension studies. Their financial preparation for retirement may be influenced by human capital, social-demographic, financial knowledge, linguistic barrier, and psychological factors (e.g., Lusardi & Mitchell, 2011; Topa, Moriano, & Moreno, 2012). The rocketing number of immigrants combined with the aging problem and the associated increasing focus on pensions urge us to analyze life-cycle differences in retirement planning and financial wealth between natives and immigrants. For example, Statistics Netherlands predicts that the Dutch population with a migration background will increase from 24.5% (2021) to 30%-40% in 2050. It is hardly known as to whether and how Dutch immigrants prepare differently for retirement from natives. This study aims to better understand factors that influence retirement planning and financial wealth for immigrants and native Dutch. Particularly, we not only for the first time show how financial literacy and IQ jointly predict pension planning, but emphasize the importance of a previously unexplored factor - cultural temporal values, which goes beyond the effects of financial literacy, IQ or other individual characteristics.

Factors influence pension planning

Studies have identified many demographic and psychological factors that can influence people's retirement planning, such as financial knowledge, saving intentions, future time horizon, and financial risk tolerance (e.g., Hershey & Mowen, 2000; Hudomiet, Carvalho, & Rohwedder, 2018; Tanaka, Camerer, & Nguyen, 2010; van Rooij, Lusardi, & Alessie, 2011a). For example, individuals with a higher level of financial literacy are more likely to develop a retirement plan and think more about their retirement (e.g., Bucher-Koenen & Lusardi, 2011; Jacobs-Lawson & Hershey, 2005; Lusardi & Mitchell, 2014; van Rooij, Lusardi, & Alessie, 2012). However, what remains less clear is whether financial literacy reflects knowledge or rather ability and cognition (van Rooij, Lusardi, & Alessie, 2011b). Despite the well-established impact of IQ on economic decisions (e.g., Burks et al., 2009; Ginblatt, Keloharju, & Linnainmaa, 2011), no study on pension planning has so far directly used measurements of individuals' IQ. Additionally, institutional differences may influence people's pension planning. For example, many Dutch may trust their pension fund instead of involving in their own planning, whereas Americans more often plan their pension by themselves (van Dalen, Henkens, & Hershey, 2010). Moreover, subjective reports of health have important effects on retirement, the effect of which is argued to be even stronger than financial variables. For example, McGarry (2003) found that changes in retirement expectations are much more affected by changes in health than by changes in income or wealth.

Interestingly, with a quite different view, Chen (2013) claims that the structure of languages can influence people's economic behaviour and retirement savings. Languages such as English and French, that grammatically separate future and present are called strong future time reference languages (e.g., "It is raining now"; "It will rain tomorrow"), whereas weak future time reference languages such as Dutch or German, do not have this feature (e.g., "Nu regent het"; "Morgen regent het") (Chen, 2013; Thieroff, 2000). Chen (2013) proposes that strong future time reference languages make the future feel more distant and make individuals less aware of the future consequences of their current behaviour, reducing future-oriented behaviour such as saving (linguistic-saving theory). His cross-country analysis showed that speakers of weak future time reference languages save more. The within-country comparisons between individuals with an identical background except for different home languages revealed that, controlling for cultural values (whether saving is considered important and thriftiness is appreciated), language still influences saving (e.g., in Brussels, individuals who speak Dutch save more than those who speak French).

A number of studies follow Chen's (2013) theory (e.g., Liang et al., 2018; Sutter, Angerer, Glätzle-Rützler, & Lergetporer, 2018), but the major problem with Chen's hypothesis is that he assumes that there is a link between language structure and the perception of the distance of the future (and further influences inter-temporal choice), but this important premise is not tested in his study or grounded on any empirical evidence. In particular, lab experiments showed that there is no effect of linguistic grammar of future time references on the perceived distance of future events (Jäggi et al., 2022), and several well-controlled experiments failed to replicate Chen's hypothesis (Chen, He & Riyanto, 2019; Thoma & Tytus, 2017). Chen also failed to replicate his own results when the original data set was re-analysed while controlling for cultural evolution (Roberts, Winters, & Chen, 2015).

In spite of the criticisms, Chen's idea on a possible link between time perception and future-oriented planning or behaviour should be valid (e.g., Earl et al. 2015; Webster, Bohlmeijer, & Westerhof, 2014). Especially, compared to the richness of research on various aspects of pension planning and adjustment, there are very few studies exploring the relations between people's thinking about time and their future retirement planning (Adams & Rau, 2011; Zacher, 2013, 2014). To study associations between time perspective and economic or management outcomes, researchers often use the Zimbardo Time Perspective Inventory (ZTPI; Zimbardo & Boyd, 1999) that considers time as multidimensional, including the past, present, and future. Time can have different types of affection. For example, the past can be divided into the past negative and past positive types. The former focuses on negative personal experiences in the past and the latter takes a nostalgic view of the past focusing on "good old days". Research shows that time perspective can associate with work-related well-being and achievement (Drake et al, 2008; see the review of Levasseur et al., 2020). Typical ZTPI items include "Painful past experiences keep being replayed in my mind", "Happy memories of good times spring readily to mind", "I complete projects on time by making steady progress", etc. Arguably, some items in ZTPI are mixed with risk aversion.

Researchers using the ZTPI measure have found that individual differences in cognitive engagement with time are related to retirement planning (e.g., Hershey & Mowen, 2000; Kerry, 2018; Mooney, Earl, Mooney, & Bateman, 2017). For example, Earl et al. (2015) explored the time perspective as a predictor of pension planning and possible consequences on the well-being of 367 Australian retirees. They found that future time perspective helps to predict individuals' retirement planning, but does not predict retirement outcomes such as retirement adjustment, life satisfaction, well-being, etc. Additionally, these authors admit that their results can be cofounded with procrastination due to some ZTPI items.

People's sense of time differs across cultures (e.g., Callizo-Romero et al., 2020; Carstensen, 2006), and people with different cultural temporal focus may attach different monetary values to past or future events (Guo et al., 2012). Taking cultural values toward time (i.e., habits of attending to past or future events) as an example, people from specific (sub)cultural groups tend to focus more on past times and older generations, they are more observant of ancient rituals, and place more value on tradition, whereas people from other cultures can have a greater focus on the future, valuing economic development, globalization, and technological progress. People who are habitually attending to past events may metaphorically tend to place the past in front of them, "in the location where they could focus on the past literally with their eyes if past events were physical objects that could be seen" (de la Fuente et al., 2014, p.1684). If people, regardless of cultures, put important things in front of them and leave less important things behind (Callizo-Romero et al., 2020), habitually attending to the past is likely to make people give less priority to the future compared to the past. Temporal values can therefore have consequences for their pension planning and their actual behaviour, potentially influencing their well-being in the long run.

So far time perspective or temporal values and pension planning have been rarely studied in a cross-cultural context (Earl et al., 2015) or with a focus on immigrants. In this study we fill this gap in the literature by investigating the impact of overall temporal values on immigrants' pension planning, homeownership, retirement savings and financial wealth, comparing immigrants with a control group of native Dutch. Unlike most studies which do not control for participants' other characteristics that may relate to the pension planning (and hence time can operate as a moderator), we additionally measure many important factors such as participants' IQ, financial knowledge, risk aversion, saving intention, patience, health, self-control and income. Particularly, IQ can be a good proxy of ability, which can provide a better understanding of the relationship between financial knowledge, cognition and pension planning. Furthermore, to better understand the effect of temporal values, we study their relations to participants' riskless assets and financial wealth both concurrently in 2016 and longitudinally four years later.

Data

We used survey data for the Netherlands collected in 2016, 2020 and 2022. We designed a special questionnaire with a set of questions including general values toward time (temporal focus questionnaire, de la Fuente et al., 2014, shortened version[1], e.g., future values item: "It is important to innovate and adapt to the new changes." Past values item: "The traditional way of living is better than the modern way.", see Appendix 1), retirement planning, risk aversion (van Rooij et al., 2011), financial knowledge (Lusardi & Mitchell, 2008), IQ (Raven's Standard Progressive Matrices Test, Raven, 1976; shortened version[2], Bilker et al., 2012), self-control, time preference (patience), saving intention, demographic information, etc. This questionnaire was administered in 2016, when we also obtained information about participants' savings, and financial wealth. Furthermore, participants who originally took the survey in 2016 were interviewed again in 2020 for their savings and financial wealth and in 2022 for their homeownership (we do not have information about other aspects in 2022). In addition, we gathered participants' self-assessed general health status (1-5) in 2016.

List of questions related to retirement planning

Q1. How much responsibility do you think generally a government should have for ensuring a reasonable standard of living for retired people? (1='It's entirely everyone's own responsibility, …, 9='It's entirely the responsibility of the government').

Q2. How much have you thought about retirement? (A lot, some, a little, or hardly at all)

Q3. If you were able to choose for yourself, at what age would you want/have wanted to stop working? (only for respondents performing paid work and older than 44 years.)

Q4. Have you ever tried to figure out how much you would need yourself to save for retirement? (Yes/No)

Q5. If participants answered "Yes" to Q4, they were asked "Have you developed a plan for retirement?" (Yes; More or less; No). Combining answers of these three categories and "No" from Q4, we coded an ordered variable with the following categories: I have tried (to figure out the amount need for retirement) and a plan has been developed; I have tried and a plan has been more or less developed; I have tried but no plan has been developed; I have never tried ("No" Q4).

Q6. Choose your answer on a scale of 1 to 9, with 1 'disagree completely' and 9 'agree totally'. "I am saving enough to retire comfortably".

Q7. Do you own the house you live in? (Yes; No)

Invitations to answer this questionnaire (in Dutch) were sent to 1471 participants in the LISS panel, administered by Centerdata (Tilburg University, The Netherlands) in 2016. The LISS panel is a representative sample of Dutch individuals of age 16 and older, covering immigrants from many countries of origin and representative in terms of gender, age, education, income and other domains. There were 1177 respondents (M_{age}=46.69, *range* 25-66, *SD*=11.89, 646 females, 531 males), including 659 immigrants (361 first-generation and 298 second-generation immigrants). We excluded participants who are retired (*n*=74). Due to participants' unwillingness of providing some

[1] Four items about temporal focus were chosen from de la Fuente et al.'s (2014) temporal focus questionnaire, which originally had 21 questions. The four items were selected based on a preliminary survey to about 100 people using the 21 items and chose the four items whose TFI had a correlation of 0.8 with that of 21 items.

[2] There were four items in total, three of which were from Bilker et al., 2012's norming study, which can predict 78-91% of the total Raven's test (60 items). To increase item discrimination, we additionally selected one item from the Raven Advanced Progressive Matrices. The score was coded as the number of correct answers.

information or dropping out of the survey between 2016 and 2020, we miss certain information for some participants and lose participants over years (e.g., the sample size of financial wealth is smaller than others, see details in observations in regression output tables). The sample is oversampled in immigrants but is representative in terms of important background characteristics, as those who failed to provide income and financial information in 2016 do not differ from others in their means of age, education, IQ, marriage, self-control, patience, or temporal values (all p>.1). The only exception is that females are less willing to reveal their financial wealth than males are (p=.079).

Data analysis plan

Dependent variables

Pension planning, perceived saving adequacy and owning of dwelling We generated three dependent variables on the role of government's/individuals' responsibility for ensuring retirees' living standard (*government*), how much people think about their retirement (*thoughtretire*) and their desired retirement age (*retireage*) (Q1-3). Then we generated three dependent variables on whether participants have figured out how much they need to save for retirement (*figout_amnt_sav*, Q4), whether they developed a saving plan for retirement (*retire_plan*, Q5), and whether they perceive themselves to have adequate savings (*perceive_sav_adeqc*, Q6). For Q7, we generated a dependent variable on whether participants own the house they live in (*dwelling*) in 2016 and 2022.

Savings and financial wealth We generated six dependent variables on participants' riskless assets (savings) and financial wealth in 2016 and 2020, which were log-transformed except 0 values (*sav16*; *finasset16*; *sav20*; *finasset20*).

Independent variables

For our key variable on temporal values, participants rated the degree to which they agreed on the statement at a scale of 1-9 (1=completely disagree; 9=total agree). Based on scores testing future values items and past values items, we generated a Temporal-focus Index (*TFI*) for each participant: *TFI* = (mean of future values score − mean of past-values score) / (mean of future-values score + mean of past-values score) (de la Fuente et al., 2014). *TFI* ranges from −1 to 1, where −1 represents (completely) past-focused, 0 represents present-focused and 1 represents future-focused.

Additionally, we generated the following independent variables: *health*, *IQ*, *risk aversion*, *patience* (time preference), *financial knowledge, self-control*, *education (high*; *low)*, *saving intention*, *income* (log-transformed), and eight group dummies *DutchNative*, *Turkey*, *Morocco*, *Indonesia*, *Surinam*, *Netherlands Antilles*, *otherNonWestern*, *otherWestern*. Moreover, we generated standard demographic variables *female*, *age*, *marriage*, *number of children*, etc.

Ordered probit models were used to analyse the ordinal dependent variables *government*, *thoughtretire*, *retire_plan* or *perceive_sav_adeqc*, probit regressions for binary dependent variables *figout_amnt_sav* or *dwelling*, and OLS regressions for dependent variables *retireage*, *sav* or *finasset*.

In addition, three sensitivity analyses were conducted. First, we replaced the *TFI* with the original cultural past temporal values and future temporal values to check which temporal values are significant and which values have a larger impact. Second, because the effects of *TFI* and *Age* can be non-linear, we used a generalized additive model (a generalized linear model, Wood, 2017) in which the linear response variable depends linearly on unknown smooth functions of some predictor variables (*TFI* and *Age*). Third, as *Age* usually negatively associates with TFI (de la Fuente et al., 2014) but also relates to our dependent variables, we ran GAM models while excluding *Age* or *TFI* to check the robustness of results of TFI.

Results

Some descriptive results of main variables (e.g., financial literacy, IQ, TFI) and a histogram of TFI can be found in Appendix 2 and Appendix 3. In general, comparing the raw data, immigrants (M=2.10, SD=1.07) are significantly less financially literate than native Dutch (M=2.38, SD=0.90) (all p's<.05 for all groups, exceptions are Indonesians, p=.84, and western immigrants, p=.31). Immigrants (M=0.02, SD=0.19) overall have a significantly larger TFI (more future-focused) than native Dutch (M=-0.013, SD=0.20, p=.003), but separately, immigrants from Turkey, Morocco, Netherlands Antilles and Surinam (all p's>0.12) are not significantly more future-focused than native Dutch. Finally, controlling for IQ (β =0.28, p<.001), education (β=0.32, p<.001), gender (β =-0.21, p<.001), age (β=0.007, p<.001), risk aversion (β=0.10, p<.001), and other factors, TFI (β=.58, p<.001) significantly predicts financial knowledge.

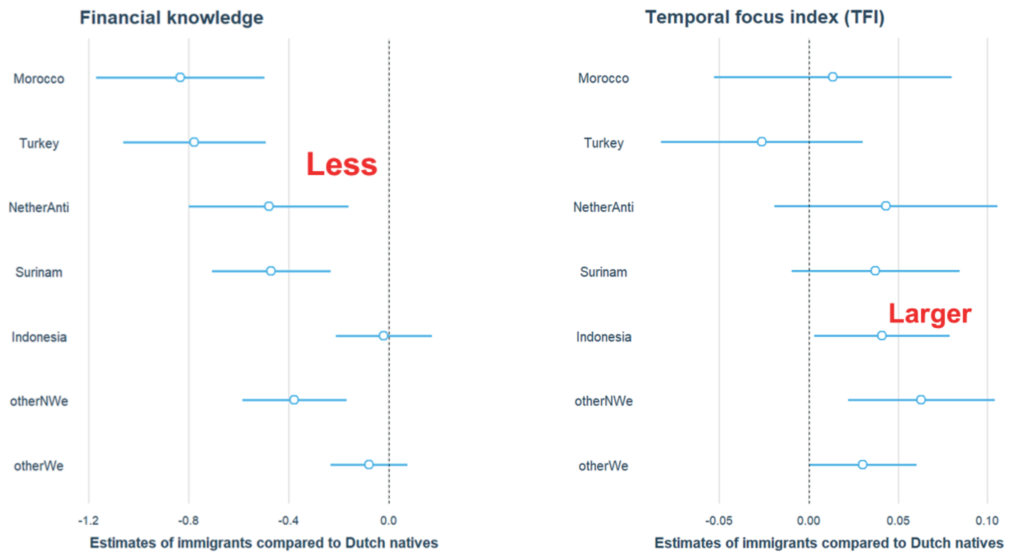


Figure 1. Immigrants compared to Dutch natives: Financial knowledge (left) and TFI (right).

Pension planning, saving adequacy, and home ownership

Table 1: TFI predicts various aspects of pension planning.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	governm	thoughtretire	Retireage	figuresavretire	dev_plan	savadeqacy
tfi	-0.708***	0.429*	3.193**	0.764**	0.627*	0.435*
	(0.191)	(0.207)	(1.146)	(0.254)	(0.264)	(0.199)
selfcontrol	0.0630**	0.0352	0.111	0.0941**	0.0819**	0.0605**
	(0.0215)	(0.0235)	(0.150)	(0.0288)	(0.0297)	(0.0224)
patience	-0.0413*	0.0475**	-0.111	0.0924***	0.0827***	0.170***
	(0.0167)	(0.0183)	(0.111)	(0.0225)	(0.0229)	(0.0178)
riskaverse	0.00779	0.0300	0.219†	0.0188	0.0103	-0.00543
	(0.0199)	(0.0216)	(0.127)	(0.0262)	(0.0266)	(0.0205)
highedu1	-0.150*	0.0447	-0.124	0.0462	0.0111	0.110
	(0.0760)	(0.0823)	(0.514)	(0.0968)	(0.0986)	(0.0773)
age	0.00318	0.0423***	0.219***	0.0272***	0.0276***	0.0185***
	(0.00336)	(0.00378)	(0.0427)	(0.00435)	(0.00455)	(0.00346)
finaKnow	-0.0275	0.0991*	0.134	0.151**	0.150**	0.0208
	(0.0401)	(0.0443)	(0.298)	(0.0537)	(0.0554)	(0.0408)
female	0.017(0.072)	0.011(0.0777)	-0.167(0.517)	-0.0934(0.0927)	-0.044(0.10)	0.065(0.073)
childrenum	-0.0259	-0.111**	-0.0729	-0.0837†	-0.0946*	-0.0907**
	(0.0319)	(0.0349)	(0.220)	(0.0428)	(0.0437)	(0.0326)
married	-0.0525	0.163*	0.114	0.361***	0.334**	0.366***
	(0.0773)	(0.0833)	(0.491)	(0.0996)	(0.102)	(0.0790)
IQ	-0.0293	-0.0187	0.0782	0.0968*	0.0612	0.0669†
	(0.0361)	(0.0388)	(0.249)	(0.0476)	(0.0476)	(0.0369)
inc.unknwn	-0.147(0.167)	0.347(0.183)†	0.260(4.415)	0.338(0.222)	0.263(0.225)	0.274(0.172)
logincome	0.0124	0.0524**	0.235	0.0437*	0.0368	0.0507**
	(0.0163)	(0.0181)	(0.565)	(0.0221)	(0.0227)	(0.0170)
Turkey	0.297†	0.313†	-0.344	-0.150	0.0162	0.0924
	(0.172)	(0.189)	(1.759)	(0.245)	(0.246)	(0.174)
Morocco	0.524**	0.416†	0.988	-1.134*	-4.741	-0.678**
	(0.198)	(0.214)	(1.763)	(0.490)	(120.9)	(0.216)
NetherAnti	0.183	0.0237	-1.853	-0.373	-0.555†	-0.517**
	(0.191)	(0.207)	(1.354)	(0.279)	(0.296)	(0.200)
Surinam	0.0867	0.306†	-1.684†	-0.317	-0.243	-0.244
	(0.152)	(0.165)	(0.992)	(0.201)	(0.211)	(0.156)
Indonesia	0.0492	0.360**	-0.521	0.0401	0.0632	-0.274*
	(0.118)	(0.126)	(0.724)	(0.147)	(0.148)	(0.121)
otherNWe	0.0181	0.151	0.964	-0.100	0.0669	-0.136
	(0.129)	(0.141)	(0.959)	(0.165)	(0.170)	(0.131)
otherWe	0.163†	-0.0358	-0.999	0.0180	-0.00298	-0.307**
	(0.0942)	(0.102)	(0.641)	(0.118)	(0.120)	(0.0963)
gvrnmnt	-	0.0200	-0.0341	-0.128***	-0.127***	-0.104***
		(0.0227)	(0.139)	(0.0263)	(0.0278)	(0.0218)
saveintention	-	0.0393(0.0244)	0.221(0.145)	0.0482(0.0297)	0.0468(0.03)	0.1(0.024)***
health16	-0.15(0.05)**	-0.0432(0.05)	1.076(0.35)**	-	0.0412(0.06)	0.24(0.05)***
Obs.	946	946	293	1,088	946	946
PseudoR^2/R^2	0.03	0.10	0.236	0.174	0.121	0.088

Note: ***p<.001, **p<.01, *p<.05, †p<.1. The dependent variables (1)-(6) are from Q1-6, respectively. 1,2,5,6=ordered probit; 3=OLS, 4=probit.

First, we describe what people think about the government's responsibility for ensuring a living standard of retired people (Q1), how much they think of retirement (Q2) and their desired retirement age (Q3). Results show that (1) people who have a larger TFI, a better health situation, have higher education, less self-control or more patience tend to think that individuals should be more responsible for their retirement income. (2) people who have a larger TFI, who are older, more patient, financially more literate with higher income think more often about their retirement; (3) people who have a larger TFI, older but better health and a stronger risk aversion (*p*=.086) hope to retire later; and (4) immigrants (especially Moroccans) significantly more often think it is the government's responsibility to ensure a sufficient standard of living during retirement. They also think more often about their retirement than the native Dutch (e.g., Indonesian) even though there are no differences in desired retirement age. In short, the results show that, keeping other factors constant, TFI predicts how much people think about retirement, the extent to which they think it is the government's instead of the individuals' responsibility to ensure sufficient retirement income, and the desired retirement age (see Table 1 and Figure 2 for effect sizes and details).

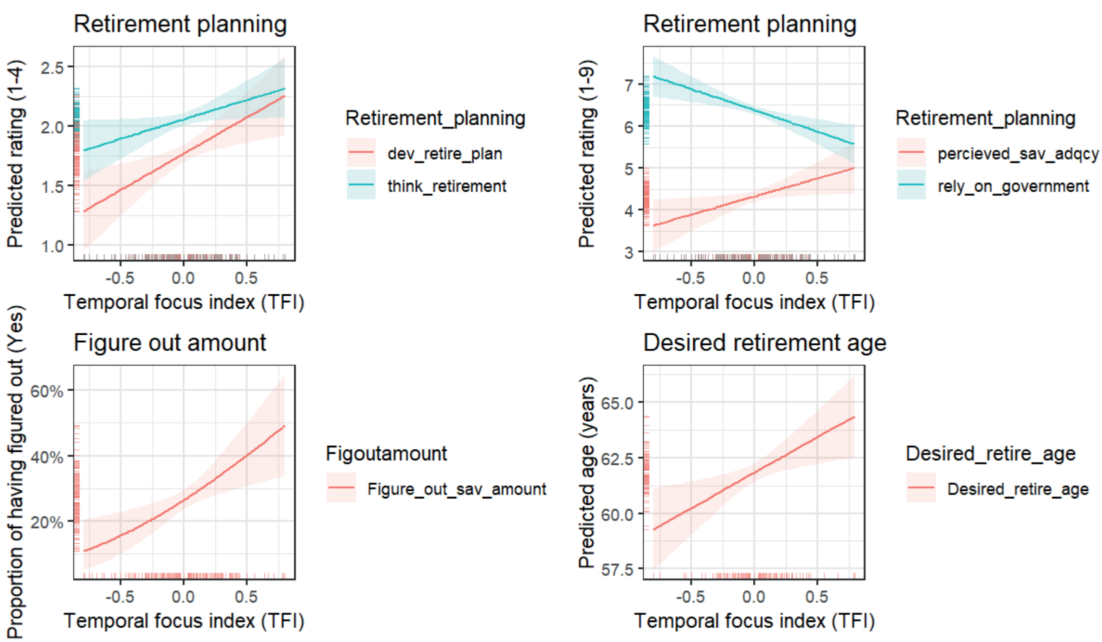


Figure 2. TFI predicts how much people think of retirement; whether having a retirement plan; the degree of relying on government's responsibility; perceived saving adequacy; proportion of figuring out amount of savings needed and the desired retirement age. For a visualisation purpose, the estimates based on ordered probit models are plotted with OLS estimates (the same variables are consistently significant). Shaded areas are 95% confidence interval bands.

Next we examine factors that affect whether participants have tried to figure out the amount they need to save for retirement (RQ4) and whether they have developed a retirement plan (RQ5). Consistent with past research, individuals' financial knowledge, marital status, income, self-control, age and number of children are significant predictors. Beyond these factors, TFI, perceived government responsibility and IQ (for RQ4) significantly influence pension planning. Specifically, controlling for other factors, those who have a larger TFI (p=.003; p=.017), a higher IQ, and less trust in the government's responsibility have a higher probability of knowing how much they need to save for retirement and on developing a retirement plan (Table 1, (4)-(5)). Immigrants from Morocco are 32.72% (average marginal effect) less likely to try to figure out the amount they need to save for retirement, whereas other immigrants are not significantly different from the native Dutch in these aspects (Figure 3).

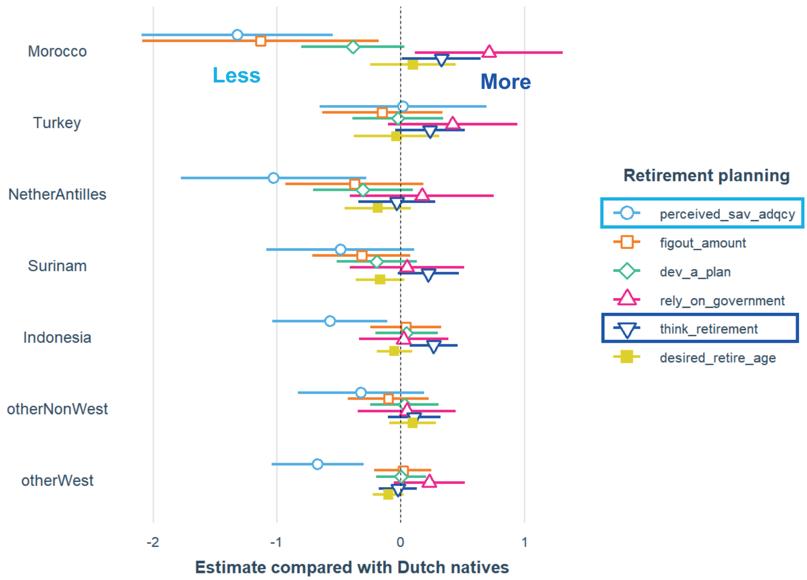


Figure 3. A comparison of retirement planning between different immigrant groups and Dutch natives, while controlling for demographic and other related variables. For visualisation purposes the estimates based upon ordered probit models are plotted with OLS estimates (the same variables are consistently significant.)

For perceived savings adequacy (RQ6), individuals who have a larger TFI (p=.029) are more likely to think that they have adequate savings for retirement, controlling for demographic factors (marriage, children number, income, age, all p's<.01), health, saving intention, trust in government's responsibility, patience (all p's<.001), self-control (p=.007), risk aversion (p=.792), education (p=.154), IQ (p=.07) and financial knowledge (p=.610). Compared to Dutch natives, immigrants (except Turkish, Surinam and other non-westerners) more often perceive their retirement savings are inadequate.

Finally, for home ownership (RQ7), participants who have a larger TFI (AME=0.15, p=.035) are more likely to own their dwelling in 2016, controlling for significant factors of health (p=.003), age (p=.002), financial knowledge (p=.012), income (p=.043), marital status (p<.001), number of children (p<.001) and education (p=.076). In comparison to native Dutch, only immigrants from Turkey (p=.85) and Western immigrants (p=.10) are not significantly different whereas immigrants from Morocco (AME=-0.53, p<.001), Netherlands Antilles (AME=-0.20, p=.005), Suriname (AME=-0.13, p=.015) and other non-Western (AME=-0.17, p<.001) and Indonesians (AME=-0.08, p=.054) are significantly less likely to live in their own dwelling (Figure 4), keeping other factors constant. Furthermore, TFI still predicts participants' homeownership in 2022 (AME=0.20, p=.015), keeping others constant. When the baseline homeownership in 2016 is additionally controlled for, the effect of TFI still holds (AME=0.11, p=.042). This indicates that, everything being equal, participants who had a larger TFI in 2016 are more likely to have an ownership of a dwelling six years later (Table 2, Figure 5a). When TFI increases by 0.1 unit, the probability of owning a dwelling is expected to increase by 0.015, 0.020 and 0.011 point in 2016, 2022 and 2022_ctrl16.

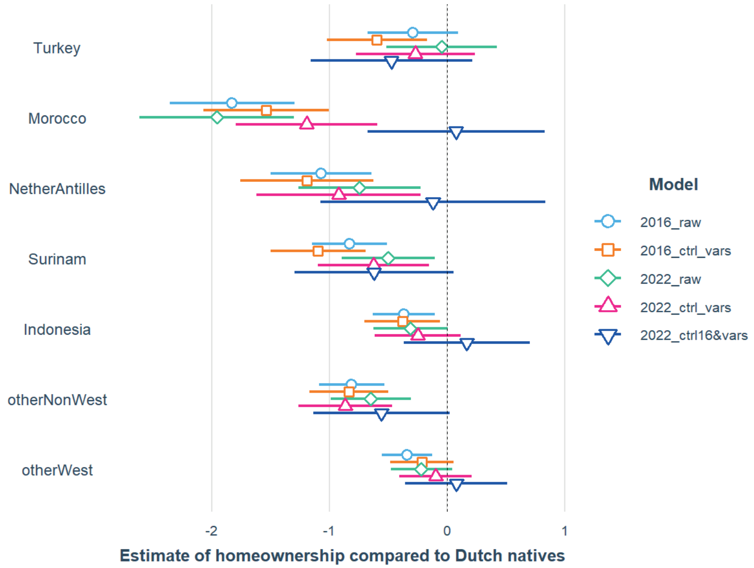


Figure 4. A comparison of homeownership between different immigrant groups and Dutch natives for different models. *Raw* – model with raw data of 8 groups; *ctrl_vars* model controlling for demographic and related variables; ctrl16&vars model controlling for all variables and the baseline dwelling in 2016.

Table 2: TFI predicts homeownership, log-transformed savings and financial wealth.

Variables	ownhome16	ownhome20	ownhome20_16	savings16	savings20	savings20_16	finasset16	finasset20	finasset20_ctrl16
ownhome16			2.867(0.189)***						
savings16						0.610(0.0412)***			
finasset16									0.580(0.0407)***
health	0.201**	0.183*	0.0798	0.375*	0.260	0.128	0.304	0.281	0.140
	(0.0667)	(0.0783)	(0.110)	(0.184)	(0.217)	(0.185)	(0.188)	(0.219)	(0.190)
tfi	0.564*	0.736*	0.897*	2.393**	2.882***	1.805*	2.324**	3.218***	2.224**
	(0.267)	(0.301)	(0.441)	(0.781)	(0.826)	(0.723)	(0.805)	(0.830)	(0.745)
saveintention	0.0257	0.0527	0.0895†	0.283**	0.134	-0.0107	0.309***	0.189†	-0.000701
	(0.0308)	(0.0353)	(0.0513)	(0.0899)	(0.103)	(0.0892)	(0.0919)	(0.105)	(0.0924)
financialKnow	0.137*	0.128*	0.0974	1.105***	1.001***	0.432*	1.142***	0.995***	0.422*
	(0.0549)	(0.0633)	(0.0874)	(0.172)	(0.202)	(0.182)	(0.176)	(0.204)	(0.186)
IQ	0.072(0.051)	0.082(0.058)	0.011(0.084)	0.16(0.15)	0.19(0.17)	0.08(0.15)	0.13(0.41)	0.25(0.18)	0.107(0.159)
female	0.105(0.102)	0.014(0.117)	-0.203(0.165)	-0.30(0.30)	-0.05(0.33)	0.18(0.29)	-0.37(0.30)	-0.08(0.33)	0.183(0.297)
highedu1	0.195†	0.386**	0.309†	0.420	0.586†	0.395	0.613†	0.694†	0.378
	(0.110)	(0.127)	(0.177)	(0.310)	(0.353)	(0.303)	(0.317)	(0.357)	(0.309)
age	0.0141**	0.00242	-0.0111	-0.0160	-0.00168	-0.00221	-0.00986	0.00224	-0.00648
	(0.00463)	(0.00553)	(0.00790)	(0.0137)	(0.0162)	(0.0140)	(0.0140)	(0.0163)	(0.0143)
childrenum	0.203***	0.0471	-0.158*	-0.00310	0.129	0.209†	0.00901	0.168	0.205
	(0.0494)	(0.0530)	(0.0753)	(0.127)	(0.145)	(0.124)	(0.130)	(0.149)	(0.129)
married	0.880***	0.808***	0.244	-0.0573	0.598	0.260	0.0659	0.773*	0.445
	(0.109)	(0.128)	(0.186)	(0.322)	(0.364)	(0.318)	(0.329)	(0.368)	(0.328)
riskaverse	0.05(0.028)†	0.063(0.03)†	0.048(0.048)	0.12(0.08)	0.14(0.1)	-0.04(0.08)	0.09(0.08)	0.11(0.09)	-0.027(0.08)
selfcontrol	0.009(0.031)	-0.001(0.035)	-0.019(0.05)	0.2(0.09)†	0.16(0.1)	-0.05(0.09)	0.14(0.09)	0.151(0.1)	-0.027(0.089)
income	0.0468*	0.0288	-0.0213	0.337***	0.206**	0.0204	0.365***	0.229**	0.0488
	(0.0231)	(0.0257)	(0.0364)	(0.0689)	(0.0787)	(0.0702)	(0.0704)	(0.0801)	(0.0721)
Turkey	-0.0450	-0.269	-0.473	-3.058***	-2.824**	-1.551*	-2.980***	-3.016***	-1.950*
	(0.244)	(0.258)	(0.354)	(0.688)	(0.896)	(0.773)	(0.702)	(0.899)	(0.784)
Morocco	-1.955***	-1.193***	0.0768	-3.088***	-2.152**	-0.650	-3.244***	-2.349**	-0.850
	(0.326)	(0.293)	(0.383)	(0.738)	(0.825)	(0.695)	(0.753)	(0.829)	(0.709)
NetherAnti	-0.743**	-0.921**	-0.119	-1.990**	-1.680†	-0.769	-2.179**	-1.775†	-0.878
	(0.266)	(0.356)	(0.499)	(0.730)	(0.993)	(0.817)	(0.761)	(0.995)	(0.874)
Surinam	-0.497*	-0.624*	-0.620†	-2.996***	-1.997**	-1.194†	-2.949***	-2.119**	-1.537*
	(0.204)	(0.243)	(0.334)	(0.629)	(0.671)	(0.646)	(0.642)	(0.683)	(0.672)
Indonesia	-0.309†	-0.248	0.168	-1.710***	-0.536	-0.477	-1.553**	-0.601	-0.683
	(0.160)	(0.188)	(0.277)	(0.493)	(0.591)	(0.537)	(0.506)	(0.599)	(0.554)
otherNWe	-0.646***	-0.864***	-0.557†	-1.202*	-1.390*	-0.886†	-1.159*	-1.420*	-0.935
	(0.174)	(0.205)	(0.294)	(0.522)	(0.625)	(0.532)	(0.536)	(0.627)	(0.545)
otherWe	-0.218	-0.0965	0.0794	-1.274***	-0.260	-0.172	-1.264**	-0.381	-0.238
	(0.132)	(0.157)	(0.222)	(0.382)	(0.427)	(0.366)	(0.392)	(0.432)	(0.377)
Observations	946	734	734	602	486	391	597	474	382
Pseudo R^2/R^2	0.249	0.230	0.634	0.389	0.324	0.603	0.397	0.353	0.609

Note: ***$p<.001$, **$p<.01$, *$p<.05$, †$p<.1$. Insignificant variables *patience*, *and income_unknown* are omitted from the table. Probit model for homeownership (Pseudo R^2) and OLS for savings and financial wealth (R^2).

Savings and financial wealth

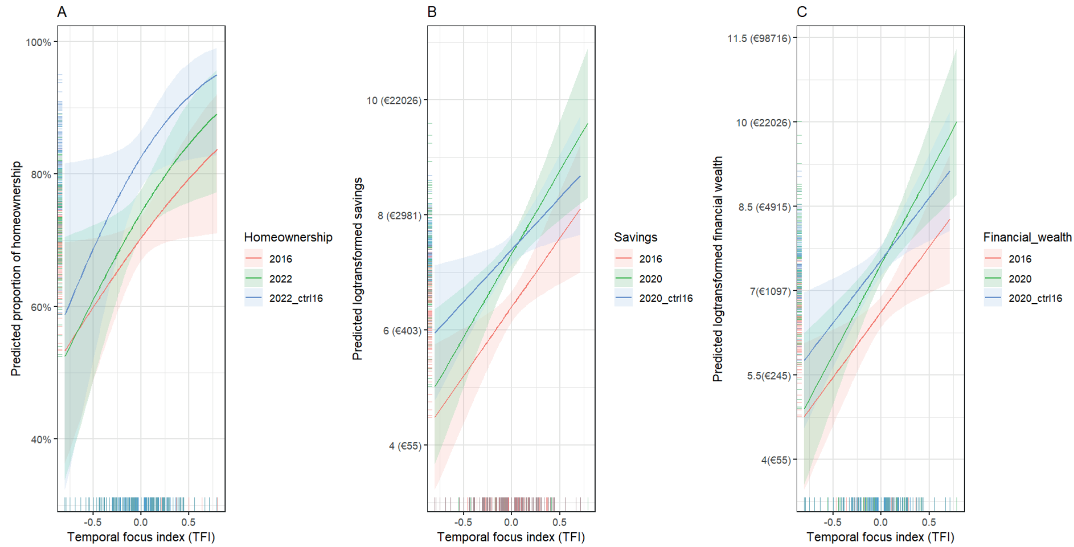


Figure 5. TFI predicts (A) homeownership in 2016, 2022 and 2022 while controlling for 2016 baseline; (B) savings, and (C) financial wealth in 2016, 2020 and 2020 while controlling for 2016 baseline condition.

Individuals with a higher TFI have more savings in the concurrent year 2016 (p=.002; see Table 2 and Figure5B), controlling for significant factors of financial knowledge (p<.001), health (p=.042), saving intention (p=002), self-control (p=.065), income (p<.001) and other demographic variables. Furthermore, TFI (p<.001) and financial knowledge (p<.001) still significantly help to predict the amount of savings in 2020. When the concurrent amount of savings in 2016 (p<.001) is additionally controlled for as a baseline, most predictors in the regression model become insignificant. However, TFI is still highly significant (p=.013) (controlling for the other significant factor financial knowledge p=.018), suggesting that TFI can predict savings in a long-term. When TFI increases 0.1 unit [range -0.8, 0.8], the amount of savings is expected to increase by about 27%[1], 33.38% and 19.84% in 2016, 2022 and 2022_ctrl16. The native Dutch have about 232% ~ 2076% more savings than almost all immigrant groups in both 2016 and 2020, but the differences is insignificant (except Turkish, effect size=371%, p=.046 and Surinam, effect size=229%, p=.066) when the baseline of savings in 2016 is controlled for.

Finally, for the financial wealth (Table 2 and Figure 5C), similarly, TFI significantly (p<.004) predicts the participants' financial assets in the concurrent year 2016 and 2020, keeping significant factors financial knowledge (p<.001), income (p<.001), saving intention (p_{16}=.001 and p_{20}=.073), education (p=.053) and other factors constant. Crucially, TFI (p=.003) and financial knowledge (p=.024) are persistently significant even after additionally controlling for the financial wealth of

[1] As we use log-level models and the estimated coefficients are often not small (e.g., bigger than 0.15 in absolute value), we use the formula (exp(estimated coefficient*unit of independent variable)-1)*100% to calculate the effect size.

2016 (p<.001) in the model used to predict 2020. When TFI increases by 0.1 unit, the amount of financial wealth is expected to increase by about 26.11%, 37.99% and 24.86% in 2016, 2022 and 2022_ctrl16. The native Dutch had about 219% ~ 2453% more financial wealth compared to all immigrant groups in 2016 and the differences (about 314% ~ 1949%) remained for all groups in 2020 (except the "other western" p=.316 and Indonesia p=.378 groups). However, when the baseline financial wealth in 2016 is controlled for, only Turkish (p=.013) and Surinam (p=.023) and other non-western groups (p=.087) have significantly less financial wealth than the Dutch.

Sensitivity analyses

Splitting TFI into past temporal and future temporal values

Given the persistent significant effect of TFI, we further replace the TFI with the original cultural past temporal values and future temporal values to check which temporal values have a larger impact. Interestingly, for questions related to future pension planning and retirement thinking, both past and future temporal values have significant influences but in an opposite direction (Q1-7 except Q2). Surprisingly, for results related to financial facts such as savings and assets, it is mainly the past temporal values that negatively predict the savings and financial wealth in 2016 and 2020, whereas the future temporal values are usually not significant (Table 3). Thus, individuals who are less past-focused are more likely to have more savings and financial wealth concurrently and in the future, while keeping demographic information and other controlling variables constant.

Table 3: Splitting TFI into past and future temporal values when predicting all dependent variables.

Variables	past temporal values	future temporal values
government	0.099***	-0.031
thought_retire	-0.038(p=.16)	0.044 (p=.12)
desired_retire_age	-0.302*	0.335*
figout_amnt	-.0662*	0.096**
dev_plan_retire	-.067*	.069†(p=.056)
feel_sav_adqcy	-.003	.085**
own_dwelling16	-.051	.084*
own_dwelling22	-.081*	.073(p=.077)
own_dwel22_ctrl16	-.133*	0.03
savings16	-.303**	0.166(p=.12)
savings20	-0.370***	0.211† (p=.076)
savings20_ctrl16	-.296***	.051
fin_wealth16	-.240**	0.179(p=.106)
fin_wealth20	-0.401***	0.249*
fin_wealth20_ctrl16	-3.18**	0.105

***p<.001, **p<.01, *p<.05, †p<.1

Examining TFI using nonlinear GAM model

It could be that TFI and age may have a non-linear impact on pension planning and financial wealth, so we built a GAM model by fitting the data of *TFI* and *age* each with a smoothed (non-linear) term. Age usually has a negative association with *TFI* (de la Fuente et al., 2014), but when *age* and *TFI* both positively affect the dependent variables, it is more justified to include *age* in the model when examining the effect of TFI to avoid this potential omitted variable. This is also reflected in the fitness of model, as the adjusted R^2 of model decreased when a significant variable *age* is dropped (model 1 vs. model 2, Table 4). Nevertheless, as shown in Table 4, the effects of *TFI* on pension planning, savings and financial wealth are robust, regardless of whether including *age* in the model. Furthermore, TFI is not a proxy of age, as when TFI is dropped in the model, age itself is not significant in many predictions. In addition, as shown in Figure 6, the effects of *TFI* on most dependent variables are linear except four (*government*, *desired_retire_age*, *figout_amnt* and *own_dewelling16*).

Table 4: TFI, age and pension planning, savings and financial wealth (using GAM models).

DVs	Model 1			Model 2 (exl. Age)		Model 3 (exl. TFI)	
	edf (TFI)	*edf (Age)*	*Adj. R^2*	*edf (TFI)*	*Adj. R^2*	*edf (Age)*	*Adj. R^2*
government	2.35**	1.20	0.06	2.34**	0.06	1.01	0.048
thought_retire	1.00†(*p*=.06)	2.8***	0.22	1.0	0.09	2.86***	0.217
desired_retire_age	3.34***	1.94***	0.23	3.38***	0.151	1.81***	0.15
figout_amnt	6.02†(*p*=.078)	1.54***	0.19	1.00**	0.148	1.38***	0.18
dev_plan_retire	1.00**	2.15***	0.14	1.00**	0.11	2.24***	0.137
feel_sav_adqcy	1.00*	2.20***	0.17	1.00*	0.13	2.27***	0.161
own_dwelling16	2.02*	1.00**	0.282	2.04*	0.278	1.00**	0.274
own_dwelling22	1.00**	2.26	0.271	1.00**	0.265	2.19	0.258
own_dwel22_ctrl16	1.00*	1.90	0.702	1.00*	0.698	1.81	0.70
savings16	1.00**	1.00	0.366	1.00**	0.366	1.00	0.357
savings20	1.00***	1.00	0.292	1.00***	0.294	1.00	0.275
savings20_ctrl16	1.00*	1.00	0.578	1.00*	0.579	1.02	0.572
fin_wealth16	1.00**	1.00	0.374	1.00**	0.375	1.00	0.366
fin_wealth20	1.00***	1.00	0.321	1.00***	0.323	1.00	0.30
fin_wealth20_ctrl16	1.00**	1.00	0.584	1.00**	0.585	1.00	0.57

Note: Numbers estimated from generalized additive models are the effective degrees of freedom (edf), which are used as a proxy for the degree of non-linearity relationships. An edf of 1 is equivalent to a linear relationship, an edf > 1 and ≤ 2 is a weakly non-linear relationship, and an edf > 2 indicates a highly non-linear relationship (Zuur et al. 2009). Model 1 shows results of smoothed *TFI* and *age* with all control variables, model 2 drops *age* and model 3 drops *TFI*. ****p*<0.001, ***p*<0.01, **p*<0.05, †*p*<0.1.

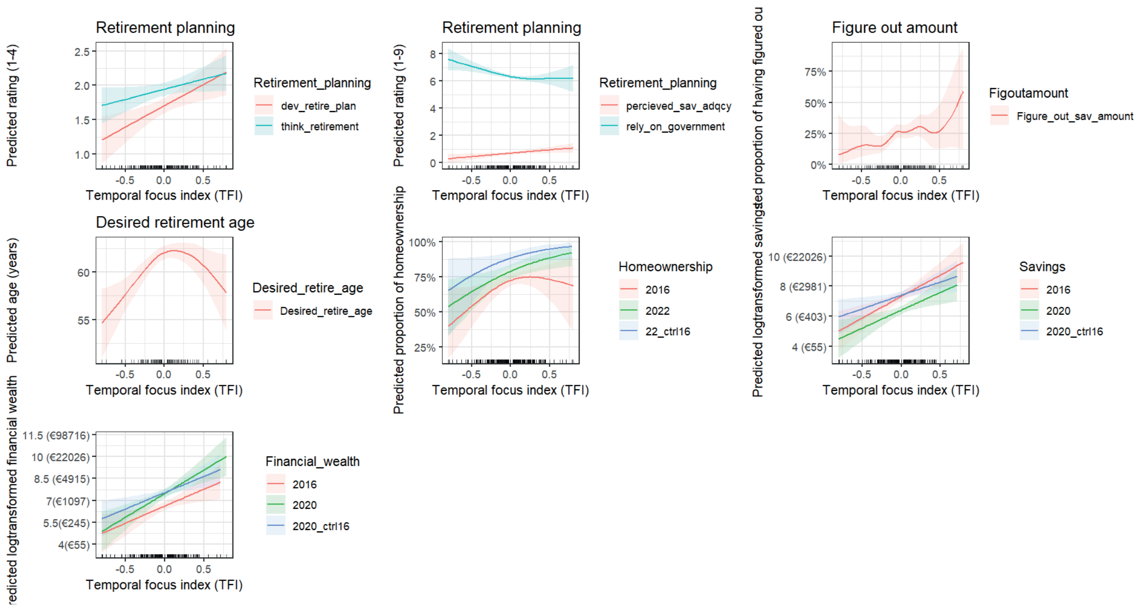


Figure 6. Relationship between *TFI* and retirement planning, home ownership, savings and financial wealth.

Discussion

In this paper we use survey data to study native Dutch and immigrants' pension planning, homeownership, retirement savings, and financial wealth in the Netherlands. In addition to considering many important factors such as financial literacy, education and health, we introduce temporal values, IQ and other individual characteristics into pension planning study. We first discover that people's temporal values can predict the extent to which they think about retirement and the government's responsibility for ensuring the living standard of retired people. Furthermore, individuals' TFI, IQ, and perception of the government's responsibility have significant effects on their pension planning, beyond well-known factors of financial knowledge, health, income, self-control, saving intention, age, etc. Importantly, we find that temporal values can not only predict participants' homeownership, actual savings, and financial wealth concurrently in 2016 but also several years later, even after controlling for the baseline in 2016.

In comparison to the Dutch natives, immigrants from Morocco rely more on the government's responsibility for ensuring retirement income and think more often about retirement, and are less likely to figure out the amount they need to save for retirement. All immigrant groups (except Turkish, Surinam and other non-westerners) subjectively feel that their retirement savings is less adequate, and immigrants from Morocco, Netherlands Antilles, Suriname, and other non-western backgrounds are less likely to own a dwelling. Additionally, all immigrant groups have less savings and financial wealth than Dutch natives.

To the best of our knowledge, this is the first study showing that people's perception of time has such a long-term relationship with financial well-being. We found that individuals' TFI persistently predicts their retirement planning, dwelling ownership, savings, and financial wealth even after controlling for financial knowledge, IQ, health and other significant factors. Immigrants are generally more future-focused than the native Dutch, which well explains why immigrants, though less financially literate, still think more often about their pension than the native Dutch. Our study makes both practical and theoretical contributions.

First, the findings have strong implications for policy related to pension planning: (1) The low level of financial literacy among immigrants suggests that policy measures to improve the level of financial literacy targeted at vulnerable groups can also be targeted at these immigrants; (2) educators and social media can induce people to focus less on the past but more on the future; (3) policy should target tailor made pension communication to specific groups (e.g., Morocco), particularly with current ongoing pension reforms that put more responsibility with the individuals themselves.

Second, the study contributes to the debate as to whether financial knowledge measures knowledge or simply ability and cognition (e.g., van Rooij, Lusardi, & Alessie, 2011b). Our results show that financial literacy has a significant positive influence on retirement planning but the effect becomes smaller in size when IQ is additionally controlled for. This suggests that financial knowledge can be partially mediated by IQ, given that a higher IQ may lead to higher financial knowledge. This urges researchers to consider a better control for individuals' cognitive ability in pension planning studies.

Furthermore, past studies have shown that people's time preference (patience), future time perspective (e.g., Jacobs-Lawsona & Hershey, 2005) or future horizons (van Rooij et al., 2011) can have an impact on their pension planning. However, these measurements only study the extent to which one thinks about the future with a reference point of now and do not consider the extent to which one thinks about the past or the magnitude differences between one's thinking about the past and the future. In the current study we measure participants' temporal values towards both the past and the future and compute the temporal focus index to represent whether a participant is relatively past- or future-focused. The innovative finding is that both future and past temporal values are strong predictors of retirement planning, but people's past temporal values appear to be a better predictor and have a stronger effect size than the future temporal values in predicting fact-based savings, assets and wealth.

These results contribute to the theory of temporal focus (cf. Shipp et al., 2009). Past research shows that people's temporal values can explain their mental space-time mappings as to whether individuals put a past or future event in front of or behind them (Callizo-Romero et al., 2020, Chapter 2). Given that people usually prioritize important things in front of them and leave less important things behind, we propose that habitually attending to the past is likely to lead people to give less priority to the future compared to the past. Thus temporal values can have consequences for people's planning and behaviour, influencing retirement planning and financial well-being in the long term. Indeed, our results reveal associations between temporal values, retirement thinking, pension planning and economic outcomes. Our study has moved important steps forward from a cross-cultural comparison of labelling of past and future events as a function of individuals' temporal focus, and further shows that habits of more attending to the past or future predict people's overall well-being concurrently and longitudinally. If temporal values affect planning and behaviour, we expect that the effect of temporal values on wellbeing may be generalised to other aspects such as health behaviour, smoking, diet, disease, wages, happiness, etc.

One caveat of the current study is whether the associations between TFI and the outcome variables are causal effects. First, TFI is found to be negatively associated with age, e.g., 80 years old people are more past-focused (smaller TFI) than 20 years old students (de la Fuente et al., 2014), but that is likely to be a cohort effect rather than a change of TFI over years within a person. Particularly, when age positively correlates with some dependent variables such as pension planning, TFI does not negatively correlate with the dependent variables but also has a positive correlation. This shows that TFI is not a proxy of age. Furthermore, our sensitivity analysis shows that the effect of TFI is robust when age is excluded or controlled for.

Second, one may argue that the TFI effect can be affected by health. Although it is possible that an individual's momentary temporal focus is impacted by some extreme health condition, this is less likely to be the case for TFI in this study. On the one hand, TFI is still significant after controlling for health and the results are largely robust when we exclude health in the regressions. On the other hand, health is not significant in predicting many dependent variables (e.g., *figure_out_amount*) regardless of whether we include TFI or not, while TFI is always significant.

More importantly, people's values are generally stable, like a personality. Most research on temporal focus has framed it as a trait-like, general characteristic. Shipp (2020) reviews that change in temporal focus is mainly fixed after childhood and general temporal focus is relatively stable during most of one's adult life (Aspinwall, 2005). Furthermore, neuroscience research reveals that the general tendency to focus more on the past or the future relates to brain function and certain brain regions (e.g., Szpunar, Watson, & McDermott, 2007) and such a biological basis for mental temporal thought may be relatively stable (Shipp, 2020). Therefore, it is reasonable to assume that the TFI in our study is stable, especially only over a short period of 4-5 years.

Nevertheless, it could be the case that better financial conditions make people less past-oriented (the reverse causality). To better understand the possible causal effect of temporal values, we have additionally controlled for a number of important related individual characteristics (e.g., IQ, financial literacy, health, self-control, risk aversion, saving intention) that affect pension planning and financial wealth, and have used longitudinal predictions for several years later, but we still find an effect of TFI in predicting the future. Of course, there might be an omitted variable [1] that influences both an individual's TFI and all the dependent variables, though it is difficult to imagine what the variable may be. If that is the case, we have discovered a powerful marker of a deep omitted variable that can cause differences in pension planning and financial wellbeing.

Appendix 1. Questions of temporal-focus questionnaire, risk averse, self-control, time preference, financial future time perspective, financial knowledge, and saving intention.

Please rate to what extent you agree on the following statement (1=disagree completely, 9=totally agree)

Temporal focus questionnaire shortened version.

1. The traditional way of living is better than the modern way. (past focus)
2. Present day youth need to keep the values of their parents and grandparents. (past focus)
3. It is important to innovate and adapt to the new changes. (future focus)
4. Social and cultural changes will make people happier. (future focus)

Financial knowledge

Q1. Compound interest: Suppose you had € 100 in a savings account and the interest rate was 2% per year. After 5 years, how much do you think you would have in the account if you left the money to grow?

(a) More than € 102; (b) Exactly € 102; (c) Less than € 102; (d) Do not know

Q2. Inflation: Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, how much would you be able to buy with the money in this account?

(a) More than today; (b) Exactly the same; (c) Less than today; (d) Do not know

Q3. Diversification of risk: Do you think that the following statement is true or false?

When an investor spreads money between 20 stocks, rather than 2, the risk of losing a lot money increases.

(a) True; (b) False; (c) Do not know

Risk aversion (1=disagree completely, 9=totally agree)

I think it is more important to have safe investments and guaranteed returns than to take risks to have a chance to get the highest possible returns.

Self-control (1=disagree completely, 9=totally agree)

I am a highly disciplined person and stick to what I planned to do.

Time preference (patience) (1=disagree completely, 9=totally agree)

I am willing to sacrifice my well-being in the present to achieve certain goals in the future.

Financial future time perspective (1=disagree completely, 9=totally agree)

I live for the present and don't think about my financial future.

Saving intention (1=I immediately spend all my money, 9=I want to save as much as possible)

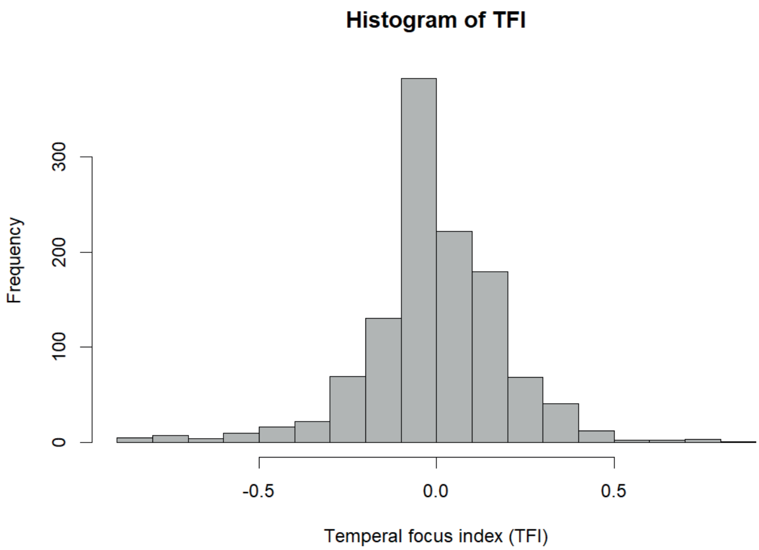
Suppose you have money that remains after having paid for food, rent, and other fixed or necessary expenditures, what would you do with the money?

[1] An alternative interpretation of the effect could be the degree of conservative and innovative attitudes. In the literature, conservatism is considered as a social attitude and defined as resistance to change (e.g., Honderich, 1990). However, Pienaar, Beukes and Esterhuyse (2006) found that at least for adolescents, high levels of conservatism experience high levels of psychological well-being, which seems to have a reversed relationship direction to our finding.

Appendix 2. Descriptives about the main variables

var	n	mean	sd	min	max	var	n	mean	sd	min	max
tfi	1175	0.01	0.19	-0.8	0.8	Turkey	1177	0.04	0.2	0	1
finanLasardi	1168	2.22	1.01	0	3	Morocco	1177	0.03	0.17	0	1
IQ	1162	2.59	1.05	0	4	NetherAnti	1177	0.03	0.18	0	1
inc_unknown	1177	0.08	0.26	0	1	Surinam	1177	0.06	0.25	0	1
logincome	1177	6.05	2.83	0	9.21	Indonesia	1177	0.11	0.31	0	1
retired	1175	0.06	0.24	0	1	otherNWe	1177	0.09	0.28	0	1
female	1177	0.55	0.5	0	1	otherWe	1177	0.2	0.4	0	1
age	1177	46.69	11.89	25	66	immigrant	1177	0.56	0.5	0	1
childrenum	1177	0.86	1.11	0	5	logriskles16	705	6.38	4.25	0	13.06
health16	1024	3.07	0.77	1	5	logfinasset16	695	6.58	4.36	0	14.01
highedu1	1177	0.39	0.49	0	1	logriskles20	559	7.37	4.02	0	13.75
patience	1175	4.26	2.06	1	9	logfinasset20	541	7.5	4.12	0	14.39
married	1177	0.54	0.5	0	1	Ownhouse16	1177	0.66	0.47	0	1
government	1171	6.28	1.75	1	9	ownhouse22	844	0.7	0.46	0	1
futureatten	1175	5.81	1.37	1	9	desired_retireage	333	61.8	3.98	50	80
pastatten	1175	5.79	1.5	1	9	bifiguresavretire	1175	0.32	0.47	0	1
riskaverse	1165	6.25	1.88	1	9	planretire	1175	0.81	1.23	0	3
selfcontrol	1165	6.18	1.72	1	9	liveforpresent	1175	4.51	2.18	1	9
thoughtretire	1175	2.04	0.96	1	4	saveintention	1170	6.15	1.65	1	9
selfass_savadeqacy	1175	4.33	2.47	1	9						

Appendix 3. Histogram of TFI



References

Adams, G. A., & Rau, B. L. (2011). Putting off tomorrow to do what you want today: Planning for retirement. *American Psychologist*, *66*, 180–192.

Alessie, R., van Rooij, M., & Lusardi, A. (2011). Financial literacy and retirement preparation in the Netherlands. *Journal of Pension Economics & Finance*, *10*(4), 527-545.

Aspinwall, L. G. (2005). The psychology of future-oriented thinking: From achievement to proactive coping, adaptation, and aging. *Motivation and Emotion*, *29*(4), 203-235.

Bilker, W. B., Hansen, J. A., Brensinger, C. M., Richard, J., Gur, R. E., & Gur, R. C. (2012). Development of abbreviated nine-item forms of the Raven's standard progressive matrices test. *Assessment, 19*(3), 354-369.

Boisclair, D., Lusardi, A., & Michaud, P. C. (2017). Financial literacy and retirement planning in Canada. *Journal of Pension Economics & Finance*, *16*(3), 277-296.

Burks, S. V., Carpenter, J. P., Goette, L., & Rustichini, A. (2009). Cognitive skills affect economic preferences, strategic behavior, and job attachment. *PNAS, 106*(19), 7745–7750.

Brown, M., & Graf, R. (2013). Financial literacy and retirement planning in Switzerland. *Numeracy*, *6*(2), 6.

Bucher-Koenen, T., & Lusardi, A. (2011). Financial literacy and retirement planning in Germany. *Journal of Pension Economics and Finance*, *10*(4), 565-584.

Callizo-Romero, C., Tutnjević, S., Pandza, M., Ouellet, M., Kranjec, A., Ilić, S., Gu, Y., Göksun, T., Chahboun, S., Casasanto, D. & Santiago, J., (2020). Temporal focus and time spatialization across cultures. *Psychonomic Bulletin & Review*, *27*(6),1247-1258.

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

Chen, M. K. (2013). The effect of language on economic behavior: Evidence from savings rates, health behaviors, and retirement assets. *American Economic Review*, *103*(2), 690-731.

Chen, J. I., He, T. S., & Riyanto, Y. E. (2019). The effect of language on economic behavior: Examining the causal link between future tense and time preference in the lab. *European Economic Review*, *120*, 103307.

De la Fuente, J., Santiago, J., Román, A., Dumitrache, C., & Casasanto, D. (2014). When you think about it, your past is in front of you: How culture shapes spatial conceptions of time. *Psychological Science*, *25*, 1682-1690.

Earl, J. K., Bednall, T. C., & Muratore, A. M. (2015). A matter of time: Why some people plan for retirement and others do not. *Work, Aging and Retirement*, *1*(2), 181-189.

Grinblatt, M., Keloharju, M., & Linnainmaa, J. (2011). IQ and stock market participation. *The Journal of Finance, 66*(6), 2121-2164.

Guo, T., Ji, L. J., Spina, R., & Zhang, Z. (2012). Culture, temporal focus, and values of the past and the future. *Personality and Social Psychology Bulletin, 38*(8), 1030-1040.

Hershey, D. A., & Mowen, J. C. (2000). Psychological determinants of financial preparedness for retirement. *The Gerontologist, 40*(6), 687-697.

Honderich T. (1990). *Conservatism.* London: Hamish Hamilton

Hudomiet, P., Parker, A.M., & Rohwedder, S. (2018). Cognitive ability, personality, and pathways to retirement: An exploratory study. *Work, Aging, and Retirement*, *4*, 52-66.

Isphording, I. E., & Otten, S. (2014). Linguistic barriers in the destination language acquisition of immigrants. *Journal of Economic Behavior & Organization*, *105*, 30-50.

Jacobs-Lawson, J. M., & Hershey, D. A. (2005). Influence of future time perspective, financial knowledge, and financial risk tolerance on retirement saving behaviors. *Financial Services Review*, *14*(4), 331.

Jäggi, T., Sato, S., Gillioz, C., & Gygax, P. M. (2022). Is the future near or far depending on the verb tense markers used? An experimental investigation into the effects of the grammaticalization of the future. *PLOS ONE*, *17*(1), e0262778.

Kerry, M. J. (2018). Psychological antecedents of retirement planning: A systematic review. *Frontiers in Psychology, 9*, 1870.

Levasseur, L., Shipp, A. J., Fried, Y., Rousseau, D. M., & Zimbardo, P. G. (2020). New perspectives on time perspective and temporal focus. *Journal of Organizational Behavior*, *41*(3), 235-243.

Li, H., & Cao, Y. (2018). The hope of the future: The experience of pregnancy influences women's implicit space–time mappings. *The Journal of Social Psychology, 158*(2), 152-156.

Liang, H., Marquis, C., Renneboog, L., & Sun, S. L. (2018). Future-time framing: The effect of language on corporate future orientation. *Organization Science, 29*(6), 1093-1111.

Lusardi, A., & Mitchell, O. S. (2008). Planning and financial literacy: How do women fare? *American Economic Review*, *98*(2), 413–417.

Lusardi, A., & Mitchell, O. S. (2011). Financial literacy and retirement planning in the United States. *Journal of Pension Economics and Finance*, *10*(04), 509-525.

Lusardi, A., Mitchell, O. S., & Curto, V. (2014). Financial literacy and financial sophistication in the older population. *Journal of Pension Economics & Finance*, *13*(4), 347-366.

McGarry, K. (2004). Health and retirement do changes in health affect retirement expectations?. *Journal of Human Resources, 39*(3), 624-648.

Pienaar, J. M., Beukes, R. B., & Esterhuyse, K. G. (2006). The relationship between conservatism and psychological well-being in adolescents. *South African Journal of Psychology*, *36*(2), 391-406.

Raven, J.C. (1976) *Raven's standard progressive matrices test*. Texas, Harcourt Assessment.

Roberts, S. G., Winters, J., & Chen, K. (2015). Future tense and economic decisions: controlling for cultural evolution. *PLOS ONE, 10*(7), e0132145.

Shipp, A. J. (2020). Temporal focus: A review of the past with an eye to the future. In Frederick M. E. Grouzet (Ed.), *The Oxford handbook of psychology of time travel and temporality* (online edn). Oxford Academic. https://doi.org/10.1093/oxfordhb/9780190256685.013.9

Shipp, A. J., Edwards, J. R., & Lambert, L. S. (2009). Conceptualization and measurement of temporal focus: The subjective experience of the past, present, and future. *Organizational Behavior and Human Decision Processes*, *110*, 1–22.

Sutter, M., Angerer, S., Glätzle-Rützler, D., & Lergetporer, P. (2018). Language group differences in time preferences: Evidence from primary school children in a bilingual city. *European Economic Review, 106*, 21-34.

Szpunar, K. K., Watson, J. M., & McDermott, K. B. (2007). Neural substrates of envisioning the future. *Proceedings of the National Academy of Sciences*, *104*(2), 642–647.

Tanaka, T., Camerer, C. F., & Nguyen, Q. (2010). Risk and time preferences: Linking experimental and household survey data from Vietnam. *The American Economic Review, 100*(1), 557–571.

Thieroff, R. (2000). On the areal distribution of tense-aspect categories in Europe, In: Tense and Aspect in the Languages of Europe, ed. Östen Dahl, Berlin: Mouton de Gruyter, 265-305.

Thoma, D., & Tytus, A. E. (2018). How cross-linguistic differences in the grammaticalization of future time reference influence intertemporal choices. *Cognitive Science*, *42*(3), 974-1000.

Drake, L., Duncan, E., Sutherland, F., Abernethy, C., & Henry, C. (2008). Time perspective and correlates of wellbeing. *Time & Society*, *17*(1), 47-61.

Topa, G., Moriano, J. A., & Moreno, A. (2012). Psychosocial determinants of financial planning for retirement among immigrants in Europe. *Journal of Economic Psychology, 33*(3), 527-537.

Van Dalen, H. P., Henkens, K., & Hershey, D. A. (2010). Perceptions and expectations of pension savings adequacy: A comparative study of Dutch and American workers. *Ageing and Society*, *30*(05), 731-754.

Van Rooij, M. C., Lusardi, A., & Alessie, R. J. (2011a). Financial literacy and retirement planning in the Netherlands. *Journal of Economic Psychology*, *32*(4), 593-608.

Van Rooij, M. C., Lusardi, A., & Alessie, R. J. (2011b). Financial literacy and stock market participation. *Journal of Financial Economics*, *101*(2), 449-472.

Van Rooij, M. C., Lusardi, A., & Alessie, R. J. (2012). Financial literacy, retirement planning and household wealth. *The Economic Journal*, *122*(560), 449-478.

Webster, J. D., Bohlmeijer, E. T., & Westerhof, G. J. (2014). Time to flourish: The relationship of temporal perspective to well-being and wisdom across adulthood. *Aging & Mental Health, 18*(8), 1046-1056.

Wood, S. N. (2017). *Generalized additive models: an introduction with R*. CRC press.

Zacher, H. (2013). Older job seekers' job search intensity: The interplay of proactive personality, age and occupational future time perspective. *Ageing and Society*, *33*, 1139–1166.

Zacher, H. (2014). Individual difference predictors of change in career adaptability over time. *Journal of Vocational Behavior*, *84*, 188–198.

Zimbardo, P. G., & Boyd, J. N. (1999). Putting time in perspective: A valid, reliable individual-differences metric. *Journal of Personality and Social Psychology*, *77*(6), 1271–1288.

Zuur, A.F., Ieno, E.N, Walker, N.J., Saveliev, A.A, & Smith, G.M. (2009) *Mixed effects models and extensions in ecology with R*. Springer-Verlag, New York.

Chapter 6. Time to get attention: The effect of temporal values on health, income and happiness

Abstract

We study the effect of people's temporal values (habits of attending to past or future events) on their health, labour market performance and happiness. Participants' (N=1177) data were initially collected in 2016 and then again in a follow-up study in 2020-2021. We find that habitually more attending to the future is negatively associated with diseases (heart attack; high cholesterol; diabetes; high-blood pressure; Covid19), but positively with health-related behaviour (eating vegetables and fruit; less smoking), health status (e.g., healthy weight; long life expectancy), income, hourly wage, financial satisfaction and happiness. Furthermore, such temporal values predict participants' future situation of these aspects of well-being in 2020-2021, even after controlling for the 2016 baseline situation, IQ, self-control, patience, risk aversion and demographic information. Given that habitually attending to the past is likely to lead people to give less priority to the future compared to the past, we propose *a temporal values and well-being hypothesis*: Temporal values have consequences for people's planning and behaviour, thus influencing individuals' concurrent and longitudinal overall well-being. Our findings have strong implications for theories of time perception, measurements of temporal values, and for a better understanding of factors that influence people's health, income, and happiness.

Keywords: temporal focus; time; well-being; health; income; labour market performance; financial satisfaction; happiness

Acknowledgements: This work is supported by a grant from The Netherlands Organization for Scientific Research, via NWO Research Talent (406-15-298) to YQZ.

An abstract of the chapter has been published as:

Zheng, Y., Gu, Y., & van Soest, A. (2022). Time to get attention: The effect of temporal values on health, income and happiness. *Proceedings of the Annual Meeting of the Cognitive Science Society, 44*. Retrieved from https://escholarship.org/uc/item/7hx523xm

Introduction

"Life is nothing but time" (Dasa, 2014). The concept of time is not merely an objective physic reality but also has psychological influence on people's cognitive processing and behaviour (e.g., Carstensen, 2006). The present study focuses on the latter, investigating the effect of temporal values on people's health, income, and happiness, concurrently and longitudinally.

People's perception of time can influence their thinking and behaviour. Studies on the subjective sense of time have mainly investigated people's time perspective, which is "[t]he totality of the individual's views of his/her psychological future and psychological past existing at a given [objective] time" (Lewin, 1951, p.75). The seminal work on time perspective is the Zimbardo Time Perspective Inventory (ZTPI; Zimbardo & Boyd, 1999). It establishes a comprehensive measure of individual differences in time perspective, considering time as multidimensional (i.e., past, present, and future), having different affective states (e.g., past negative vs. past positive), and related to many outcomes of interest such as well-being and achievement (see the review of Levasseur et al., 2020). ZTPI includes 56 items, such as the extent to which an individual agrees with the statements "Painful past experiences keep being replayed in my mind", "Happy memories of good times spring readily to mind", "I complete projects on time by making steady progress", "Taking risks keeps my life from becoming boring" (arguably, this is a measurement of risk aversion rather than time), etc. Researchers using this time measurement have found that individual differences in cognitive engagement with time (mixed with risk aversion) can influence work outcomes such as well-being, decision making, motivation, and achievement (e.g., Drake et al., 2008; Lasane & Jones, 1999; Seijts, 1998; Shipp & Aeon, 2019; Stolarski & Matthews, 2016; Zhang & Howell, 2011; Zimbardo & Boyd, 1999). Additionally, Shipp et al. (2009) created a Temporal Focus Scale (TFS) that tests primarily how much people generally think about the past, present and future (e.g., "I think about things from my past", "I think about where I am today", "I think about times to come"). This measurement only has 12 items, but does not consider any cultural attitudes about time.

Unlike focusing on ZTPI (Zimbardo & Boyd, 1999) or TFS (Shipp et al., 2009), another line of research investigates time at a more global level that focuses on people's general values toward time (i.e., habits of attending to past or future events). For example, de la Fuente et al. (2014) state that people from specific (sub)culture groups tend to focus more on past times and older generations, are more observant of ancient rituals, and place more value on tradition, whereas people from other cultures can have a greater focus on the future, valuing economic development, globalization, and technological progress. Fuente et al. (2014) hypothesize that people who are habitually attending to past events metaphorically tend to place the past in front of them, "in the location where they could focus on the past literally with their eyes if past events were physical objects that could be seen" (de la Fuente et al., 2014, p.1684). This hypothesis is originally proposed for cross-cultural comparisons, but it has been applied to study individual differences within a given culture as well. For example, regardless of cultures, individuals who are more attending to the future are more likely to place the future ahead and the past behind them (Callizo-Romero et al., 2020). Interestingly, Guo et al. (2012) found that cultural temporal focus affects how people value future and past events. For example, Canadians put more monetary value to a future event than to an identical event in the past, but Chinese people attach more monetary value to an event in the past than to an identical event in the future.

In the context of a completely different theoretical framework, the economist M. Keith Chen claims that how people talk about time influences their economic behaviour (Chen, 2013). He assumes that the grammar of temporal language affects people's perception of temporal distance, which in turn can affect the value of future rewards (linguistic-saving hypothesis). This hypothesis predicts that individuals speak languages that grammatically separate future and now, giving speakers the impression that the future is far away (e.g., "It is raining now" vs. "It WILL rain tomorrow.") and making them less aware of the future consequences of their current behaviour. It implies that they are less willing to sacrifice the present pleasure for the future (such as planning less for the retirement, having less savings, poorer health, etc.)

All these studies on time perspective, temporal focus scale and economic behaviour or linguistic-saving theory have raised at least four important issues. First, most studies pursue a better understanding of correlations between time perspective and outcomes. They typically do not control for participants' other characteristics that may relate to the outcomes, or sometimes mix risk aversion with time perspective, so that time perspective could operate as a moderator (e.g., Shipp et al., 2009). Second, it is still unclear whether temporal focus mirrors thinking about a specific time (e.g., past, present, or future) or whether all time periods matter (Levasseur et al., 2020), resulting in different balances between past and future attention. Third, for the *linguistic-saving hypothesis*, Chen did not test any link between temporal language and perception of temporal distance. In particular, recent research shows that there is no effect of linguistic grammar of future time references on the perceived distance of future events (Jäggi et al., 2022), and several studies, including a re-analysis of Chen's original data set (see Roberts, Winters, & Chen, 2015) as well as lab experiments, failed to replicate Chen's (2013) hypothesis (Chen, He & Riyanto, 2019; Thoma & Tytus, 2017). In addition, although there are studies showing that time perspective and temporal focus scale correlate to future-oriented planning or behaviour, few studies have investigated the influence of general temporal values on such aspects (Callizo-Romero et al., 2022). The study of the effect of cultural temporal focus on monetary values by Guo et al. (2012) in fact did not test participants' temporal focus.

In the current study we aim to propose an alternative theory of time perception and wellbeing. We investigated the impact of general temporal values on several measures of well-being: people's health, financial situation (i.e., gross net income, hourly wages) and happiness. The general values of time (habitual attentional focus on the past or the future), surprisingly, have hardly been studied outside the context of a temporal diagram task in which participants label the past and future events in front of and behind a character (e.g. Chapter 2; Callizo-Romero et al., 2020). According to the temporal-focus hypothesis (de la Fuente et al., 2014), if people put important things in front of them and leave less important things behind, habitually attending to the past is likely to lead people to give less priority to the future than the past. Thus temporal values have consequences for individuals' planning and behaviour, which can in turn influence their overall well-being in the long term. We call this hypothesis the *temporal-values and well-being hypothesis*.

In our study, to reduce the potential problem of confounding factors due to unobserved characteristics, we additionally measure a number of important factors such as participants' IQ, risk aversion, patience, self-control and income, most of which are rarely controlled for in existing studies. Furthermore, outcomes such as health and disease can be significantly influenced by genetics. Therefore, we have first obtained data of participants' health, disease, income and happiness as a baseline control in 2016, and gathered such information of the same participants again in 2020-2021. We thus use participants' attitudes toward time in 2016 to predict their future well-being, while controlling for their well-being in 2016. This helps to better understand possible causal relations between temporal focus and dependent variables, given the fact that time progresses unidirectionally such that future health, disease, labour market participation and happiness cannot influence people's general temporal values four or five years back. The results of our study not only have theoretical implications for cognitive processing of time, but also provide a better understanding of factors that may influence people's health, disease, income, and happiness.

Data

We use survey data for the Netherlands in 2016, 2020 and 2021. We have designed a special questionnaire with a set of questions including attitudes toward time (temporal focus questionnaire, de la Fuente et al., 2014, shortened version, e.g., future-focused item: "It is important to innovate and adapt to the new changes." Past-focused item: "The traditional way of living is better than the modern way.", IQ (Raven's Standard Progressive Matrices Test, Raven, 1976; shortened version, Bilker et al., 2012), self-control, risk aversion (van Rooij et al., 2011), time preference (patience), financial future time perspective, demographic information, etc (see a full list of these measures in the appendix 1 of Chapter 5).

The questionnaire was administered in Dutch to 1471 participants in the Longitudinal Internet Studies for the Social Sciences (LISS), managed by Centerdata (Tilburg University, The Netherlands) in 2016. There were 1177 respondents (M_{age}=46.69, *range* 25-66, *SD*=11.89, 646 females, 531 males), including 659 participants with some immigrant background (361 first-generation and 298 second-generation immigrants; immigrants were oversampled, in the sense that all first and second generation immigrants in the LISS panel were invited to participate, plus a random subsample of LISS panel participants without an immigration background).

We obtained participants' background such as employment status and demographic information. We also obtained information about participants' health (Questions 1-12), financial satisfaction, happiness (Q13-15), labour market performance (monthly gross net income, employment, and weekly hours of paid work) and financial wealth (the gross amount of financial assets) in the same year 2016. Moreover, participants who originally took the survey in 2016 were traced in 2020 to obtain their health, disease, happiness, and financial wealth, and in 2021 to obtain their labour market performance. We additionally obtained information about whether participants got Covid19 in 2020 and 2021 and whether they smoked in 2016 and 2021 (gathered from waves 9, 13 and 14 of the longitudinal study of Health in the LISS panel).

Questions related to health and happiness

Q1. Do you eat raw/cooked vegetables? (1=never, 6=every day)

Q2. Do you eat fruit? (1=never, 6=every day)

Q3. Do you smoke now: Yes (1) or No (0)

Q4. How would you describe your health, generally speaking? (1 poor; 2 moderate; 3 good; 4 very good; 5 excellent)

Q5. Did you have contact with a medical specialist over the past 12 months? (0 no; 1 yes)

Q6. Has a physician told you this last year that you suffer from one of the following diseases/problems? (1-angina, 2-a heart attack/heart failure, 3-high blood pressure/ hypertension, 4-high cholesterol, 5-diabetes/too high blood sugar level, 6-cancer, 7-a gastric/duodenal/peptic ulcer) (0 no; 1 yes)

Q7. I do not take any medicine: yes (1), no (0)

Q8. How tall are you? How much do you weigh, without clothes and shoes?

Q9. Ten questions about a number of actions (e.g., moving) that some people have difficulties with. (1 without any trouble, 5 cannot perform it at all)

Q10. Thirteen questions about self-help ability (e.g., dressing) that some people have difficulties with. (1 without any trouble, 5 cannot perform it at all)

Q11. How would you rate your chance of living to be 80 years old or older? (0 no chance at all, 10 absolutely certain)

Q12. Has a physician told you this last year that you suffer from COVID-19 (new corona virus)?

Q13. How satisfied are you with your financial situation? (0=not at all satisfied, 10=entirely satisfied)

Q14. Can you indicate, on a scale from 0 to 10, to what degree you consider yourself happy? (0 means that you are not at all happy, and 10 means that you are extremely happy.)

Q15. How do you feel over the past month? I felt happy: (1=never, 6=continuously)

Due to participants' unwillingness to provide some information or dropping out of the survey between 2016 and 2020, the sample size that can be used for our analysis is between 777 to 541 participants depending on the question (e.g., the sample size of financial wealth is smaller than others). Furthermore, in 2021, we have obtained net income information of 810, paid work status of

730 and weekly working hours of 382 participants. We do not have the latest data for other aspects of 2021. Participants were paid every time answering questions. We oversampled immigrants but the sample is generally not affected by selectivity bias due to nonresponse, as those who failed or refused to provide income and financial information in 2016 generally do not differ in their average age, education, IQ, marriage, self-control, patience, temporal values, etc. (all *p*'s>.1); the only exception here is that females are less willing to reveal their financial wealth than males are.

Dependent variables

Health

We used Q1-12 to study the correlation between general temporal values and health, chronic diseases and life expectancy. We first generated two dependent variables on whether people eat vegetables and fruits, which were only available for the year 2016: *eatveg* and *eatfruit* (Q1-2). As for smoking (Q3), we generated two dependent variables *smokenow16* and *smokenow21.* Then we generated 7 dependent variables (Q4-11) on participants' self-assessed health (*health*): whether seeing a specialist (*no_specialist = 1* if the respondent did not contact a specialist, 0 otherwise), having a chronic disease (*no_disease = 1* if the respondent did not have any of the diseases in Q6, 0 otherwise), taking medication (*no_medicine = 1* if no medication was taken (Q7)), having a healthy weight (*healthy_BMI:* Body Mass Index between BMI between 18.5 and 25; cf. WHO, 2005), the degree of difficulty in physical movement (*move_difficulty*) and self-care ability (*life_ability*), computed as the means of their question lists, and life expectancy (*live80+*). These variables are all labelled with the corresponding year of measurement, 2016 or 2020 (e.g., *health16*; *health20*; *disease16*; *disease20*; *healthy_BMI16*; *healthy_BMI20*, etc). For the analysis of Covid19 (Q12), we generated a binary dummy *covidbin*, where those who got the coronavirus either in 2020 or 2021 was coded as 1.

Income and hourly wages

We generated two dependent variables for participants' monthly individual net income and net hourly wages in 2016 and 2021, which are log-transformed (*logincome16*, *logincome21*, *loghourwages16* and *loghourwages21*). We computed the hourly wages by dividing monthly gross net income by four times the number of working hours per week. As in the LISS panel a 0 (zero) doesn't necessarily mean a person has no income[1] and many Dutch person in the Netherlands can get some income due to the social security system, those who reported 0 income (*N*=115) are excluded in the analysis of income.

[1] It is noted in the LISS panel that: "Since some people prefer not to make their income information available to CentERdata, a 0 (zero) can mean two different things: (1) that there is no income at all, or (2) that a panel member does not know what the income is or does not want to make that information available to us. In the second case, panel members ought to indicate that they do not know what the income is. Unfortunately, not all panel members do so, so that there are and continue to be panel members that enter (0) while they actually do have an income. It is impossible to determine who these panel members are, however." (codebook_BackgroundVariables_EN_9.3, p.8/13; Retrieved April 10, 2023, from https://www.dataarchive.lissdata.nl/study_units/view/322).

Financial satisfaction and happiness

We used Q13-15 to generate three dependent variables on participants' financial satisfaction (*FinancialSatisfaction*), overall happiness (*generalhappy*) and recent happiness (*recenthappy*) in 2016 and 2020.

Independent variables

For our key variable on temporal values, participants rated the extent to which they agreed on the four statements at a scale of 1-9, where 1=completely disagree and 9= totally agree. Based on scores testing future-focused attitude and past-focused attitude, we generated a Temporal-focus Index (*TFI*) for each participant: *TFI*=(mean of future-focused score−mean of past-focused score)/(mean of future-focused score+mean of past-focused score) (de la Fuente et al., 2014). *TFI* ranges from −1 to 1, where −1 represents past-focused, 0 represents present-focused and 1 represents future-focused.

Additionally, we generated the following independent variables: *IQ*, *risk aversion*, *patience* (time preference), *self-control*, *education (high; low)*, *logincome* (log-transformed income), *financial future time perspective* and log-transformed financial assets (*logfinassets*). Moreover, we controlled for demographic information such as *gender*, *age*, *marriage*, *number of children* and whether a participant is an *immigrant* or not, etc. Sample statistics of the main variables are presented in Appendix 1. For a complementary description of the variables, see also Appendix 1 of Chapter 5.

Results

We used different regression models to study the effect of *TFI* on health, income, and happiness, with all related dependent variables in the concurrent year 2016. Furthermore, we examined whether *TFI* can predict these dependent variables in the future (e.g., *health20*; *happydegree20*; *logincome21*), controlling for their current value or not. Additionally, we did two sensitivity analyses: (1) using a GAM model (Wood, 2017) to examine possible non-linear effects of TFI or age, and (2) analysing the effect of TFI without including age as TFI and age are correlated.

Health, chronic disease and life expectancy

The regression results in Table 1 show that participants with a higher TFI more often eat vegetables (β=.67, p=.001) and fruits (β=.43, p=.029) (Q1-2), controlling for individual's patience, self-control, risk aversion, IQ, and demographic factors (see also Figure 1a). Participants with a larger TFI are less likely to smoke, either in 2016 (β=-.78, p=.003) or in 2021 (β=-1.5, p<.001). Interestingly, when the participant's baseline smoking behaviour in 2016 is also controlled for, TFI can still predict whether a participant will be a smoker in 2021 (β=-1.14, p=.024) (Figure 1b). Even we limit our analysis only on those who smoked in 2016, TFI still significantly predicts their quitting of smoking in 2021 (β=-1.64, p=.033). On average, an increase of 1 unit of TFI predicts a reduction of 0.2 (2016), 0.32 (2021) and 0.11 (2021_ctrl16) percentage points in the likelihood to smoke, and predicts

0.53 percentage points increase in the likelihood to quit smoking in the next five years for those whose smoked in 2016.

Table 1. TFI and frequency of eating vegetables, fruits and whether smoking now in the year 2016.

Variables	**eatveg16[a]**	**eatfruit16[a]**	**smoke16[b]**	**smoke21[b]**	**smoke21[b]ctrl16**	**smoke21[b](smoke16=1)**
tfi	0.669***	0.426*	-0.779**	-1.503***	-1.114*	-1.637*
	(0.195)	(0.195)	(0.262)	(0.337)	(0.487)	(0.747)
highedu1	0.458***	0.239**	-0.41***	-0.0463	0.164	0.241
	(0.0803)	(0.0796)	(0.113)	(0.145)	(0.216)	(0.326)
patience	-0.00686	0.0160	-0.0460†	-0.0146	0.0343	0.0631
	(0.0176)	(0.0177)	(0.0240)	(0.0304)	(0.0448)	(0.0623)
selfcontrol	-0.00264	0.0835***	0.010	0.0853*	0.0785	0.0678
	(0.0222)	(0.0223)	(0.0305)	(0.0409)	(0.0595)	(0.0883)
riskaverse	0.0536**	-0.000782	0.029	-0.0302	-0.0903†	-0.0817
	(0.0200)	(0.0200)	(0.0274)	(0.0347)	(0.0503)	(0.0780)
age	0.0114***	0.00680*	0.0062	0.00598	0.000750	0.00264
	(0.00338)	(0.00338)	(0.00466)	(0.00625)	(0.00895)	(0.0129)
male1	-0.436***	-0.320***	0.233*	0.125	-0.201	-0.288
	(0.0763)	(0.0760)	(0.103)	(0.135)	(0.198)	(0.279)
childrenum	0.0400	-0.00994	-0.0237	-0.0335	-0.0403	-0.0172
	(0.0336)	(0.0334)	(0.0479)	(0.0639)	(0.0966)	(0.141)
married1	0.0802	0.187*	-0.38***	-0.420**	-0.180	0.0814
	(0.0802)	(0.0808)	(0.110)	(0.149)	(0.212)	(0.293)
IQ	0.125***	-0.0433	-0.0286	-0.0511	-0.0675	-0.0762
	(0.0355)	(0.0358)	(0.0484)	(0.0646)	(0.0944)	(0.136)
immigrant1	-0.130†	-0.0849	0.0362	-0.0426	0.0740	0.00606
	(0.0741)	(0.0743)	(0.1012)	(0.137)	(0.198)	(0.277)
logincome16	0.00445	0.0131	-0.015	-0.0422	-0.00228	-0.0106
	(0.0164)	(0.0164)	(0.022)	(0.0279)	(0.0420)	(0.0594)
smoke16					2.63***(0.2)	
Constant			-0.600	-0.928†	-2.148**	0.176
			(0.387)	(0.505)	(0.716)	(0.959)
Observations	931	931	933	649	624	119
Pseudo R^2	0.052	0.024	0.066	0.082	0.56	0.07

Note: Standard errors in parentheses, ****p*<.001, ***p*<.01, **p*<.05, †*p*<.1. The dependent variables *eatveg16*, *eatfruit16*, *smoke16, smoke21*, are from Q1-3. a=ordered probit model; b=probit model. Smoke21(smoke16=1) refers to smoking in 2021 conditional on smoking in 2016.

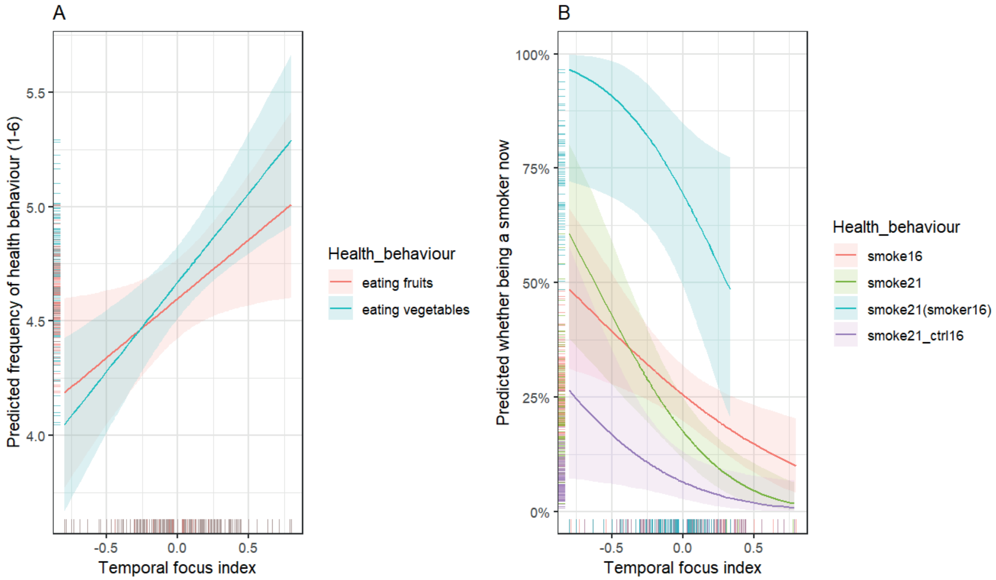


Figure 1. TFI predicts individuals' health behaviour: (A) the frequency of eating fruits and vegetables (1-6). For the purpose of visualisation, it is plotted based on OLS results (consistent with results from oprobit models); (B) whether an individual is smoking now in 2016, 2021, 2021(2016 smoke=1) and 2021 controlling for 2016 baseline. Shaded areas are 95% CI bands; rugs display the distribution of a variable.

In general, as shown in Table 2, a larger TFI is associated with a better health status (Q4) in 2016 (β=.51, p=.01), keeping other variables constant. TFI also predicts health in 2020 (β=.78, p<.001), even after controlling for the 2016 health situation as a baseline (β=.51, p=.034). As for the prediction of chronic disease, participants with a smaller TFI are significantly more likely to get diseases (Q6, *average marginal effect (AME)* = 0.23[1], p=.001) (e.g., high blood pressure, AME=-0.09, p=.057; high cholesterol, AME=-0.08 p=.047; heart attack, AME=-0.06, p=.005; diabetes, AME=-0.12, p<.001, Figure 2c). A lower TFI also predicts more need to visit a specialized doctor (Q5, AME=0.22, p<.001) and a lower likelihood to have a healthy weight (BMI) (Q8, AME=-0.13, p=.022) four years later in 2020. This remains to be (marginally) significant (AME=0.21, p=.025 and AME=-0.23, p=.062) when controlling for the 2016 situation as a baseline. Relatedly, TFI negatively predicts the possibility of taking any medicine (Q7, AME=0.20, p=.003, see some examples of regression results for selected dependent variables in Table 2 and visualisations of the effects in Figure 2).

In addition, participants' TFI is negatively associated with difficulty in physical movements (Q9, β=-.22, p=.024), and difficulty in self-care ability (Q10, β=-.16, p=.058) in 2016. Surprisingly, the TFI can still predict these two aspects for 2020 after controlling for the 2016 condition and other factors. The results suggest that given the same level of physical movement or self-care ability in 2016, those

[1] An increase of 1 unit in TFI associates with a decrease of 0.23 in probability of getting diseases.

who are more future focused have significantly less difficulty in psychical movement (β=-.24, p=.004) and less difficulty in self-care ability (β=-.17, p=.003) four years later, keeping others constant.

Table 2. TFI's prediction for health and diseases in 2020, controlling for the baseline in 2016.

Variables	**health20[a]**	**nomedic20[b]**	**nodisease20[b]**	**healthyBMI20[b]**	**diabetes20[b]**	**heartattack20[b]**
Tfi	0.508*	0.957**	1.104**	0.641†	-2.433***	-2.020**
	(0.240)	(0.342)	(0.338)	(0.342)	(0.583)	(0.721)
IQ	0.110*	0.134*	0.128*	0.108†	0.0605	0.205
	(0.0450)	(0.0653)	(0.0608)	(0.0632)	(0.126)	(0.168)
selfcontrol	0.0222	0.0585	0.0351	0.0399	-0.0658	-0.134
	(0.0284)	(0.0395)	(0.0375)	(0.0406)	(0.0769)	(0.0997)
Patience	0.00646	0.0192	0.0351	-0.0370	-0.118†	0.0665
	(0.0213)	(0.0300)	(0.0286)	(0.0301)	(0.0647)	(0.0756)
riskaverse	0.00910	-0.0812*	0.0161	-0.0139	-0.0541	-0.0631
	(0.0247)	(0.0347)	(0.0335)	(0.0353)	(0.0589)	(0.0843)
highedu1	0.000871	-0.111	-0.207	0.126	0.124	-0.113
	(0.0991)	(0.138)	(0.132)	(0.139)	(0.296)	(0.379)
Age	-0.0130**	-0.0319***	-0.0289***	0.00299	0.0424*	0.0261
	(0.00434)	(0.00623)	(0.00599)	(0.00607)	(0.0166)	(0.0183)
male1	0.221*	0.145	0.195	-0.190	0.0129	0.140
	(0.0942)	(0.131)	(0.125)	(0.132)	(0.275)	(0.385)
childrenum	0.00593	0.0365	0.104†	-0.0548	-0.281	-0.539
	(0.0418)	(0.0591)	(0.0569)	(0.0582)	(0.174)	(0.370)
married1	0.101	0.267†	0.159	0.184	-0.0296	0.123
	(0.103)	(0.146)	(0.136)	(0.143)	(0.286)	(0.343)
logincome16	-0.00806	0.00158	0.0292	0.0227	-0.0121	0.0772
	(0.0205)	(0.0273)	(0.0268)	(0.0295)	(0.0621)	(0.118)
immigrant1	-0.00622	0.0233	0.0263	-0.0821	0.373	0.434
	(0.0936)	(0.130)	(0.124)	(0.132)	(0.273)	(0.361)
health16	1.10***(0.07)					
nomedic16		2.03***(0.13)				
nodiseases16			1.71***(0.12)			
healthyBMI16				2.24***(0.13)		
diabetes16					2.77***(0.35)	
heartattack16						2.52***(0.43)
Constant		-0.0714	-0.597	-1.905***	-3.462**	-4.157**
		(0.473)	(0.464)	(0.492)	(1.128)	(1.446)
Observations	683	680	671	676	671	671
Pseudo R^2	0.22	0.45	0.36	0.47	0.54	0.51

Note: Standard errors in parentheses, ***p<.001, **p<.01, *p<.05, †p<.1. The listed example dependent variables are from Q4, 6, 7, and 8. a=ordered probit model; b=probit model.

Finally, TFI has a significant positive correlation with people's self-perceived life expectancy both in 2016 (Q11, β=.51, p=.002) and four years later (β=.59, p=.001). The effect of TFI in predicting life expectancy in 2020 is persistent (β=.45, p=.035) even after controlling for significant factors including the 2016 baseline. This indicates that habitually attending less to the past but more to the future increases the chances that self-perceived life expectancy exceeds 80 years. Interestingly, TFI even significantly predicts whether participants would get the Covid19 in 2020 or 2021 (β=-1.28, *p*=.012, AME=-.09) (Q12). As Figure 2d shows, people with a smaller TFI had a higher probability of getting covid19 compared to those who had a larger TFI.

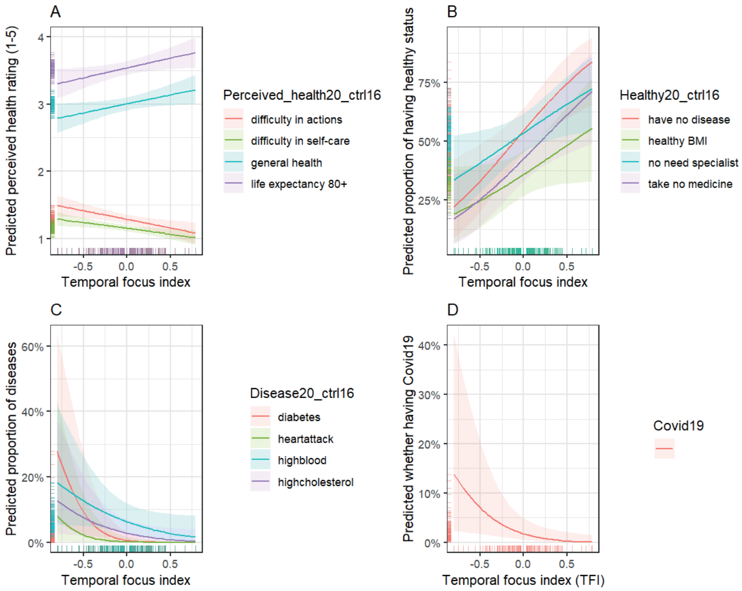


Figure 2. Controlling for the 2016 baseline conditions and other related factors, TFI predicts people's (A) perceived health including general health status, self-help ability, difficulty in actions, life expectancy in 2020; (B) facts related to being healthy including whether having a disease, a healthy BMI, needing a specialist and taking any medicine in 2020; (C) the probability of having diabetes, heart attack, high-blood pressure and high cholesterol in 2020; (D) TFI also predicts the probability of incidence of Covid19 during 2020 or 2021.

Income and hourly wages

As shown in Table3, temporal focus is significantly associated with participants' concurrent income in 2016 (β=0.34, p<.001) and five years later in 2021 (β=0.44, p<.001), while controlling for education, gender, and IQ. Given that males and females often have different labour market performance in the Netherlands (Yao & van Ours, 2015), we added an interaction term between gender and TFI. The result shows that there is a significant interaction between TFI and gender, suggesting that the effect is more pronounced for females (β_{16}=0.52, p_{16}<.001; β_{20}=0.75, p_{20}<.001) than for males (β_{16}=0.16, p_{16}=.18; β_{20}=0.20, p_{20}=.139). Interestingly, even when income in 2016 is additionally controlled for, a larger TFI indeed still predicts a higher income five years later (β=0.13, p=.06), which is mainly driven by females (β=0.20, p=.0398, see Table 3).

Table 4 shows that in 2016 TFI does not appear to be significantly associated with participants' hourly wages (β=0.07, p=.42), but when TFI is split into past and future focus values, the future focus is significant (β=0.23, p=.049). Furthermore, TFI predicts hourly wages five years later in 2021 (β=0.36, p=.01), controlling for education (p<.001), IQ (p=.056), age (p=.004), gender (p<.001) and other variables. Importantly, after additionally controlling for hourly wages in 2016 (p<.001) for the prediction of 2021, most factors become insignificant except education (β=0.15, p=.003), gender (β=0.24, p<.001) and TFI (β=0.24, p=.07). This shows that everything else being equal, including the hourly wage in 2016, participants who have a higher TFI in 2016 have a higher hourly wage five years later than those with a lower TFI in 2016 (Figure 3b), especially for females (β=0.50, p=.019).

Table 3. TFI and income in 2016 and prediction for 2021, controlling for income2016 baseline.

Variables	**logincome16**	**logincome21**	**logincome21_ctrl16**
logincome16			0.721***
			(0.0245)
Tfi	0.519***	0.752***	0.204*
	(0.125)	(0.147)	(0.0992)
tfi× male	-0.355*	-0.557**	-0.138
	(0.171)	(0.193)	(0.128)
IQ	0.0526**	0.0857***	0.0467***
	(0.0170)	(0.0189)	(0.0126)
highedu1	0.397***	0.346***	0.0592*
	(0.0363)	(0.0403)	(0.0284)
patience	0.0122	0.00555	-0.00347
	(0.00827)	(0.00893)	(0.00591)
selfcontrol	0.0164	0.0159	0.00561
	(0.0102)	(0.0114)	(0.00755)
riskaverse	-0.00668	-0.00467	-0.00396
	(0.00934)	(0.0102)	(0.00671)
age	0.00191	-0.00424*	-0.00417***
	(0.00154)	(0.00175)	(0.00115)
male1	0.379***	0.426***	0.123***
	(0.0340)	(0.0374)	(0.0267)
childrenum	0.0168	0.0150	0.00180
	(0.0158)	(0.0175)	(0.0115)
married1	0.0297	0.00650	-0.00525
	(0.0371)	(0.0411)	(0.0272)
immigrant1	-0.0452	-0.0676†	-0.00609
	(0.0345)	(0.0384)	(0.0254)
Constant	6.631***	7.061***	2.217***
	(0.114)	(0.128)	(0.185)
Observations	960	683	683
Adjusted R^2	0.254	0.312	0.700

Note: OLS estimates. *** p<.001, ** p<.01, * p<.05, † p<.1.

Table 4. TFI and log-transformed net hourly wage in 2016 and prediction for 2021, while controlling for log-transformed net hourly wage in 2016.

Variables	loghourwage16a	loghourwage16b	loghourwage21	loghourwage21_ctrl16
loghourwage16				0.572***(0.0607)
tfi	0.0674		0.512*	0.505*
	(0.0840)		(0.216)	(0.214)
pastatten		0.0033(0.011)		
futureatten		0.023*(0.012)		
highedu1	0.203***	0.201***	0.248***	0.151**
	(0.0330)	(0.0331)	(0.0530)	(0.0516)
tfi ×male			-0.259	-0.426
			(0.276)	(0.272)
IQ	0.0231	0.0241	0.0534*	0.0454†
	(0.0166)	(0.0166)	(0.0268)	(0.0261)
age	0.00935***	0.00923***	0.00758**	0.00115
	(0.00146)	(0.00146)	(0.00262)	(0.00254)
male1	0.0377	0.0385	0.207***	0.200***
	(0.0314)	(0.0313)	(0.0509)	(0.0485)
childrenum	0.00508	0.00527	-0.0184	-0.00999
	(0.0145)	(0.0145)	(0.0229)	(0.0214)
married1	0.00578	0.00747	-0.0448	-0.00427
	(0.0341)	(0.0340)	(0.0559)	(0.0527)
immigrant1	-0.0762*	-0.0803*	-0.0671	-0.0609
	(0.0316)	(0.0316)	(0.0510)	(0.0482)
Constant	2.036***	1.887***	2.174***	1.007***
	(0.0850)	(0.124)	(0.145)	(0.189)
Observations	636	636	372	305
Adjusted R^2	0.123	0.126	0.146	0.336

Note: For the model of 2016 net hourly wage, when the *TFI* is split into *past* and *future* focus values, the *future focus* is significant (hourwage16b). OLS estimates. *** p<.001, ** p<.01, * p<.05, † p<.1.

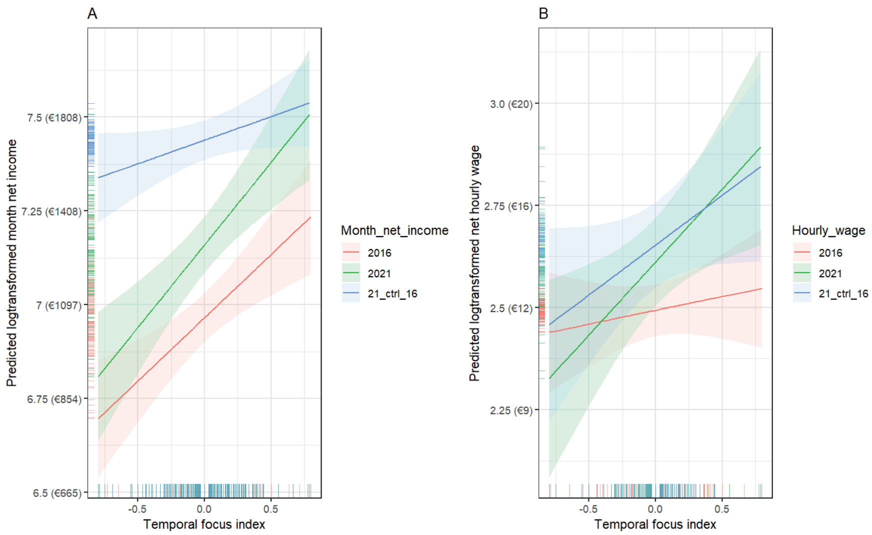


Figure 3. TFI predicts (A) monthly net income and (B) net hourly wage in 2016, 2021 and 2021 controlling for the baseline condition in 2016 and other related factors.

Financial satisfaction and happiness

Table 5 shows that participants with a higher TFI have greater financial satisfaction both in 2016 (β=0.42, p=.07) and 2020 (β=1.09, p<.001), keeping other factors constant (e.g., people with higher wealth, more patient, thinking more about their financial future, with higher self-control and IQ, being native Dutch rather than immigrants are more satisfied with their financial situation. The TFI effect is still significant (β=1.01, p<.001) in the prediction for 2020 after additionally controlling for financial satisfaction in 2016, where self-control, marital status, income, risk aversion, IQ and being an immigrant also predict future financial satisfaction in 2020. Importantly, the positive effect of TFI is beyond these significant factors (Table 5 and Figure 4A).

Table 5. TFI and financial satisfaction in 2016 and prediction for 2020 controlling for 2016 baseline.

Variables	**Financial Satisfaction16**	**Financial Satisfaction20**	**FinaSatis20 ctrl for FinaSatis16**
satisfin16			0.442***(0.0347)
tfi	0.424†	1.094***	1.018***
	(0.234)	(0.269)	(0.277)
male1	-0.0795	0.0654	0.122
	(0.0901)	(0.103)	(0.106)
IQ	0.0613	0.0621	0.0830
	(0.0436)	(0.0504)	(0.0519)
liveforpresent	-0.0352†	-0.0423†	-0.0295
	(0.0197)	(0.0226)	(0.0233)
patience	0.0404†	0.0484*	0.0278
	(0.0211)	(0.0235)	(0.0244)
selfcontrol	0.106***	0.103***	0.0608†
	(0.0264)	(0.0305)	(0.0315)
riskaverse	0.00270	-0.0626*	-0.0958***
	(0.0240)	(0.0275)	(0.0285)
highedu1	0.174†	0.185†	0.144
	(0.0947)	(0.107)	(0.111)
age	0.00437	0.00891†	0.00767
	(0.00397)	(0.00464)	(0.00484)
childrenum	-0.0635	-0.000314	0.0250
	(0.0387)	(0.0442)	(0.0462)
married1	0.412***	0.301**	0.0412
	(0.0962)	(0.111)	(0.118)
logfinasset16	0.101***	0.0754***	0.0221
	(0.0123)	(0.0134)	(0.0147)
immigrant1	-0.318***	-0.427***	-0.260*
	(0.0922)	(0.106)	(0.112)
logincome	0.0675**	0.0521*	0.000924
	(0.0211)	(0.0237)	(0.0255)
Pseudo R^2	0.106	0.095	0.196
Observations	600	468	442

Note: ***p<.001, **p<.01, *p<.05, †p<.1. Ordered probit models.

Furthermore, in Table 6 we see that participants who have a higher TFI felt significantly happier last month and in general, both in the concurrent year 2016 (general happiness: β=0.66, p=.007; recent happiness: β=0.49, p=.043) and four years later in 2020 (both p<.001), controlling for other factors (e.g., marriage, number of children, health, income, wealth, gender, IQ, self-control, patience, immigrants). Furthermore, although our results show that in 2016 people who are healthier, have better self-control, more patience and a higher IQ, and are native Dutch rather than immigrants, feel happier four years later, TFI can persistently predict participants' future happiness (general happiness: β=0.81, p=.004, recent happiness, β=0.6, p=.032) beyond all these significant control variables while additionally controlling for their 2016 happiness degree (p<.001) (see predicted effects in Figure 4B and Figure 4C).

Table 6. TFI predicts recent and general happiness in 2016, 2020, and 2020 while controlling for the baseline condition of recent or general happiness in 2016.

Variables	General happy16	General happy20	General happy 20_ctrl16	Recent happy16	Recent happy20	Recent happy 20_ctrl16
generalhappy16			0.494***(0.04)			
recenthappy16						0.614***(0.058)
tfi	0.659**	0.977***	0.810**	0.495*	0.793**	0.599*
	(0.244)	(0.273)	(0.283)	(0.244)	(0.274)	(0.279)
IQ	0.0654	0.0836	0.107*	0.0790†	0.0680	0.0275
	(0.0447)	(0.0512)	(0.0530)	(0.0449)	(0.0519)	(0.0529)
health16	0.575***	0.512***	0.269***	0.586***	0.500***	0.244**
	(0.0618)	(0.0689)	(0.0744)	(0.0625)	(0.0706)	(0.0756)
patience	0.0153	0.0751**	0.0674**	0.0458*	0.0405†	0.0209
	(0.0216)	(0.0235)	(0.0248)	(0.0215)	(0.0239)	(0.0244)
selfcontrol	0.0778**	0.114***	0.106**	0.0342	0.0822**	0.0750*
	(0.0275)	(0.0312)	(0.0323)	(0.0270)	(0.0313)	(0.0319)
riskaverse	0.0213	0.00153	-0.00976	0.00816	-0.0604*	-0.0724*
	(0.0246)	(0.0275)	(0.0284)	(0.0247)	(0.0279)	(0.0285)
highedu1	0.133	0.0433	-0.00210	-0.191*	-0.0536	0.0340
	(0.0974)	(0.109)	(0.113)	(0.0972)	(0.111)	(0.113)
age	0.0101*	0.0122*	0.00292	0.00911*	0.0150**	0.0110*
	(0.00421)	(0.00479)	(0.00500)	(0.00417)	(0.00484)	(0.00495)
male1	-0.315***	-0.219*	-0.0945	-0.109	-0.207†	-0.129
	(0.0941)	(0.106)	(0.111)	(0.0938)	(0.107)	(0.110)
childrenum	-0.0709†	-0.0569	-0.0616	0.000790	0.0440	0.0549
	(0.0400)	(0.0444)	(0.0461)	(0.0396)	(0.0458)	(0.0465)
married1	0.306**	0.220†	0.0498	0.229*	0.215†	0.0758
	(0.100)	(0.114)	(0.119)	(0.0995)	(0.116)	(0.119)
immignew	-0.306**	-0.39***	-0.261*	-0.0670	-0.257*	-0.205†
	(0.0947)	(0.108)	(0.114)	(0.0940)	(0.109)	(0.111)
logincome16	0.00445	-0.00087	-0.0244	0.0192	0.0288	0.0289
	(0.0213)	(0.0238)	(0.0245)	(0.0215)	(0.0244)	(0.0248)
logfinasset16	0.0343**	-0.00140	-0.0325*	0.0115	0.00448	0.00472
	(0.0123)	(0.0134)	(0.0141)	(0.0122)	(0.0138)	(0.0140)
Pseudo R^2	0.097	0.0904	0.199	0.0798	0.0841	0.1701
Observations	571	458	437	606	464	463

Note. Ordered probit models. ***p<.001, **p<.01, *p<.05, † p<.1.

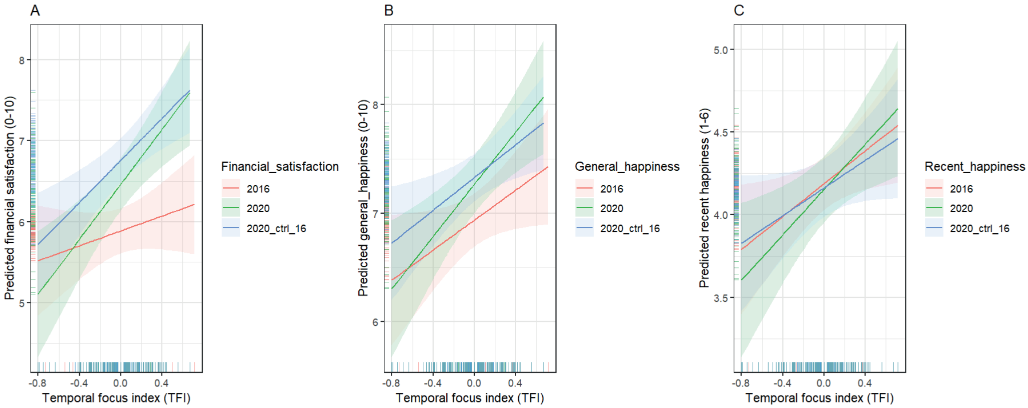


Figure 4. TFI predicts (A) financial satisfaction, (B) general happiness and (C) recent happiness in 2016, 2020 and 2020 while controlling for baseline condition in 2016 and other factors. For visualisation purposes, figures are plotted using OLS results, which are consistent with the oprobit model results.

Sensitivity analyses

It could be that TFI and age may have a non-linear relationship with the dependent variables, so we built a GAM model (Wood, 2017) by fitting the data of *TFI* and *age* each with a smoothed (non-linear) term. Age usually has a negative association with *TFI* (de la Fuente et al., 2014), but when *age* and *TFI* both positively affect the dependent variables, it is more justified to include *age* in the model when examining the effect of TFI to avoid this potential omitted variable. This is also reflected in the goodness of fit of the model, as the adjusted R^2 decreased when *age* (a significant variable) is dropped (model 1 vs. model 2, Table 7). Nevertheless, as shown in Table 7, the effects of *TFI* are robust, regardless of whether including *age* in the model. Furthermore, TFI is not a proxy of age, as when TFI is dropped in the model, age itself is not significant in many predictions. In addition, as shown in Figure 5 and 6, the effects of *TFI* on most dependent variables are still linear except smoking21_ctrl16, diseases and females' income and hourly wage. It seems that the TFI value of -0.25 is an important threshold for health and income. After this threshold, changes become less pronounced and sometimes level out (e.g., female's income and hourly age).

Table 7. TFI, age and health, income, hourly wage, financial satisfaction and happiness (using GAM models).

DVs	Model 1			Model 2 (exl. Age)		Model 3 (exl. TFI)	
	edf (TFI)	*edf (Age)*	*Adj. R^2*	*edf (TFI)*	*Adj. R^2*	*edf (Age)*	*Adj. R^2*
eat_vegetable	1.00***	1.00**	0.133	1.00***	0.124	1.00**	0.122
eat_fruit	1.00*	1.00†(*p*=0.09)	0.053	1.00*	0.051	1.00(*p*=0.108)	0.04
smoke16	1.00**	2.72	0.056	1.00 **	0.53	2.65	0.046
smoke21	1.0***	1.12	0.054	1.00***	.056	1.77	0.020
smoke21_ctrl16	4.57**	1.00	0.596	4.57**	0.596	1.00	0.559
health20_ctrl16	1.00*	1.00**	0.391	1.00*	0.384	1.00**	0.387
nomedic20_ctrl16	1.90*	1.00***	0.53	1.97*	0.51	3.47***	0.52
nodiseases20_ctrl16	3.25**	1.19***	0.43	3.00*	0.412	1.00***	0.42
heltyweit20_ctrl16	1.00*	1.00	0.53	1.00*	0.531	1.08	0.526
highcholes20_ctrl16	1.00(*p*=0.14)	3.55**	0.487	1.27	0.456	3.74**	0.489
heartattak20_ctrl16	1.52**	1.00	0.42	1.45*	0.408	1.00	0.393
diabetesbi20_ctrl16	1.00***	1.00*	0.466	1.00***	0.446	1.8†(*p*=0.08)	0.42
highblodp20_ctrl16	1.00*	1.00**	0.478	1.00†(*p*=0.06)	0.473	1.00**	0.47
nospecial20_ctrl16	1.71*	2.15***	0.16	1.84†(*p*=0.06)	0.14	2.01**	0.152
movediffi20_ctrl16	2.397*	2.592	0.47	2.384*	0.466	2.688	0.462
lifedifficul20_ctrl16	1.00**	1.987	0.534	1.00**	0.532	2.201	0.529
live80to_20_ctrl 16	1.00*	2.56†(*p*=0.069)	0.424	1.00*	0.418	2.63*	0.421
Covidbi	1.00**	1.00*	0.00748	1.00**	0.00016	1.00*	-0.002
generalhappy20_ ctrl16	4.008*	1.00	0.496	4.062*	0.498	1.005	0.481
recenthappy20_ctrl16	1.818[a]	2.188*	0.392	1.682(*p*=0.12)	0.381	2.28*	0.388
satisfin20_ctrl16	1.002***	1.00	0.502	1.001***	0.503	1.223	0.488
logincome16: female(F)	1.852 ***	3.321***	0.274	1.771***	0.254	3.048***	0.256
logincome16: male(M)	1.104†(*p*=0.097)			1.047			
logincome21: F	3.697***	2.649**	0.334	3.66***	0.321	2.267*	0.29
logincome21: M	1.00†(*p*=0.0637)			1.001(*p*=0.113)			
logincome21_ctrl16: F	3.241*	1.00 ***	0.703	3.15*	0.698	1.00 ***	0.699
logincome21_ctrl16: M	1.00			1.00			
loghwage16: F	1.00[b] **	4.193 ***	0.141	1.192 **	0.0782	3.976***	0.131
loghwage16: M	1.00[b]			1.001			
loghwage21: F	4.54***	2.02**	0.206	4.559***	0.181	2.239	0.137
loghwage21: M	1.00(*p*=0.109)			1.00			
loghwage21_ctrl16: F	4.977***	3.403*	0.44	4.892***	0.42	3.12*	0.349
loghwage21_ctrl16: M	1.00			1.00			

Note: Numbers estimated from generalized additive models are the effective degrees of freedom (edf), which are used as a proxy for the degree of non-linearity relationships. An edf of 1 is equivalent to a linear relationship, an edf > 1 and ≤ 2 is a weakly non-linear relationship, and an edf > 2 indicates a highly non-linear relationship (Zuur et al. 2009). Model 1 shows results of smoothed *TFI* and *age* with all control variables, model 2 drops *age* and model 3 drops *TFI*. ***p<0.001, **p<0.01, *p<0.05, †p<0.1.
a: if tfi> -0.1, p<.05; b: The significance indicates future temporal values split from the TFI.

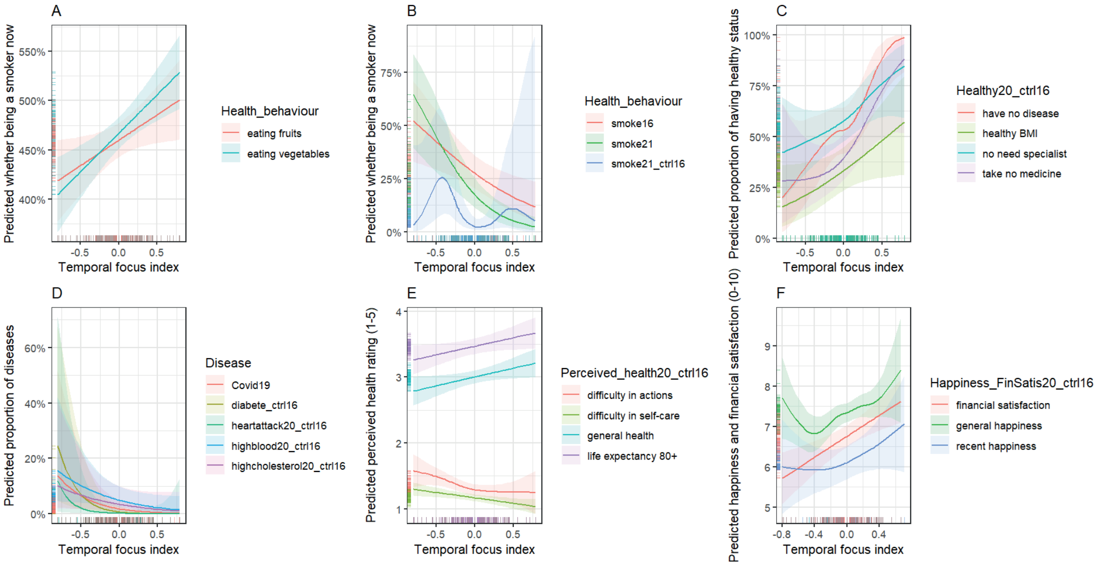


Figure 5. Relationship between *TFI* and diets, smoking, health, disease and happiness using GAM model.

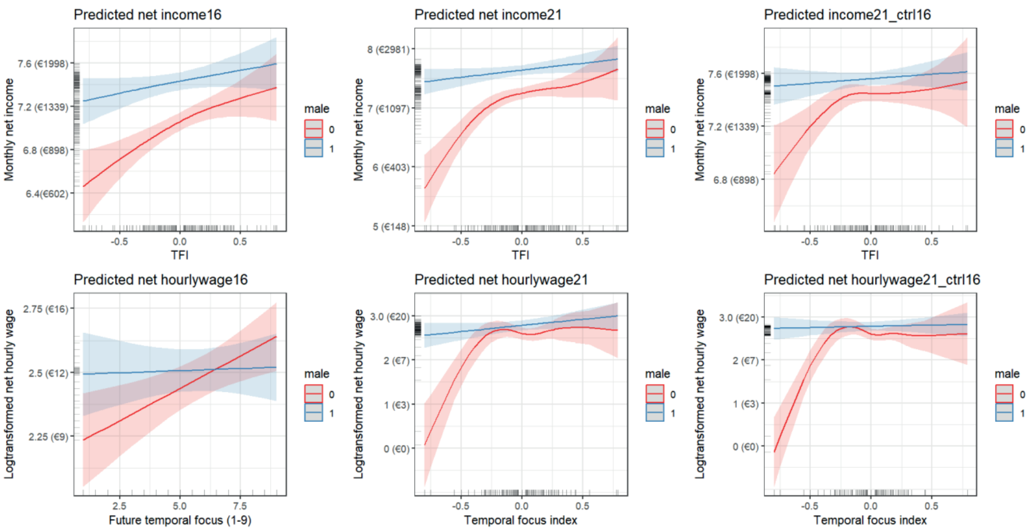


Figure 6. Relationship between *TFI* and net monthly income and net hourly wage in 2016, 2021 using GAM models.

Discussion

In this study we analyse the relationship between people's general attitudes toward time and their health, income, and happiness. First for health, we find that people's TFI correlates with their frequency of eating fruit and vegetables, as well as smoking behaviour in 2016. TFI also predicts whether a person is a smoker 5 years later even after controlling for the baseline smoking situation in 2016. Furthermore, keeping all other explanatory variables constant, people who are habitually more attending to the future, are less likely to have chronic diseases (e.g., heart attack, diabetes) or Covid19, less often take medicines, and are less likely to see a specialist. They also have less difficulty in physical movement, better self-care ability, and expect to live longer than those who are more attending to the past. One may argue that people's health status may reversely influence their temporal focus (e.g., worse in health leads to more past-focused). This is possible for momentary temporal focus when people have some extreme change in health status (Skipp, 2020). However, such reverse causality is less likely in our study because: (1) our study investigates people's general temporal focus (people's values toward time), which is relatively stable during most of one's adult life (Aspinwall, 2005). It is implausible that healthy behaviour such as eating fruit and vegetables and quitting smoking would reversely make people less attending to the past. (2) We have used each participant's 2016 health status and diseases as baseline controls and studied the changes in health status and diseases in 2020 referencing 2016. It is impossible that suffering from certain diseases, getting Covid19 or taking medicines can cause participants to be more past-focused four years earlier. Thus participants' overall temporal values can indeed predict their future health.

As for income and hourly wages, consistent with past research (e.g., Blau & Kahn, 2017; Zagorsky, 2007), we find that there is an income and wage gap between females and males, and that IQ and education positively predict future income and hourly wages. However, the innovative finding in our study is that temporal focus associates with an individual's (especially for females') income and hourly wage concurrently and in the future. Compared to people who are habitually more future-focused, those who are more past-focused are less likely to have higher income and hourly wages five years later, keeping other factors constant. This shows that habits of attending to the past or future can have a long-term relationship with an individual's income and hourly wages. Interestingly, we find that TFI even predicts people's homeownership, savings and financial assets four or six years in the future (Chapter 6). These results combined suggest that people's temporal values help substantially to make a long-term prediction for their financial well-being.

Furthermore, we show that temporal values are associated with people's financial satisfaction and happiness concurrently and in the future. Previous studies have mostly used the Zimbardo Time Perspective Inventory (Zimbardo & Boyd, 1999) and find that a future time perspective did not correlate with subjective happiness or life satisfaction (Drake et al., 2008), but happiness is more associated with the relative importance and emotional valence people assign to their past, present, and future (Zhang, Howell, & Stolarski, 2013). Different from their time perspective measurement, in our study we use the shortened temporal focus questionnaire and show a significant correlation between people's TFI and their concurrent and future happiness. Our results are informative because: First, instead of studying one specific time independently (e.g., past OR future), we have used the TFI that reflects a continuum between past, present and future temporal values. Second, we have controlled for important factors of participants' health, financial wealth, income, gender, marriage, and number of children, IQ, self-control, patience, education, etc.. No previous studies investigating the perception of time and happiness have considered all these factors, even though people who are more patient, better in self-controlling and higher in IQ are significantly happier as shown from our results. Third, unlike most research only investigating a concurrent correlation, we have done a longitudinal study showing that temporal values predict people's future financial satisfaction and happiness.

In short, our study shows that, regardless of native Dutch or immigrants, people's habits of attending to the past or future are not only associated with their current health-related behaviour, diseases, life expectancy, income and happiness, but also predict their future situation. Such results support our *temporal values and well-being hypothesis*, proposing that individuals' temporal values can affect their attentional priority of the future and past which further influences their behaviour and future well-being. Given that individuals who are habitually attending to past events may metaphorically tend to place the past in front of them, in the place where they could focus on the past as if past events were physical objects that could be seen (de la Fuente et al., 2014; Callizo-Romero et al., 2020), and given that people usually put important things in front of them and leave less important things behind, habitually focusing on the past is likely to lead people to give less priority to the future compared to the past. Therefore, temporal values[2] can have consequences for their *planning and behaviour*, influencing overall well-being in the long term.

Our study has a number of contributions. Theoretically, our hypothesis is novel. It is different from Chen's (2013) linguistic-saving hypothesis as we are not testing the effects of structures of temporal language on economic behaviour but directly testing the effects of time values on wellbeing. Furthermore, our results go beyond Guo et al.'s (2012) finding that cultural temporal focus affects how people value future and past events, but reveal that general cultural temporal values (different from individual momentary temporal focus) can predict various aspects of wellbeing. Methodologically, our study shows predictive power of a shortened version of temporal focus testing items with more than two dozen dependent variables ranging from economic behaviour, health and disease, to happiness, smoking and diet. These four items can be used in future studies on well-being.

Furthermore, there are several practical implications. First, given that a low TFI predicts less desirable wellbeing in a few years (if no prevention is taken), the government, family doctors and aid units should treat those who have a negative TFI as a potential vulnerable group. Those people

[2] One alternative interpretation of TFI is that it measures those who are more conservative verses more innovative and progressive. However, previous research shows that conservative people experience higher degree of happiness (Burton, Plaks & Peterson, 2015; Schlenker, Chambers, & Le, 2011). Additionally, conservatives also tend to be healthier than liberals and are less likely to smoke and take more exercising, etc. (Chan, 2019; Subramanian & Perkins, 2010). This is reversed to our findings that a lower TFI (more past-focused) relates to less healthy and less happy. Given the four items represent 80% of the original temporal focus questionnaire (21 items see https://onlinelibrary.wiley.com/action/downloadSupplement?doi=10.1111%2Fcogs.12804&file=cogs12804-sup-0002-SupMat2.pdf), they are more likely to measure people's values towards time.

should be alerted to take more preventive actions in planning their life and work, and have more adaptive behaviour to health and diets. In addition, TFI predicts females' net monthly income and hourly wage. Targeting females who have a lower TFI may not only help them improve their labour market performance but also reduce gender wage gap and improve gender equality in the future.

Our results may also have some potential psychotherapy and clinical implications. For example, a popular treatment for depression is to encourage patients to adopt a more present-focused temporal thinking (Shapiro et al., 2006). Given our results show that past-focused people are less happy, it is intriguing to think whether psychedelics can induce a mental state that is less focused on the past and therefore less unhappy (Speth et al., 2016). If so, such psychedelics may be a useful medicine. Likewise, it is exciting to examine whether nutritionist and doctors can promote their customers/patients to have more future-focused thinking and therefore eat more often vegetables and fruit but smoke less.

In addition, given that TFI is affected by cultural environment but is quite stable over most of the whole adulthood (Aspinwall, 2005), it is important to penetrate the optimal temporal thought into elementary and junior education. Providing a better environment that can form a more future-focused and less past-focused temporal values cannot only improve national quality in terms of planning but may also have an important influence on people's overall well-being in the short and long run.

Finally, although our study aims to better understand a possible causal effect of temporal values by controlling for more individual characteristics and using longitudinal predictions, one can still argue that there can be an omitted variable that influences both an individual's TFI and all the dependent variables. If TFI is not causing but rather reflecting deep differences that drive the overall wellbeing, then TFI acts as a powerful marker of such an omitted variable. Because TFI predicts more than 30 dependent variables in different fields (chapter 6 and this chapter) even after controlling for well-known factors such as IQ, education, financial literacy and SES, we believe it deserves attention from researchers.

Appendix 1 Sample statistics of the main variables

vars	n	mean	Sd	min	max	Vars	n	mean	sd	min	max
age	1177	46.69	11.89	25	66	live80to_ord20	776	6.4	2.03	0	10
childrenum	1177	0.86	1.11	0	5	liveforpresent	1175	4.51	2.18	1	9
covidbi	688	0.04	0.19	0	1	logfinasset16	695	6.58	4.36	0	14.01
diabetesbi16	1011	0.04	0.2	0	1	loghourwage16	648	2.57	0.52	0	4.61
diabetesbi20	776	0.05	0.21	0	1	loghourwage21	382	2.76	0.64	-0.69	5.99
eatfruit16	1017	4.68	1.35	1	6	logincome16	1177	6.05	2.83	0	9.21
eatvegetb16	1017	4.68	1.32	1	6	logincome21	880	6.28	2.81	0	9.47
employed16	1153	0.68	0.47	0	1	Male	1177	1.45	0.5	1	2
employed21	730	0.62	0.49	0	1	Married	1177	1.54	0.5	1	2
recenthappy16	1023	4.13	1.08	1	6	movedifficulty16	1020	1.33	0.58	1	5
recenthappy20	776	4.14	1.14	1	6	movedifficulty20	776	1.36	0.58	1	5
futureatten	1175	5.81	1.37	1	9	nodiseasesbi16	1011	0.6	0.49	0	1
generalhappy16	995	6.96	1.72	0	10	nodiseasesbi20	776	0.57	0.5	0	1
generalhappy20	755	7.17	1.64	0	10	nomedic16	1021	0.56	0.5	0	1
health16	1024	3.07	0.77	1	5	nomedic20	776	0.51	0.5	0	1
health20	777	3.09	0.78	1	5	nospecialbi16	1017	0.58	0.49	0	1
heartattackbi16	1011	0.02	0.14	0	1	nospecialbi20	776	0.57	0.5	0	1
heartattackbi20	776	0.02	0.14	0	1	Pastatten	1175	5.79	1.5	1	9
heltyweight16	1023	0.47	0.5	0	1	Patience	1175	4.26	2.06	1	9
heltyweight20	776	0.42	0.49	0	1	Riskaverse	1165	6.25	1.88	1	9
highbloodpre16	1011	0.12	0.32	0	1	satisfin16	999	6.27	2.03	0	10
highbloodpre20	776	0.12	0.33	0	1	satisfin20	739	6.81	1.9	0	10
highcholesbi16	1011	0.07	0.26	0	1	Selfcontrol	1165	6.18	1.72	1	9
highcholesbi20	776	0.09	0.29	0	1	selfhelp16	1014	1.17	0.48	1	5
highedu1	1177	1.39	0.49	1	2	selfhelp20	776	1.17	0.41	1	5
hourlywage16	648	14.84	9	0	100	smokenow16	1020	0.2	0.4	0	1
hourlywage21	382	19.6	25.67	0	400	smokenow21	704	0.14	0.35	0	1
immigrant	1177	0.56	0.5	0	1	Tfi	1175	0.01	0.19	-0.8	0.8
inc_unknown16	1177	0.08	0.26	0	1	IQ	1162	2.59	1.05	0	4
inc_unknown21	880	0.08	0.27	0	1	live80to_ord16	1024	6.36	2.14	0	10

References

Aspinwall, L. G. (2005). The psychology of future-oriented thinking: From achievement to proactive coping, adaptation, and aging. *Motivation and Emotion*, *29*(4), 203-235.

Blau, F. D., & Kahn, L. M. (2017). The gender wage gap: Extent, trends, and explanations. *Journal of Economic Literature*, *55*(3), 789-865.

Bilker, W. B., Hansen, J. A., Brensinger, C. M., Richard, J., Gur, R. E., & Gur, R. C. (2012). Development of abbreviated nine-item forms of the Raven's standard progressive matrices test. *Assessment*, *19*(3), 354-369.

Burton, C. M., Plaks, J. E., & Peterson, J. B. (2015). Why do conservatives report being happier than liberals? The contribution of neuroticism. *Journal of Social and Political Psychology*, *3*(1), 89-102.

Callizo-Romero, C., Tutnjević, S., Pandza, M., Ouellet, M., Kranjec, A., Ilić, S., Gu, Y., Göksun, T., Chahboun, S., Casasanto, D. & Santiago, J., (2020). Temporal focus and time spatialization across cultures. *Psychonomic Bulletin & Review*, *27*(6), 1247-1258.

Callizo-Romero, C., Tutnjević, S., Pandza, M., Ouellet, M., Kranjec, A., Ilić, S., Gu, Y., Göksun, T., Chahboun, S., Casasanto, D. & Santiago, J. (2022). Does time extend asymmetrically into the past and the future? A multitask crosscultural study. *Language and Cognition*, *14*(2), 275-302.

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

Chan, E. Y. (2019). Political orientation and physical health: The role of personal responsibility. *Personality and Individual Differences*, *141*, 117-122.

Chen, J. I., He, T. S., & Riyanto, Y. E. (2019). The effect of language on economic behavior: Examining the causal link between future tense and time preference in the lab. *European Economic Review*, *120*, 103307.

Chen, M. K. (2013). The effect of language on economic behavior: Evidence from savings rates, health behaviors, and retirement assets. *American Economic Review, 103*(2), 690-731.

Dasa., S., (2014*) Life Is nothing but time: Time is life*, *life is time*. Soul Science University Press.

de la Fuente, J., Santiago, J., Román, A., Dumitrache, C., & Casasanto, D. (2014). When you think about it, your past is in front of you: How culture shapes spatial conceptions of time. *Psychological Science*, *25*, 1682-90.

Drake, L., Duncan, E., Sutherland, F., Abernethy, C., & Henry, C. (2008). Time perspective and correlates of wellbeing. *Time & Society*, *17*(1), 47-61.

Guo, T., Ji, L. J., Spina, R., & Zhang, Z. (2012). Culture, temporal focus, and values of the past and the future. *Personality and Social Psychology Bulletin, 38*(8), 1030-1040.

Jäggi, T., Sato, S., Gillioz, C., & Gygax, P. M. (2022). Is the future near or far depending on the verb tense markers used? An experimental investigation into the effects of the grammaticalization of the future. *PLOS ONE*, *17*(1), e0262778.

Lasane, T. P., & Jones, J. M. (1999). Temporal orientation and academic goal-setting: The mediating properties of a motivational self. *Journal of Social Behavior and Personality*, *14*, 31–44.

Levasseur, L., Shipp, A. J., Fried, Y., Rousseau, D. M., & Zimbardo, P. G. (2020). New perspectives on time perspective and temporal focus. *Journal of Organizational Behavior*, *41*(3), 235-243.

Lewin, K. (1951). Field theory in the social sciences: Selected theoretical papers. New York: Harper.

Raven, J.C. (1976) *Raven's standard progressive matrices test*. Texas, Harcourt Assessment.

Roberts, S. G., Winters, J., & Chen, K. (2015). Future tense and economic decisions: controlling for cultural evolution. *PLOS ONE, 10*(7), e0132145.

Schlenker, B. R., Chambers, J. R., & Le, B. M. (2012). Conservatives are happier than liberals, but why? Political ideology, personality, and life satisfaction. *Journal of Research in Personality*, *46*(2), 127-146.

Seijts, G. H. (1998). The importance of future time perspective in theories of work motivation. *Journal of Psychology*, *132*, 154–168.

Shapiro, S. L., Carlson, L. E., Astin, J. A., & Freedman, B. (2006). Mechanisms of mindfulness. *Journal of Clinical Psychology*, *62*(3), 373-386.

Shipp, A. J., Edwards, J. R., & Lambert, L. S. (2009). Conceptualization and measurement of temporal focus: The subjective experience of the past, present, and future. *Organizational Behavior and Human Decision Processes*, *110*, 1–22.

Shipp, A. J. (2020). Temporal focus: A review of the past with an eye to the future. In F. Grouzet (Ed.), *Oxford Handbook of Psychology of Time Travel and Temporality*. OUP: Oxford, UK.

Shipp, A. J., & Aeon, B. (2019). Temporal focus: Thinking about the past, present, and future. *Current Opinion in Psychology*, *26*, 37–43.

Speth, J., Speth, C., Kaelen, M., Schloerscheidt, A. M., Feilding, A., Nutt, D. J., & Carhart-Harris, R. L. (2016). Decreased mental time travel to the past correlates with default-mode network disintegration under lysergic acid diethylamide. *Journal of Psychopharmacology*, *30*(4), 344-353.

Stolarski, M., & Matthews, G. (2016). Time perspectives predict mood states and satisfaction with life over and above personality. *Current Psychology*, *35*, 516–526.

Subramanian, S. V., & Perkins, J. M. (2010). Are republicans healthier than democrats?. *International Journal of Epidemiology*, *39*(3), 930-931.

Thoma, D., & Tytus, A. E. (2018). How cross-linguistic differences in the grammaticalization of future time reference influence intertemporal choices. *Cognitive Science*, *42*(3), 974-1000.

Van Rooij, M. C., Lusardi, A., & Alessie, R. J. (2011). Financial literacy and stock market participation. *Journal of Financial Economics*, *101*(2), 449-472.

Wood, S. N. (2017). *Generalized additive models: an introduction with R*. CRC press.

World Health Organization. (2005). *Surveillance of chronic disease risk factors: country level data and comparable estimates*, 1-95.

Yao, Y., & van Ours, J. C. (2015). Language skills and labor market performance of immigrants in the Netherlands. *Labour Economics*, *34*, 76-85.

Zagorsky, J. L. (2007). Do you have to be smart to be rich? The impact of IQ on wealth, income and financial distress. *Intelligence*, *35*(5), 489-501.

Zhang, J. W., Howell, R. T., & Stolarski, M. (2013). Comparing three methods to measure a balanced time perspective: The relationship between a balanced time perspective and subjective well-being. *Journal of Happiness Studies*, *14*(1), 169-184.

Zimbardo, P. G., & Boyd, J. N. (1999). Putting time in perspective: A valid, reliable individual-differences metric. *Journal of Personality and Social Psychology*, *77*(6), 1271–1288.

Zuur, A.F., Ieno, E.N, Walker, N.J., Saveliev, A.A, & Smith, G.M. (2009) *Mixed effects models and extensions in ecology with R*. Springer-Verlag, New York.

Chapter 7. The value of host-country language: The effect of Dutch language proficiency on immigrants' income, savings and financial wealth in the Netherlands

Abstract

We study the effect of Dutch proficiency on immigrants' labour market performance, savings and financial wealth in the Netherlands. Different from past research, we had participants (*N*=659) take a language proficiency test apart from self-reported assessments, and measured participants' IQ, patience, saving intention, risk aversion, self-control, temporal focus, etc. to better control for individual characteristics. Immigrants' labour market performance and financial wealth were initially surveyed in 2016, and then again in 2020-2021. We find that Dutch proficiency affects immigrants' earnings (employment probabilities; income; hourly wages) in 2016 and predicts participants' earnings in 2021 even after controlling for the baseline in 2016, individual characteristics and demographic information. Furthermore, the results for the first time reveal that language proficiency can also predict immigrants' current and future savings and financial wealth. Importantly, using an instrumental variables approach we show that language proficiency has a causal effect. Our findings have theoretical and policy implications.

Keywords: language proficiency; income; labour market performance; financial wealth; immigrant; wages; IQ

Acknowledgements: This work is supported by a grant from The Netherlands Organization for Scientific Research, via NWO Research Talent (406-15-298) to YQZ. Results have been orally presented at the EuroSLA31 (European Second Language Association, Freiburg, 2022), Cognitive Science 2022 (Canada), and BALL2022 (British Association of Applied Linguistics, Belfast).

An abstract of this chapter has been published as:

Zheng, Y., Gu, Y., Backus, A., & van Soest, A. (2022). The value of host-country language: The effect of Dutch language proficiency on immigrants' income, savings and financial wealth in the Netherlands. *Proceedings of the Annual Meeting of the Cognitive Science Society, 44*. Retrieved from https://escholarship.org/uc/item/88g132bk

Introduction

"Non-native Dutch speakers must achieve a C1 level of Dutch within two years, which is a prerequisite for a permanent employment contract". This sentence appears commonly in job advertisements for assistant professors at Dutch universities. Immigrants, regardless of their education level, cannot escape the host country's language. Linguistic barriers can constitute distinctive hurdles for their economic and social integration (Isphording & Otten, 2014), and the lack of host-country language skills can be a severe obstacle to immigrants' career success.

Studies investigating the relationship between language proficiency and immigrants' labour market performance have shown that host-country language proficiency has an impact on employment possibilities and earnings. For example, researchers have found a relation between speaking and writing proficiency and immigrants' earnings in Germany (Dustmann, 1994), between language skills and employment possibility of immigrants in the UK (Dustmann & Fabbri, 2003), Italy (Luca et al., 2022), and Switzerland (Wong, 2022), between English proficiency, age of arrival, and earnings among US immigrants (Bleakley & Chin, 2004), and between sign language proficiency of Chinese deaf signers and their occupational prestige and income (Zheng, Lin & Gu, 2023). Recent studies also suggest that there is an effect of language proficiency on the gender wage gap (Miranda & Zhu, 2020), for example due to a negative effect of immigrants' language problems on females' hourly wages (Yao & van Ours, 2015).

However, research about language effects on labour market performance often confronts three problems. First, higher language proficiency and labour market performance may be correlated through unobserved characteristics such as a higher IQ or ability in general, making language proficiency endogenous in a regression model. This may lead to an upward bias in the estimated effects of language because those who have a higher ability may better learn the host-country language and more easily find a job. Second, the correlation could be bidirectional: undeniably, good language skills increase immigrants' chances to secure a job, but the experience of working in the host-country language environment may also reversely cause an improvement in language proficiency. Third, all studies on this topic have used self-assessment to measure immigrants' language proficiency from survey data, which may have substantial measurement errors that lead to an underestimation of the language effects (see the discussions in, e.g., Dustmann & van Soest, 2001, 2002; Dustmann & Fabbri, 2003; Yao & van Ours, 2015).

To account for the abovementioned potential sources of endogeneity, most empirical studies rely on the method of instrumental variables (IV), where a valid instrument induces changes in the independent variable but has no independent effect on the dependent variable (Angrist, Imbens & Rubin, 1994). Such an econometric method allows uncovering the causal effect of the independent variable on the dependent variable. Several instruments for immigrants' language proficiency have been proposed in the literature, such as age and number of children (Chiswick & Miller, 1995), overseas marriage (Chiswick, 1998), parental education and linguistic distance between the immigrant's mother tongue and the language of the host country (Dustmann & van Soest, 2001, 2002), the interaction between the age of arrival to the host country and whether the immigrant spoke the host-country language when growing up (Yao & van Ours, 2015) (although "when growing up" may be a bit vague in a time frame (e.g., what exact age range that "when growing up" refers to is not specified)). Recently, the most often used instrument exploits the age of arrival in the host country, typically using an interaction between the maximum of age at arrival minus 11 or 9 years and zero, and a dummy for whether an immigrant was born in a country not speaking the host-country language (e.g., Bleakley & Chin, 2004, 2010; Budría, Colino & Martínez de Ibarreta, 2019; Di Paolo & Raymond, 2012; Miranda & Zhu, 2021). The choice of the age cut-off of 9 or 11 years can have different bases. In linguistics, the *Critical Period* for acquiring a native-like language generally lies between 6 and 12 depending on different linguistic aspects such as phonology, lexicon, morphology, or syntax (e.g., Johnson & Newport, 1989; Long, 2005; Mayberry et al., 2002). In economics, the age cut-off relies on empirical evidence that native-like proficiency is typically achieved if an immigrant arrives in the host country before a certain age such as 9 or 11 (e.g., Bleakley & Chin, 2004; Tam & Page, 2016). Using such instruments, several studies claim to find a causal effect of language proficiency on immigrants' employment possibilities and earnings, but no study has examined its potential influence on other aspects such as immigrants' savings and financial assets.

In our research, focusing on immigrants in the Netherlands, we move one step forward by studying the effect of host-country language proficiency on immigrants' savings and financial assets, in addition to investigating its impact on their labour market performance (i.e., employment status, net monthly income, and hourly wage). To reduce the potential problem of unobserved characteristics, we additionally control for important factors such as immigrants' IQ, risk aversion, saving intention, patience, financial future time perspective, self-control, and cultural temporal focus - factors that are relevant but have not been controlled for in existing studies. Particularly, IQ is a good proxy of (unobserved) ability. To reduce the measurement error of self-assessed language proficiency, we had all immigrant participants in the survey take a standard Dutch language placement test, besides self-assessing their speaking and reading Dutch proficiency. In addition, in our study, immigrants' labour market performance and financial wealth were initially surveyed in 2016 and again in 2020 or 2021. We use concurrent language proficiency to predict the future situation while controlling for the situation in 2016. This helps to understand the relations between language proficiency and dependent variables, because time progresses unidirectionally such that future labour market performance or wealth cannot influence past Dutch proficiency.

We follow the recent studies by using two-stage least square regression (2SLS) with instrument the interaction between age at arrival minus 11 or 9 years old and a dummy for whether an immigrant was not born in a Dutch-speaking country. The logic of the relationship between age of arrival and

Dutch proficiency is as follows: Suppose child A arrived in Amsterdam at 10 whereas child B arrived at 12. Child A has a better Dutch proficiency because of an earlier age of arrival (see Figure 1), but we do not assume child A has a better ability. We also use a second set of instruments based on the linguistic family of the language that an immigrant speaks best. The idea is that immigrants' best-spoken language can have varying linguistic distance to Dutch. Consequently, immigrants may have different Dutch proficiency while they do not differ in their general ability. For example, speakers of western Germanic languages such as English and German find it easier to learn Dutch (and usually have higher Dutch proficiency) than Italians and French immigrants, but we do not expect English and French speakers to differ in their general ability. The results of our study not only contribute to the validation of theory on the effect of language and individual differences on immigrants' financial well-being, but also have strong implications for policymakers.

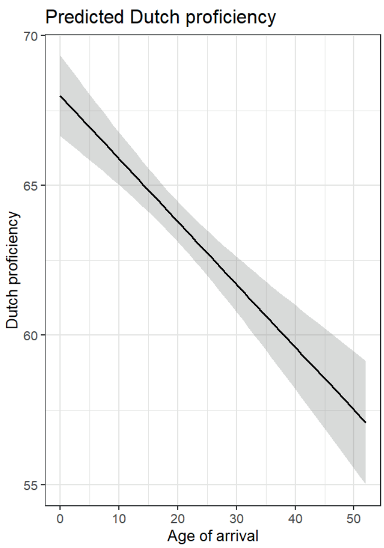


Figure 1. Predicted examined Dutch proficiency as a function of age of arrival in our study.

Data

We used survey data for the Netherlands in 2016, 2020 and 2021. We have designed a special questionnaire with a set of questions including immigrant's linguistic background, cultural values towards time (past or future temporal focused, de la Fuente et al., 2014, shortened version e.g., future-focused item: "It is important to innovate and adapt to the new changes". Past-focused item: "The traditional way of living is better than the modern way"), IQ (Raven's Standard Progressive Matrices Test, Raven, 1976; shortened version, Bilker et al., 2012), financial literacy (Lusardi & Mitchell, 2008), risk aversion (van Rooij et al., 2011), time preference (patience), saving intention, self-control, financial future time perspective, demographic information, etc. (For details of these measures, see Appendix 1, Chapter 5).

To measure Dutch proficiency, all participants took a Dutch placement test of DIALANG, which is seen as a reliable language diagnosis system (Alderson, 2005). In this test, participants get 75 "words", some of which are real, and some of which are pseudowords. For each "word", participants choose the option "Yes" if they think the "word" does exist and "No" if they think it is an invented word. They were told to finish the task independently without referring to a dictionary or internet search.

Following Yao and van Ours (2015), we also obtained participants' self-assessment of the (1) extent to which they have trouble speaking the Dutch language when having conversation in Dutch (1=yes, often have trouble/do not speak Dutch, 2=yes, sometimes, 3=no, never) and (2) extent to which they have trouble understanding the Dutch language when reading newspapers, letters or brochures (1=yes, often have trouble/do not speak Dutch, 2=yes, sometimes, 3=no, never). In addition, participants were asked to rate how good they speak English on a scale of 1-9 (1=very bad, …, 9 =very good).

Furthermore, we obtained information about participants' net monthly income, employment status, weekly hours of paid work, riskless assets (savings), and financial wealth (the gross amount of financial assets) in 2016. Moreover, participants who took the survey in 2016 were traced in 2020 for their savings and financial wealth, and in 2021 for their income, employment status, and weekly hours of paid work.

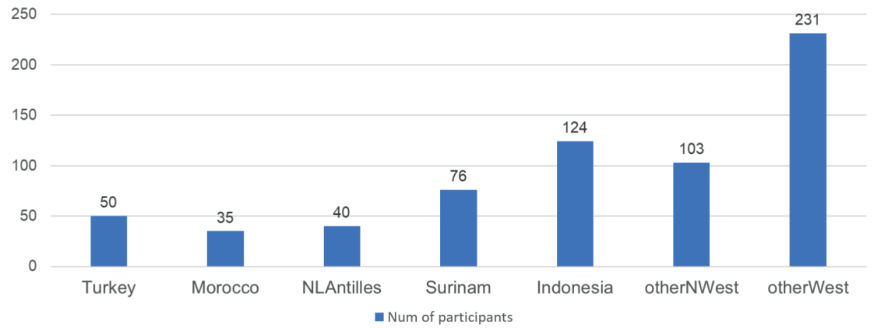


Figure 2. The number of participants in each immigrant group.

The questionnaire was administered to 771 immigrants in the LISS panel in Dutch, managed by Centerdata (Tilburg University, The Netherlands) in 2016. There were 659 respondents (M_{age}=45.34, *range* 25-66, *SD*=11.83, 352 females, 307 males), including 361 first-generation and 298 second-generation immigrants. They were mainly consisted of immigrants from Indonesia, Surinam, Turkey, Morocco, Dutch Athletes, other non-western and other western countries (see details in Figure 2). As some participants were unwilling to reveal their financial information, we have income information of 607 participants, employment status of 638, weekly working hours of 324, riskless saving of 403 and financial wealth of 394 participants in 2016. Due to sample attrition, in 2020, we have information of saving of 292 and financial wealth of 286 participants. In 2021, we have obtained income information of 434, employment status of 381 and weekly paid work hours of 199 participants. We do not have the data of participants' savings and financial wealth in 2021. Participants were always paid.

Our sample is representative in terms of important background characteristics, as those who provided or refused to provide income and financial information in 2016 do not differ significantly in their mean of age, gender, education, IQ, marriage, number of children, self-control, patience, temporal values, etc. (all $p>.1$). As the questionnaire was in Dutch, our sample is not representative of immigrants who cannot read Dutch. Undeniably, some immigrants who do not speak Dutch but have a high English proficiency may still secure a good job (e.g., Hahm & Gazzola, 2022; Muhawenayo, Habimana & Heshmati, 2022; Jiang & Lui, 2022), but in the current study we focus on the effect of host country language proficiency – Dutch.

Data analysis plan

Dependent variables

Employment, income and hourly wage

We generated four dependent variables as to (1) whether participants are employed (excluding the retired), (2) monthly net income (including those who are unemployed), (3) net income (excluding 0), (4) contract hourly wage (dividing monthly net income by four times the weekly contract hours of paid work) and actual hourly wage (dividing monthly net income by four times the total actual weekly working hours). Each dependent variable was labelled with the year 2016 or 2021 (e.g., *employed16*; *employed21*; *income16*; *hourlywage16*).

Savings and financial wealth

We generated two dependent variables on participants' savings and financial wealth in 2016 and 2020 (*saving16*; *saving20*; *finasset16*; *finasset20*). Income, hourly wages, savings and financial assets were all log-transformed.

Independent variables

For the measurement of Dutch proficiency, we mainly relied on the number of correct answers in the Dutch placement test (*exam_Dutchprf*). Although self-assessed speaking and reading proficiency (*readDutchprf*, and *speakDutchprf*) can be inaccurate, we use them for robustness checks.

In addition, we generated the following independent variables: *IQ*, *risk aversion*, *education* (high; low), *patience* (time preference), *financial knowledge*, *self-control*, *saving intention* and financial future time perspective (*live_for_present*). As people's temporal values influence their financial well-being (see Chapter 6 and Chapter 7 later), we generated a Temporal-focus Index (*TFI*) for each participant, *TFI* = (mean of future-focused items – mean of past-focused items)/(mean of future-focused items + mean of past-focused items) (de la Fuente et al., 2014). Moreover, we control for demographic factors *children number*, *gender (male1)*, *age*, *partner*, *generation2*, and education (highedu1). Probit models were used to study the effect of Dutch proficiency on whether immigrants have a paid job, with dependent variable *employed16* or *employed21*. OLS regressions were used to examine whether immigrants' Dutch proficiency is related to their net monthly income, income from paid work, hourly wages, savings and financial wealth in 2016, with dependent variable *income16*, *hourlywage16*, *saving16* or *finasset16*. Furthermore, we examined whether immigrants' Dutch proficiency can predict the future values of the dependent variables *income21*, *hourlywage21*, *saving20* and *finasset20*.

Given that males and females often have different labour market performance in the Netherlands (Yao & van Ours, 2015), we added an interaction term between gender (male1) and Dutch proficiency when the interaction was significant. In addition, even though Yao and van Ours (2015) argue that Dutch proficiency does not affect the first and second generations differently, we added an interaction term between Dutch proficiency and generation when it was significant as it could be that the first-generation immigrants may be affected more by language proficiency.

Four sensitivity analyses were conducted: (1) we used the self-assessed *readDutchprf* and *speakDutchprf* to check whether the findings are different from those using the *exam_Dutchprf* as a proficiency measurement. (2) To account for the possible influence of immigrants' length of stay on income and wealth, we used the subsample of first-generation immigrants to do a sensitivity analysis while additionally controlling for their length of stay. To account for the possible influences of immigrants' English proficiency, we did a robustness check while controlling for self-assessed English proficiency. (3) to shed light on the causal effect of language, we used two kinds of instruments, one is the interaction between *max(0, age of arrival – 9*) and not being born in a Dutch-speaking country. The other is the language family of the language an immigrant speaks best, coded with three dummies (Dutch is the baseline): (Germanic languages, non-Germanic Indo-European languages, and languages from outside the Indo-European family). And finally, to check whether the effect of Dutch proficiency is linear, we used the Generalized Additive Model (GAM), which is used often when there is no a priori reason for choosing a particular response function (such as linear, quadratic, etc.) and we want the data to 'speak for themselves'.

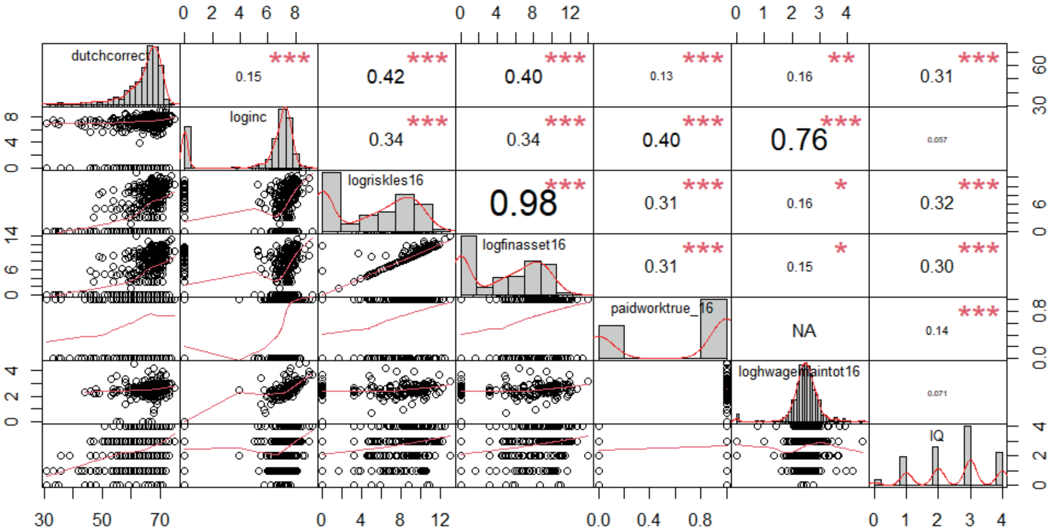
Results

Descriptives

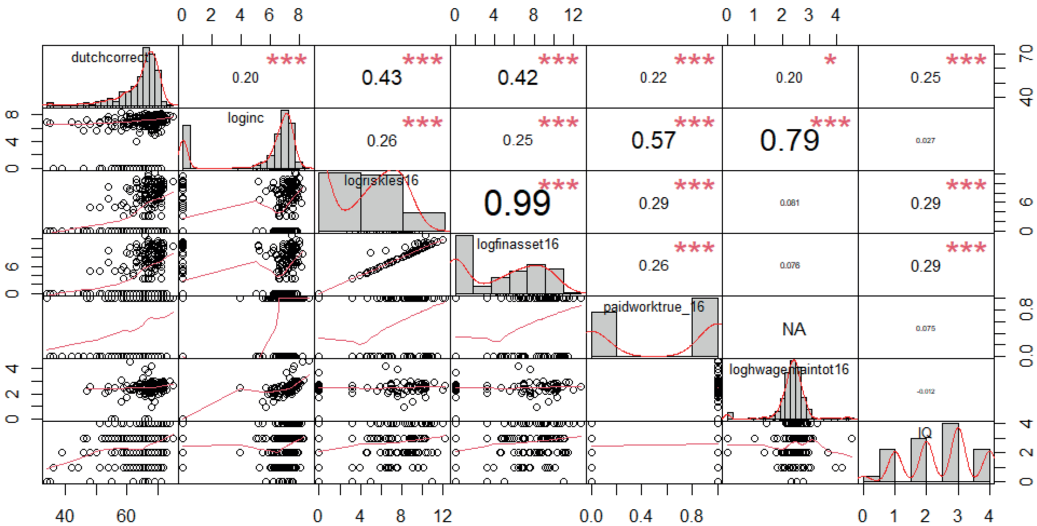
Descriptive results of the main variables (*examDutchprf, IQ, logincome*, etc.) are listed in Appendix 1. Figure 3 presents three correlation matrices between the *examDutchprf* (i.e., *dutchcorrect*) and the main dependent variables, separately for the whole sample and for the subsamples of females and males. As can be seen, examined Dutch proficiency is significantly correlated with the variables *log-*

transformed income, savings, financial wealth, hourly wage, employment possibility and IQ.

(a) Whole sample



(b) Female sample



(c) Male sample

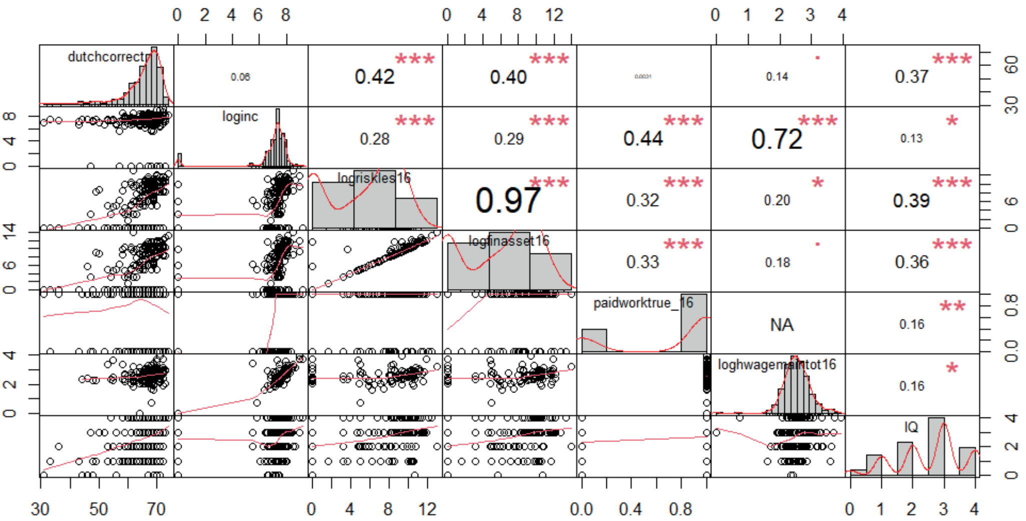


Figure 3. Correlation matrices (positioned in the upper right triangle) between *dutchcorect (examDutchprf) and logincome, logsavings, logfinancial_assets, employment status, hourly wages,* and *IQ* with histograms for each variable (on the diagonal position) and the scatter plots for any two variables (positioned in the lower left triangle). (a)-whole sample; (b)-female; (c) male.

Employment, income and hourly wage

Employment

Immigrants' *exam_Dutchprf* positively correlates with employment in 2016 (β=.027, p=.005), keeping IQ, generation, education, age, gender, number of children, partner status, *riskaverse*, *liveforpresent*, *patience*, and *self-control* constant (Table 1). However, there was a significant interaction between Dutch proficiency and gender (β=-0.035, p=.049). An analysis of this interaction showed that *exam_Dutchprf* is positively associated with the employment status of female immigrants (β=.041, p=.0009) (column (2) in Table 1), but is not associated with that of male immigrants (β=.005, p=.70). In 2021, *exam_Dutchprf* predicted females' employment status (β=.07, p=.0003) (column (4) in Table 1), and remained significant (β=.05, p=.013) even when the concurrent employment dummy *employed2016* (β=1.72, p<.001) was controlled for (column (6) in Table 1). However, there was no such an effect for males, as was also confirmed by a significant interaction between Dutch proficiency and gender shown in columns (4) and (6) in Table 1 (both p values <.037). The results are also visualized in Fig. 4.

Table 1. *ExamDutchprf* and employment in 2016, 2021, and 2021 controlling for 2016.

	Employment16		Employment 21		Employment 21(ctrl16)	
	(1)	(2)	(3)	(4)	(5)	(6)
employ16					1.750***	1.721***
					(0.197)	(0.198)
examDutch	0.027**	0.041***	0.034**	0.067***	0.026†	0.050*
	(0.009)	(0.012)	(0.013)	(0.019)	(0.015)	(0.020)
male1	0.437***	2.740*	0.535**	5.202**	0.232	4.031*
	(0.115)	(1.178)	(0.166)	(1.680)	(0.194)	(1.830)
gene2	0.144	0.149	0.089	0.075	-0.153	-0.135
	(0.121)	(0.121)	(0.171)	(0.174)	(0.202)	(0.204)
IQ	0.071	0.076	0.105	0.120	0.070	0.080
	(0.056)	(0.057)	(0.081)	(0.082)	(0.092)	(0.092)
highedu1	0.470***	0.477***	0.542**	0.541**	0.314	0.320
	(0.125)	(0.125)	(0.187)	(0.188)	(0.216)	(0.216)
Age	-0.014**	-0.014**	-0.038***	-0.041***	-0.039***	-0.041***
	(0.005)	(0.005)	(0.009)	(0.009)	(0.010)	(0.010)
Childrenum	0.051	0.052	0.060	0.057	0.005	0.010
	(0.054)	(0.054)	(0.075)	(0.076)	(0.088)	(0.089)
partnerNo	0.001	0.002	-0.077	-0.085	-0.035	-0.033
	(0.124)	(0.125)	(0.177)	(0.179)	(0.208)	(0.211)
Riskaverse	-0.029	-0.030	-0.026	-0.027	-0.027	-0.028
	(0.032)	(0.032)	(0.046)	(0.047)	(0.053)	(0.054)
liveforpresent	-0.013	-0.013	-0.023	-0.022	-0.029	-0.028
	(0.026)	(0.026)	(0.037)	(0.037)	(0.042)	(0.043)
Patience	-0.012	-0.013	0.0003	-0.004	0.0005	-0.002
	(0.026)	(0.027)	(0.036)	(0.036)	(0.041)	(0.042)
Selfcontrol	-0.019	-0.019	0.012	0.018	0.057	0.060
	(0.033)	(0.033)	(0.046)	(0.047)	(0.052)	(0.053)
saveintention	0.066†	0.061†	0.096†	0.088†	0.068	0.058
	(0.035)	(0.035)	(0.052)	(0.053)	(0.061)	(0.062)
examDutch*male1		-0.035*		-0.072**		-0.058*
		(0.018)		(0.026)		(0.028)
Constant	-1.260†	-2.143**	-1.060	-3.071*	-1.150	-2.585†
	(0.653)	(0.817)	(0.897)	(1.201)	(1.041)	(1.336)
Observations	585	585	320	320	318	318
Pseudo R^2	0.10	0.10	0.17	0.19	0.40	0.41

Note: Coefficients with standard errors in parentheses, † $p<0.1$; *$p<0.05$; **$p<0.01$; ***$p<0.001$. Probit models. (2), (4), and (6) show models with an interaction term *examDutchprf* × *male1*. *Riskaverse* (1=disagree completely, 9=totally agree): I think it is more important to have safe investments and guaranteed returns than to take risks to have a chance to get the highest possible returns. *Selfcontrol* (1=disagree completely, 9=totally agree): I am a highly disciplined person and stick to what I planned to do. *Patience* (1=disagree completely, 9=totally agree): I am willing to sacrifice my well-being in the present to achieve certain goals in the future. *Liveforpresent* (1=disagree completely, 9=totally agree): I live for the present and don't think about my financial future. *Savintention* (*1=I immediately spend all my money, 9=I want to save as much as possible*): Suppose you have money that remains after having paid for food, rent, and other fixed or necessary expenditures, what would you do with the money?

In short, Dutch proficiency did not display a robust effect on males' employment, whereas females with higher Dutch proficiency had higher employment probabilities in both 2016 and 2021. The average marginal effects (AME) were that an increase of 1 correct word in the Dutch placement test predicted an increase of 0.014 (2016), 0.020 (2021) and 0.011 (21_ctrl16) in the probability of having a job for females. (Table 1).

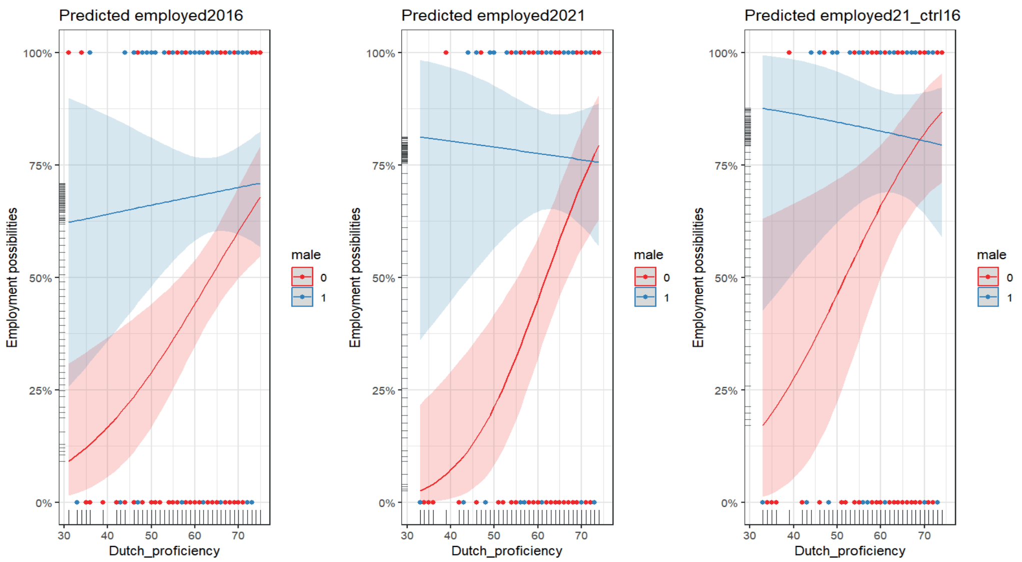


Fig 4. Dutch proficiency and employment in 2016 and 2021. (Shaded areas are 95% confidence interval bands).

Monthly net income

As shown in Table 2, *exam_Dutchprf* positively correlates with monthly net income in 2016 (β=.04, p=.0079), keeping gender[1] (β=1.42, p<.001), generation (β=0.50, p=.015), education (β=0.68, p=.0011), partner status (β=1.13, p<.001), number of children (β=0.18, p=.053), IQ (p=.91) and age (p=.58) constant. However, *exam_Dutchprf* significantly interacted with gender (β=-0.08, p=.007), revealing that examined Dutch proficiency only predicted female (p<.0001) participants' concurrent income in 2016, controlling for other variables. The AME (equals β) of *exam_Dutchprf* for females was 0.081, meaning that an increase of one correct word in the Dutch placement test was associated with an increase of income by 8.1% (visualisation in Figure 5). Furthermore, *exam_Dutchprf* still predicted female's net income in 2021 (p=.002, AME=.070), but when the concurrent 2016 income (p<.001) was additionally controlled for, the effect of Dutch proficiency became only marginally significant (p=.089, AME= 0.29). For males, *exam_Dutchprf* was not significant in 2016 or 2021 (p values>.78) (see details in Table 2).

[1] Females in the Netherlands often have a part time job, which may lead to a lower income than males.

Table 2. Examined Dutch proficiency and net monthly income in 2016, 2021, and 2021 controlling for baseline conditions and net monthly income in 2016.

	Logincome16		Logincome21		Logincome16 (excl 0)	Logincome21 (excl 0)	
	2016a	*2016b*	*2021*	*21_ctrl16*	*2016*	*2021*	*21_ctrl16*
logincome16				0.614***			0.708***
				(0.034)			(0.034)
examDutch	0.044**	0.081***	0.070**	0.029†	0.019**	0.021***	0.010*
	(0.016)	(0.021)	(0.022)	(0.017)	(0.006)	(0.006)	(0.004)
male1	1.420***	6.604***	5.540*	1.831	0.928†	1.669**	1.137**
	(0.194)	(1.925)	(2.190)	(1.667)	(0.505)	(0.571)	(0.386)
gene2	0.500*	0.495*	0.419†		0.079	0.122*	0.053
	(0.205)	(0.204)	(0.228)		(0.051)	(0.058)	(0.039)
IQ	0.012	0.023	-0.002	0.018	0.051*	0.088**	0.050**
	(0.098)	(0.097)	(0.109)	(0.084)	(0.024)	(0.028)	(0.019)
highedu1	0.683**	0.695***	0.749**	0.276	0.383***	0.353***	0.071†
	(0.208)	(0.207)	(0.233)	(0.178)	(0.052)	(0.060)	(0.043)
age	0.005	0.004	-0.007	-0.008	0.003	-0.004	-0.004*
	(0.009)	(0.009)	(0.010)	(0.007)	(0.002)	(0.003)	(0.002)
childrenum	0.178†	0.183*	-0.013	-0.120	0.059*	0.034	-0.018
	(0.092)	(0.091)	(0.100)	(0.076)	(0.024)	(0.027)	(0.018)
partnerNo	1.127***	1.109***	0.800***	0.182	0.065	0.051	-0.061
	(0.211)	(0.210)	(0.239)	(0.184)	(0.053)	(0.061)	(0.042)
riskaverse	-0.060	-0.061	-0.074	-0.058	-0.013	-0.017	-0.009
	(0.054)	(0.053)	(0.059)	(0.045)	(0.013)	(0.015)	(0.010)
liveforpresent	-0.007	-0.008	-0.058	-0.044	-0.011	-0.026*	-0.010
	(0.045)	(0.045)	(0.049)	(0.037)	(0.011)	(0.012)	(0.009)
patience	0.013	0.009	0.047	0.048	0.008	0.005	-0.004
	(0.046)	(0.045)	(0.050)	(0.038)	(0.011)	(0.013)	(0.008)
selfcontrol	-0.029	-0.025	-0.023	0.002	0.006	0.003	0.008
	(0.057)	(0.056)	(0.064)	(0.048)	(0.014)	(0.016)	(0.011)
saveintention	-0.048	-0.065	-0.099	-0.059	0.009	-0.025	-0.022†
	(0.058)	(0.058)	(0.066)	(0.050)	(0.015)	(0.017)	(0.012)
examDutch*male1		-0.079**	-0.065†	-0.023	-0.009	-0.019*	-0.015*
		(0.029)	(0.033)	(0.025)	(0.008)	(0.009)	(0.006)
Constant	2.296*	-0.007	2.366	1.710	5.383***	5.914***	1.877***
	(1.118)	(1.400)	(1.472)	(1.109)	(0.392)	(0.399)	(0.344)
Observations	590	590	424	418	513	379	352
Adjusted R^2	0.156	0.166	0.160	0.531	0.226	0.300	0.686

Note: Coefficients with standard errors in parentheses, † p<0.1; * p<0.05; ** p<0.01; *** p<0.001. OLS regressions.

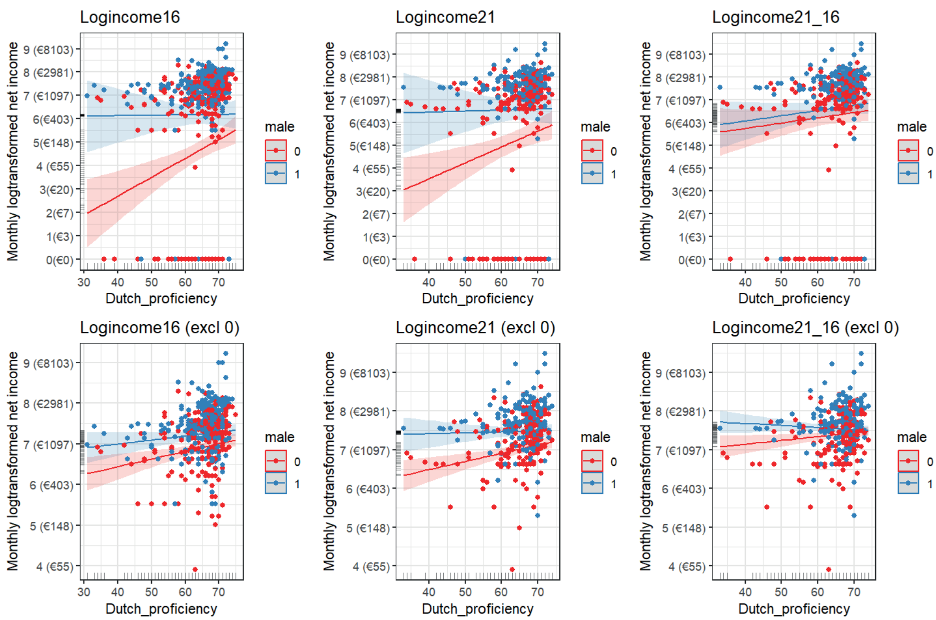


Figure 5. Dutch proficiency and monthly net income in 2016, 2021 and 2021 while controlling for baseline conditions and net monthly income in 2016.

However, note that Dutch citizens, regardless of employment status, always have income due to the social security system. Thus to reduce noise in data, it is more informative to focus on those who reported to have non-zero income. Results showed that, *exam_Dutchpf* significantly related to participants' income in 2016 (p=.0013, AME=0.014). The effect for female (p=.0017, AME=.019) appeared to be larger than for male (p=.082, AME=.01), but there was no significant interaction between gender and Dutch proficiency (β=-0.009, p=.23). Furthermore, *exam_Dutchpf* still predicted female's income in 2021 (p<.001, AME=.021) and in 2021_ctrl 2016 (p=.029, AME=.01), but did not predict male's (all p values > 0.24). This was also confirmed by a significant interaction between gender and Dutch proficiency in 2021 (p=.032) and in 21_ctrl16 (p=.011).

Hourly wage

Table 3 shows that, controlling for the significant influence of education (p<.001), age (p=.001), self-control (p=.01) and other factors, the examined Dutch proficiency positively correlated with participants' hourly wage in 2016 (p=.007, AME=0.01) and 2021 (p=.032, AME=.011), but became insignificant (p=.45) when the hourly wage in 2016 (p<.001) was additionally controlled for. There was no significant interaction between gender and Dutch proficiency (p values>.64). This indicated that Dutch proficiency predicted current and future contract hourly wage.

Table 3. Examined Dutch proficiency and hourly wages (contract and actual) in 2016, 2021, and 2021 controlling for 2016.

	Loghwage16 (contract)	Loghwage21 (contract)		Loghwage16 (actual)	Loghwage21 (actual)	
	2016	*2021*	*21_ctrl16*	*2016*	*2021*	*21_ctrl16*
loghwage16(contract)			0.604***(0.059)			
loghwage16(actual)						0.503(0.075)***
examDutch	0.010**	0.011*	0.003	0.003	0.021**	0.014†
	(0.004)	(0.005)	(0.004)	(0.005)	(0.007)	(0.008)
male1	0.044	0.069	0.027	0.067	0.168*	0.192**
	(0.037)	(0.051)	(0.039)	(0.047)	(0.067)	(0.065)
IQ	0.015	0.010	0.002	0.005	0.036	0.042
	(0.019)	(0.027)	(0.021)	(0.024)	(0.034)	(0.034)
highedu1	0.228***	0.317***	0.223***	0.216***	0.259***	0.138†
	(0.040)	(0.055)	(0.045)	(0.049)	(0.070)	(0.074)
age	0.006**	0.004	0.001	0.008***	0.005	0.002
	(0.002)	(0.003)	(0.002)	(0.002)	(0.004)	(0.004)
childrenum	0.031†	0.037	0.031†	0.051*	-0.001	-0.012
	(0.018)	(0.024)	(0.018)	(0.023)	(0.032)	(0.031)
gene2	0.050	0.053	0.048	0.030	0.039	0.062
	(0.038)	(0.052)	(0.039)	(0.049)	(0.069)	(0.068)
partnerNee	0.037	0.121*	0.041	0.113*	0.137†	0.028
	(0.043)	(0.057)	(0.045)	(0.052)	(0.075)	(0.075)
riskaverse	0.009	-0.004	-0.016	0.015	-0.003	-0.013
	(0.010)	(0.015)	(0.011)	(0.013)	(0.019)	(0.019)
liveforpresent	-0.005	-0.007	-0.006	0.004	-0.011	-0.017
	(0.009)	(0.012)	(0.009)	(0.011)	(0.016)	(0.016)
patience	0.003	0.005	0.001	-0.003	0.022	0.039*
	(0.009)	(0.012)	(0.009)	(0.011)	(0.016)	(0.015)
selfcontrol	0.029**	0.014	-0.014	0.022	-0.029	-0.032
	(0.011)	(0.016)	(0.012)	(0.014)	(0.020)	(0.020)
saveintention	-0.010	-0.002	0.003	-0.013	-0.041†	-0.076**
	(0.013)	(0.020)	(0.016)	(0.016)	(0.024)	(0.026)
Constant	1.309***	1.613***	0.990**	1.600***	1.154*	0.832
	(0.247)	(0.354)	(0.299)	(0.357)	(0.489)	(0.550)
Observations	319	178	150	314	190	146
Adjusted R^2	0.192	0.213	0.562	0.104	0.196	0.395

Note: Coefficient with standard errors in the parentheses, † p<0.1; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. OLS regressions.

However, as for the actual hourly wage, *exam_Dutchpf* did not significantly relate to participants' concurrent situation in 2016 (p=.53), but significantly predicted it in 2021 (p=.0028). Although there was no significant interaction between gender and Dutch proficiency, the effect in 2021 was more pronounced in female (p<.002, AME=.03) than in male (p=.22, AME=.012). Interestingly, when the baseline of 2016 was additionally controlled for, Dutch proficiency became marginally significant (p=.085), which was mostly driven by male (p=.069, AME=.018). This shows that everything being equal, only male participants who had a higher examined Dutch proficiency in 2016 would have a higher actual hourly wage five years later than those who had lower examined Dutch proficiency (see visualisations in Figure 6).

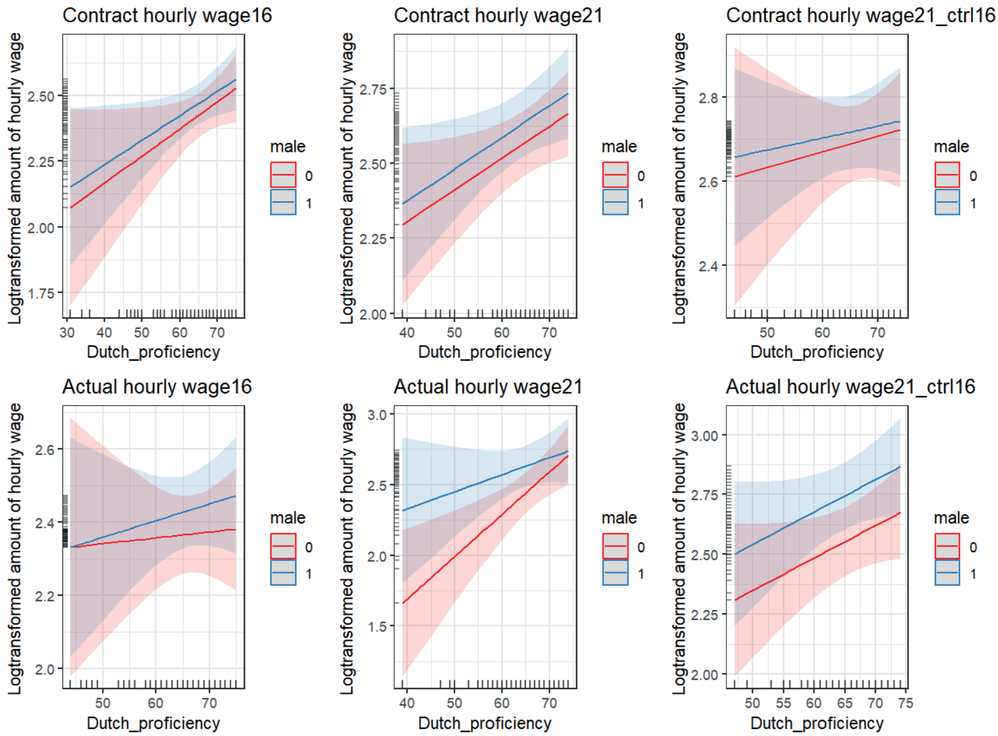


Figure 6. Dutch proficiency and hourly wage (contract and actual) in 2016, 2021 and 2021 while controlling for baseline conditions and hourly wage in 2016.

Savings and financial wealth

Regardless of generation and gender, Dutch proficiency was significantly related to immigrants' *saving2016* (p=.0012, AME=.10), controlling for the significant factors financial knowledge, education, saving intention, income (all p's<.01), TFI (p=.014), generation (p=.036) and other factors such as risk aversion, IQ, patience, self-control and demographic factors (Figure 7A, Table 4). However, in 2020 the effect of Dutch proficiency was only significant for the first generation 4 years later (p<.001, AME=.13) keeping other significant factors constant (column Saving20, Table 4).

Crucially, when the *saving2016* was additionally controlled for in the prediction of *saving2020*, most variables became insignificant. Exceptions were *saving2016* (p<.001), education (p=.055), TFI (p=.021), and an interaction of generation and examined Dutch proficiency (p=.038). These effects showed that although immigrants who had more savings in 2016, had a higher education, and were more future-focused would have more savings in 2020, examined Dutch proficiency predicted immigrants' future riskless savings beyond all these factors. The interaction term revealed that the effect of Dutch proficiency was only significant for the first generation (*p*=.007, AME=.09) but not for the second generation (*p*=.73) when predicting *saving2020*.

Similarly, for financial wealth, the results showed that immigrants' Dutch proficiency is significantly related to total assets in 2016 (*p*=.003, AME=.10) and 2020 (*p*<.001, AME=.14), controlling for financial literacy, TFI, income, generation, education, partner, saving intention, IQ, etc (Figure 7B). Again, Dutch proficiency remained significant (*p*=.037, AME=.066) after additionally controlling for the significant factor financial wealth in 2016 (*p*<.001). The effects of education (*p*=.037), TFI (*p*=.015) and financial knowledge (*p*=.076) were also (marginally) significant. Importantly, the positive effect of Dutch proficiency was beyond these significant factors. Furthermore, there was a significant interaction between Dutch proficiency and generation (*p*=.046), showing that Dutch proficiency was mainly significant for the first generation.

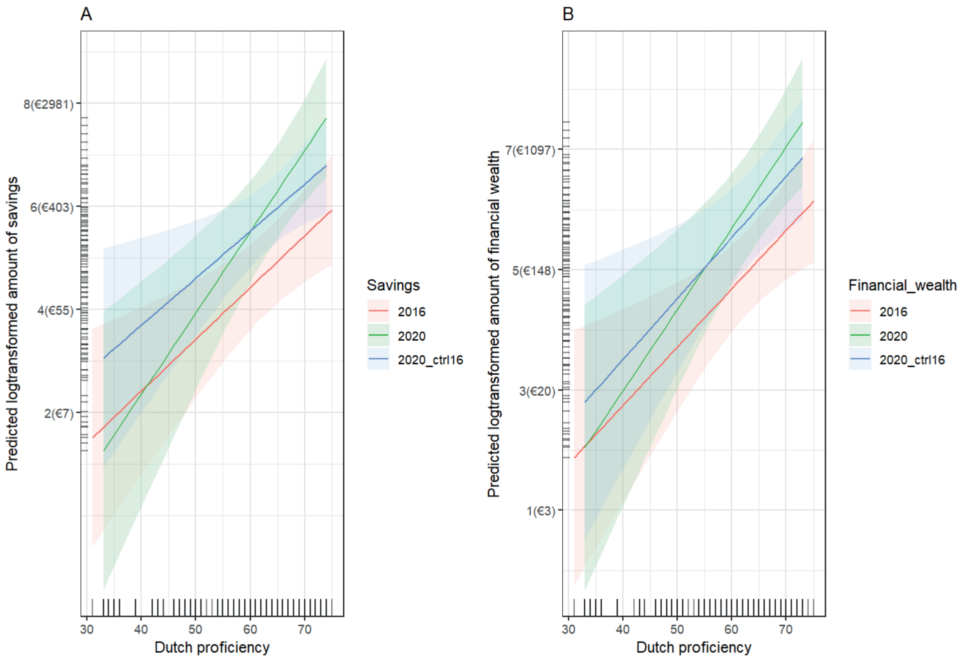


Figure 7. Immigrants' savings and financial wealth in 2016, 2020, and 2020 controlling for 2016, as a function of Dutch proficiency.

Table 4. Examined Dutch proficiency predicts savings and financial wealth (log-transformed) in 2016, 2020, and 2020 controlling for 2016.

Variables	Saving16	Saving20	Saving20_ctrl16	Finasset16	Finasset20	Finasset20_ctrl16
logsaving16			0.608***(0.053)			
logfinasset16						0.573***(0.055)
examDutch	0.101**	0.130***	0.091**	0.097**	0.135***	0.102**
	(0.031)	(0.035)	(0.034)	(0.032)	(0.036)	(0.036)
generation2	0.817*	1.149**	8.315*	0.843*	1.120*	8.882*
	(0.389)	(0.442)	(3.371)	(0.402)	(0.458)	(3.828)
highedu1	1.082**	0.985*	0.736†	1.253**	1.044*	0.862*
	(0.411)	(0.457)	(0.381)	(0.424)	(0.473)	(0.409)
riskaverse	0.111	0.078	-0.003	0.082	0.051	-0.026
	(0.103)	(0.110)	(0.093)	(0.106)	(0.113)	(0.099)
finanknowledge	0.790***	0.920***	0.364	0.841***	1.001***	0.424†
	(0.222)	(0.263)	(0.223)	(0.227)	(0.270)	(0.238)
patience	-0.038	-0.049	-0.081	-0.032	-0.035	-0.080
	(0.085)	(0.093)	(0.078)	(0.088)	(0.095)	(0.083)
selfcontrol	0.060	0.137	-0.002	0.014	0.109	0.018
	(0.107)	(0.119)	(0.099)	(0.110)	(0.122)	(0.106)
saveintention	0.370***	0.154	-0.016	0.405***	0.208	0.014
	(0.110)	(0.125)	(0.103)	(0.113)	(0.131)	(0.113)
liveforpresent	-0.138†	-0.203*	-0.038	-0.179*	-0.239*	-0.062
	(0.081)	(0.090)	(0.075)	(0.084)	(0.092)	(0.081)
age	-0.004	0.011	0.003	0.007	0.017	0.007
	(0.017)	(0.019)	(0.016)	(0.017)	(0.020)	(0.017)
IQ	0.190	-0.070	-0.115	0.124	-0.059	-0.057
	(0.195)	(0.214)	(0.181)	(0.201)	(0.222)	(0.196)
male1	0.206	-0.028	0.111	0.246	0.098	0.137
	(0.385)	(0.428)	(0.361)	(0.397)	(0.442)	(0.387)
tfi	2.548*	2.184*	2.134*	2.664*	2.336*	2.440*
	(1.032)	(1.103)	(0.920)	(1.075)	(1.129)	(0.998)
childrenum	-0.241	-0.011	0.162	-0.258	0.043	0.179
	(0.167)	(0.188)	(0.153)	(0.172)	(0.195)	(0.166)
partnerNo	-0.739†	-1.349**	-0.536	-0.880*	-1.228**	-0.495
	(0.413)	(0.453)	(0.388)	(0.426)	(0.471)	(0.417)
logincome16	0.339***	0.265**	0.036	0.350***	0.242*	0.030
	(0.082)	(0.093)	(0.082)	(0.084)	(0.097)	(0.088)
Constant	-8.042***	-7.385**	-4.017†	-7.724***	-8.037***	-5.012*
	(2.005)	(2.311)	(2.160)	(2.072)	(2.387)	(2.316)
examDutch:gene2			-0.106*(0.051)			-0.116*(0.058)
Observations	368	274	223	360	268	213
Adjusted R^2	0.374	0.365	0.663	0.380	0.375	0.646

Note: Coefficients with SE in parentheses. ***p<.001, **p<.01, *p<.05, †p<.1. OLS estimates.

Sensitivity analysis

Self-assessed reading and speaking Dutch proficiency

We used self-assessed Dutch speaking and reading proficiency instead of the test result for robustness checks. First for labour market performance, the results were largely consistent but the predictions for employment (Dutch reading proficiency) and net monthly income (neither speaking nor reading Dutch), in 2021 were no longer significant controlling for the concurrent situation in 2016 (Table 5). The predictions of hourly wages were all insignificant except one that *readDutch* predicted females' actual hourly wage in five years.

Table 5. Using self-assessed read Dutch and speak Dutch proficiency as proficiency measurements to predict dependent variables 1. employment 2. net monthly income, 3. net monthly income excluding 0, 4. hourly wage (contract), 5. hourly wage (actual) 6. savings, and 7. financial wealth.

		readDutch16			**speakDutch16**		
Dependent variables		*Pooled*	*Female*	*Male*	*Pooled*	*Female*	*Male*
1. Employed	2016	0.24†	0.45*	0.003	0.23†	0.46**	-0.11
	2021	0.27	0.47†(*p*=.063)	0.046	0.55**	0.90***	0.06
	21_ctrl16	0.28	0.37	0.16	0.54**	0.80**	0.10
2. Net monthly Income	2016	0.90***	1.69***	0.09	0.54*	0.91**	0.09
	2021	0.69***	1.21***	0.10	0.66**	1.03**	0.17
	21_ctrl16	0.098	0.06	0.14	0.20	0.32	0.05
3. Net income (excl 0)	2016	0.40**	1.01***	0.04	0.34**	0.57**	0.18
	2021	0.29	0.73*	0.04	0.15	0.40	0.01
	21_ctrl16	0.16	0.41	0.03	0.07	0.25	-0.04
4. Hourly wage (contract)	2016	0.05	-0.09	0.11† (*p*=.06)	0.007	-0.53	0.06
	2021	0.019	0.01	0.02	-0.02	-0.08	0.01
	21_ctrl16	-0.04	-0.18†	0.001	-0.003	-0.08	0.03
5. Hourly wage (actual)	2016	0.08	0.04	0.10	0.01	0.03	-0.008
	2021	0.16†	0.38**	-0.046	0.07	0.20	-0.06
	21_ctrl16	-0.07	-0.03	-0.09	0.05	0.06	0.04
		Pooled	*1st gene*	*2nd gene*	*Pooled*	*1st gene*	*2nd gene*
6. Savings	2016	0.51	0.53	0.27	1.07**	0.89†	1.66*
	2020	1.48**	1.29*	3.3*	1.33**	1.01*	3.45**
	20_ctrl16	0.90*	0.85*	1.53	0.60†	0.43	1.62†
7. Financial assets	2016	0.46	0.60	-0.72	0.96*	0.99*	0.86
	2020	1.65***	1.45**	3.55*	1.34**	0.99*	3.41**
	20_ctrl16	1.08**	0.96*	2.50†	0.75†	0.43	2.81**

Note: Numbers are coefficients. Results of female and male are obtained by adding an interaction term (examDutch × male) to the model. ***p<0.001, **p<0.01, *p<0.05, †p<0.1, Additionally, self-assessed reading and speaking Dutch showed a general influence of immigrants' Dutch proficiency on their concurrent and future savings and financial wealth. Exceptions were that reading Dutch was not significant for saving16, and speaking Dutch was only marginally significantly for saving2020 (*p*=.10) after controlling for savings in 2016. In short, the associations between Dutch proficiency and outcomes are robust, but the subjective reading and speaking Dutch scores are less likely to show significant effects.

Language effects controlling for length of stay or English proficiency

We examine whether the language effect we find is due to immigrants' different lengths of stay, as immigrants may simply have increased employment possibilities, higher income (e.g., Dustman, 1994), savings and wealth the longer their length of stay, through building a network and accumulating country specific human capital (though the fact we controlled for immigrants' generation can partially address this). We computed an independent variable *stay_length* for the first-generation immigrants by using their *age* minus the *age of arrival*. We did the robustness analysis for the first generation because the effect of *exam_Dutchpf* is mainly found in the first-generation and the length of stay of the second-generation immigrants is perfectly correlated with their *age*. Results show that the effect of *exam_Dutchpf* is robust for all dependent variables even after controlling for the length of stay, while *stay_length* itself is not significant in any model.

In addition, given that some studies show that immigrants' English language proficiency may help their labour market performance (e.g., Hahm & Gazzola, 2022; Muhawenayo, Habimana & Heshmati, 2022; Jiang & Lui, 2022, but also see a counterexample in Switzerland, Wong, 2022), we examined the effects of Dutch proficiency on dependent variables while additionally controlling for immigrants' English proficiency. We do not have any assessment from an English placement test but using a simple self-assessment as a proxy. Even if English proficiency is also found to be significant for some dependent variables (e.g., hourly wage), the effects of Dutch proficiency on all dependent variables still hold.

Estimation using instrumental variables

To account for the potential problem of endogeneity, we use 2SLS for linear models with instruments: max(0, age at arrival – 9) × a dummy for being born in a non-Dutch speaking country (e.g., Bleakley & Chin, 2004) and dummies for the language family. We use the same instruments for probit models when the dependent variable is binary.

Tables 6-7 show the results. The null hypothesis that the instruments are weak can be rejected if we are willing to tolerate a 5% or 10% relative bias of the 2SLS estimator, as the minimum eigenvalue statistics are larger than the 5% or 10 % 2SLS relative bias critical value according to the test of weak instruments. The overidentification test does not reject the validity of both types of instruments, as the p values of corresponding tests are all larger than 0.1.

The null hypothesis of the Durbin-Wu-Hausman test (a test of exogeneity of Dutch proficiency for linear model) and of the Wald test of exogeneity (for probit model) cannot be rejected (the p values of corresponding tests are all larger than 0.1), indicating that there is no significant evidence of an endogeneity problem in the analysis of employment status, hourly wages, riskless savings and financial wealth. This suggests that the results assuming exogeneity are consistent and efficient, and the effects of language proficiency on these dependent variables discussed above can be interpreted as causal effects.

As for income, the null hypotheses of the Durbin-Wu-Hausman test are rejected ($p < 0.05$), so there is endogeneity of Dutch proficiency ((b) and (c) of Table 6). The effect of language proficiency is still positively significant using 2SLS with two types of instruments. This suggests that there is a causal effect of Dutch proficiency on immigrants' income.

Table 6. Results of the first stage and second stage from the IV analysis of *ExamDutch* for labour market performance dependent variables *employment, income,* and *hourly wage*.

	(a) Employment			(b) Income			(c) Income excl. 0		(d) Hourly wage	
	1st stage	1st stage	2nd stage	1st stage	1st stage	2nd stage	1st stage	2nd stage	1st stage	2nd stage
Variables	examDutch	dutmale	employed16	examDutch	dutmale	income16	examDutch	income16	examDutch	hourlywage21
examDutch			0.0851**			0.296***		0.0417***		0.0351**
			(0.0264)			(0.0498)		(0.0115)		(0.0130)
dutmale			-0.0540			-0.174*				
			(0.0414)			(0.0728)				
male	-0.209	66.91***	3.963	-0.309	67.02***	12.79**	-0.387	0.331***	-0.761	0.183**
	(0.545)	(0.373)	(2.706)	(0.540)	(0.398)	(4.767)	(0.476)	(0.0507)	(0.628)	(0.0662)
gene2	0.832	0.302	0.0385	0.552	0.219	-0.207	0.560	-0.00310	-0.193	0.000869
	(0.559)	(0.383)	(0.149)	(0.552)	(0.407)	(0.264)	(0.563)	(0.0626)	(0.727)	(0.0722)
IQ	1.537***	0.664***	0.0183	1.607***	0.818***	-0.281*	1.642***	0.000158	0.657*	0.0234
	(0.221)	(0.151)	(0.0696)	(0.220)	(0.162)	(0.128)	(0.226)	(0.0309)	(0.316)	(0.0345)
highedu1	0.629	0.430	0.452***	0.776	0.669†	0.527*	1.465**	0.339***	0.982	0.245***
	(0.501)	(0.343)	(0.129)	(0.494)	(0.364)	(0.230)	(0.510)	(0.0561)	(0.660)	(0.0689)
age	0.0838***	0.0416**	-0.0191**	0.0988***	0.0478**	-0.00753	0.105***	-0.000305	0.127***	0.00459
	(0.0216)	(0.0148)	(0.00590)	(0.0207)	(0.0152)	(0.0106)	(0.0211)	(0.00252)	(0.0329)	(0.00376)
childrenum	-0.581**	-0.0377	0.0491	-0.537*	0.0187	0.252*	-0.496*	0.0568*	-0.397	-0.000489
	(0.218)	(0.149)	(0.0560)	(0.215)	(0.159)	(0.100)	(0.225)	(0.0244)	(0.291)	(0.0309)
married	0.471	-0.277	0.154	0.188	-0.241	-0.980***	0.371	0.0257	-1.160†	-0.117
	(0.512)	(0.351)	(0.130)	(0.507)	(0.373)	(0.233)	(0.526)	(0.0555)	(0.692)	(0.0731)
riskaverse	0.311*	0.124	-0.0414	0.342**	0.136	-0.125*	0.262*	-0.0207	0.419*	-0.00711
	(0.128)	(0.0875)	(0.0330)	(0.125)	(0.0921)	(0.0597)	(0.128)	(0.0139)	(0.172)	(0.0183)
liveforpresent	0.191†	0.0376	-0.0224	0.226*	0.107	-0.0538	0.298**	-0.0196	0.182	-0.0114
	(0.108)	(0.0736)	(0.0276)	(0.106)	(0.0781)	(0.0503)	(0.110)	(0.0122)	(0.146)	(0.0154)
patience	-0.121	-0.0886	-0.0149	-0.122	-0.0728	-0.000579	-0.177	0.0101	-0.0262	0.0205
	(0.108)	(0.0742)	(0.0273)	(0.107)	(0.0792)	(0.0496)	(0.111)	(0.0117)	(0.144)	(0.0152)
selfcontrol	0.0614	0.0287	-0.0216	0.0659	0.0876	-0.0255	0.00777	0.00419	0.240	-0.0319
	(0.134)	(0.0918)	(0.0333)	(0.133)	(0.0977)	(0.0615)	(0.137)	(0.0146)	(0.182)	(0.0194)
saveintention	0.242†	-0.00329	0.0442	0.253†	-0.0423	-0.114†	0.321*	0.00238	-0.147	-0.0329
	(0.140)	(0.0960)	(0.0363)	(0.136)	(0.1000)	(0.0648)	(0.139)	(0.0152)	(0.218)	(0.0232)
instru1	-0.198***	-0.0227		-0.0866	-0.0268		-0.137**		-0.236***	
	(0.0517)	(0.0354)		(0.0536)	(0.0395)		(0.0439)		(0.0587)	
Germbest	-0.106	0.0858		-1.886	-0.113		-2.173*		-0.437	
	(1.184)	(0.811)		(1.192)	(0.878)		(0.960)		(1.333)	
IEbest	-2.639*	0.544		-5.192***	0.394		-4.215***		-5.450***	
	(1.332)	(0.913)		(1.362)	(1.003)		(1.105)		(1.340)	
NIEbest	-5.864***	0.963		-7.943***	1.093		-4.897***		0.505	
	(1.518)	(1.039)		(1.562)	(1.151)		(1.090)		(1.512)	

instru1male	0.100	-0.0493		-0.0343	-0.0662					
	(0.0764)	(0.0523)		(0.0760)	(0.0560)					
Germbestmale	-1.366	-1.913		-0.609	-2.689*					
	(1.738)	(1.190)		(1.724)	(1.270)					
IEbestmale	-1.486	-5.229***		1.009	-4.952***					
	(1.863)	(1.276)		(1.879)	(1.385)					
NIEbestmale	1.793	-6.184***		4.090*	-6.142***					
	(1.984)	(1.358)		(2.001)	(1.475)					
Constant	54.94***	-4.370***	-4.454**	54.01***	-5.714***	-10.61***	53.67***	4.349***	57.49***	0.436
	(1.802)	(1.235)	(1.501)	(1.752)	(1.291)	(2.836)	(1.785)	(0.617)	(2.575)	(0.800)
Wald test, H0: $\beta_{\text{examDutch}} + \beta_{\text{dutmale}} = 0$						$\chi^2(1)$=3.39, Prob>chi2= 0.0656				
Wald test of exogeneity Ho: variables are exogenous	$\chi^2(2)$ = 3.62, Prob > chi2 = 0.1635									
Durbin-Wu-Hausman Test (tests of endogeneity) Ho: variables are exogenous				Durbin (score) $\chi^2(2)$ = 30.1284, p < 0.001; Wu-Hausman F(2,573) = 15.4174, p < 0.001			Durbin (score) $\chi^2(1)$ = 7.52605, p = 0.0061 Wu-Hausman F(1,498) = 7.41477, p = 0.0067		Durbin (score) $\chi^2(1)$ = 1.6071, p = 0.2049 Wu-Hausman F(1,175) = 1.49285, p = 0.2234	
Test of overidentifying restrictions: Ho: Instruments are valid	Amemiya-Lee-Newey minimum chi-sq statistic $\chi^2(6)$ = 4.68, p-value = 0.5855			Sargan (score) $\chi^2(6)$ = 3.85616, p = 0.6961; Basmann $\chi^2(6)$ = 3.74337, p = 0.7114			Sargan (score) $\chi^2(3)$ = 1.05878, p = 0.7870; Basmann $\chi^2(3)$ = 1.02581, p = 0.7950		Sargan (score) $\chi^2(3)$ = 3.31104, p = 0.3461; Basmann $\chi^2(3)$ = 3.06826, p = 0.3812	
Test of weak instruments Ho: Instruments are weak				Minimum eigenvalue statistic = 11.28 > 10% 2SLS relative bias critical value = 10.22			Minimum eigenvalue statistic = 21.3858 > 5% 2SLS relative bias critical value = 16.85		Minimum eigenvalue statistic = 16.5384 > 10% 2SLS relative bias critical value = 10.27	
Observations	585	585	585	590	590	590	513	513	190	190
R-squared	0.328	0.988		0.349	0.986	0.009	0.344	0.179	0.396	0.234

Note: (a) IVprobit and (b)-(d) 2SLS, using *instru1* (i.e., (0, age at arrival – 9) × a dummy for being born in a non-Dutch speaking country) and dummies for the language family (i.e., *Germbest*, *IEbest* and *NIEbest*) as instruments for *examDutch*, and using the interactions between *male* and instruments *instru1*, *Germbest*, *IEbest* and *NIEbest*) as instruments for *dutmale* which is the interaction between *examDutch* and *male*. Dependent variables are related to (a) employment, (b) income, (c) income excl. 0 (the observations whose income is 0 are excluded) and (d) hourly wage (i.e., the actual hourly wage in 2021). Standard errors in parentheses, ***p<0.001, **p<0.01, * p<0.05, † p<0.1.

Table 7. Results of the first stage and second stage from the IV analysis of *ExamDutch* for *savings and financial wealth* in 2016.

	(a) Savings		(b) Financial wealth	
	1st stage	2nd stage	1st stage	2nd stage
Variables	examDutch	saving16	examDutch	finasset16
examDutch		0.129#(0.0884)		0.174†(0.0918)
Male	-0.233	0.288	-0.326	0.360
	(0.637)	(0.381)	(0.644)	(0.398)
gene2	0.228	0.721#	0.311	0.621
	(0.737)	(0.445)	(0.742)	(0.466)
highedu1	0.430	1.137**	0.430	1.296**
	(0.677)	(0.404)	(0.682)	(0.419)
Riskaverse	-0.0441	0.128	-0.0143	0.101
	(0.169)	(0.101)	(0.169)	(0.104)
finacialknow	2.418***	0.744*	2.312***	0.684*
	(0.344)	(0.298)	(0.346)	(0.302)
Patience	-0.101	-0.0341	-0.0489	-0.0311
	(0.142)	(0.0838)	(0.143)	(0.0877)
Selfcontrol	0.0429	0.0629	0.0312	0.0159
	(0.176)	(0.105)	(0.177)	(0.109)
Saveintention	0.289#	0.365***	0.271#	0.388***
	(0.180)	(0.110)	(0.181)	(0.113)
Liveforpresent	0.305*	-0.150†	0.310*	-0.209*
	(0.132)	(0.0841)	(0.133)	(0.0872)
Age	0.127***	-0.00692	0.124***	-0.00348
	(0.0276)	(0.0197)	(0.0277)	(0.0203)
IQ	1.281***	0.173	1.270***	0.0500
	(0.311)	(0.218)	(0.314)	(0.226)
Tfi	2.120	2.365*	2.320	2.330*
	(1.697)	(1.042)	(1.726)	(1.099)
Childrenum	-0.419#	-0.149	-0.459†	-0.148
	(0.271)	(0.165)	(0.272)	(0.172)
Married	-0.678	0.220	-0.587	0.455
	(0.676)	(0.415)	(0.680)	(0.429)
Loginc	-0.0719	0.305***	-0.0563	0.314***
	(0.138)	(0.0812)	(0.138)	(0.0839)
instru1	-0.158***(0.0469)		-0.155**(0.0469)	
Germbest	-2.244†(1.144)		-2.223†(1.142)	
IEbest	-2.952*(1.226)		-2.954*(1.225)	
NIEbest	-2.889*(1.278)		-2.959*(1.277)	
Constant	50.56***(2.328)	-9.959*(4.385)	50.61***(2.347)	-12.04**(4.562)
Durbin-Wu-Hausman Test (tests of endogeneity) Ho: variables are exogenous	Durbin (score) $\chi^2(1)$ = .143222, p = 0.7051; Wu-Hausman F(1,350) = .136269, p = 0.7122		Durbin (score) $\chi^2(1)$ = .870111, p = 0.3509; Wu-Hausman F(1,342) = .828608, p = 0.3633	
Test of overidentifying restrictions: Ho: Instruments are valid	Sargan (score) $\chi^2(3)$ = 2.37954, p = 0.4975; Basmann $\chi^2(3)$ = 2.26486, p = 0.5193		Sargan (score) $\chi^2(3)$ = 2.5864, p = 0.4599; Basmann $\chi^2(3)$ = 2.46039, p = 0.4825	
Test of weak instruments Ho: Instruments are weak	Minimum eigenvalue statistic =11.57>10% 2SLS relative bias critical value=10.27		Minimum eigenvalue statistic=11.41 > 10% 2SLS relative bias critical value=10.27	
Observations	368	368	360	360
R-squared	0.454	0.395	0.449	0.391

Note: (a)-(b) 2SLS, using *instru1* (i.e., (0, age at arrival – 9) × a dummy for being born in a non-Dutch speaking country) and dummies for the language family (i.e., *Germbest*, *IEbest* and *NIEbest*) as instruments for *examDutch*. Dependent variables are related to (a) savings and (b) financial wealth. Standard errors in parentheses, *** p<0.001, ** p<0.01, * p<0.05, † p<0.1, # p<0.15

Examining Dutch proficiency using GAM model

It could be that Dutch proficiency and age may have a non-linear impact on labour market performance and financial wealth, so we built a GAM model by fitting the data of *exam_Dutchprf* and *age* each with a smoothed (non-linear) term. Results (Table 8) show that the effect of *exam_Dutchprf* on labour market participation, savings and financial wealth (Figures 8-9) are still robust. Interestingly, as shown in Figure 8, even having a low Dutch proficiency (exam score 30), immigrants still had about 25% of chance to be employed. For males, the employment probability improved up to about 75% if their examined Dutch score was 60, whereas for females, the employment probability did not improve much unless the examined Dutch score reached around 50. This threshold for females was also shown in their income. For example, females' income in 2021 levelled off for those who had an examined Dutch score below 50 but increased significantly for those who had a higher score than 50 (Figure 8B). Furthermore, when the score surpassed 50, immigrants' savings and financial wealth would improve significantly after 4 years (Figure 9).

Table 8. Relationship between *ExaminedDutch* and labour market participation, savings and financial wealth concurrently and in the future (using GAM model).

	Examined Dutch proficiency								
	2016			**2020/2021**			**2020/2021_ctrl2016**		
DVs	*Pooled*	*Female*	*Male*	*Pooled*	*Female*	*Male*	*Pooled*	*Female*	*Male*
1. Employed	5.157*	1.888**	2.503	1.635*	1.00***	2.38† (*p*=.07)	1.00† (*p*=.066)	1.00*	1.721
2. Net monthly Income	1.127*	1.821***	1.00	1.506*	2.010**	1.00	1.007	1.795† (*p*=.1)	1.001
3. Net monthly income (excl. 0)	1.662**	1.668**	1.00*	1.00**	1.123**	1.00	1.00	1.00*	1.00
4. Hourly wage (contract)	1.00**	1.62† (*p*=.099)	1.00*	1.13*	1.49	1.00†	.08	.078	7.1e-6
5.Hourly wage (actual)	1.00	1.00	1.00	1.429*	1.00**	1.00	0.74† (*p*=.050)	0.2	0.73† (*p*=.054)
	Pooled	*1st gene*	*2nd gene*	*Pooled*	*1st gene*	*2nd gene*	*Pooled*	*1st gene*	*2nd gene*
6. Savings	0.91**	0.88**	0.74† (*p*=.051)	1.64***	1.24***	1.07† (*p*=.07)	1.53*	1.54**	2.86e-4
7. Financial assets	0.905**	0.96**	0.49	1.87***	1.55***	1.11† (*p*=.058)	1.836**	1.842**	.0009

Note: Numbers estimated from generalized additive models are the effective degrees of freedom (edf), which are used as a proxy for the degree of non-linearity relationships. An edf of 1 is equivalent to a linear relationship, an edf > 1 and ≤ 2 is a weakly non-linear relationship, and an edf > 2 indicates a highly non-linear relationship (Zuur et al. 2009). Results of female and male are obtained by adding an interaction term (examDutch × male) to the model. ****p*<0.001, ***p*<0.01, **p*<0.05, †*p*<0.1.

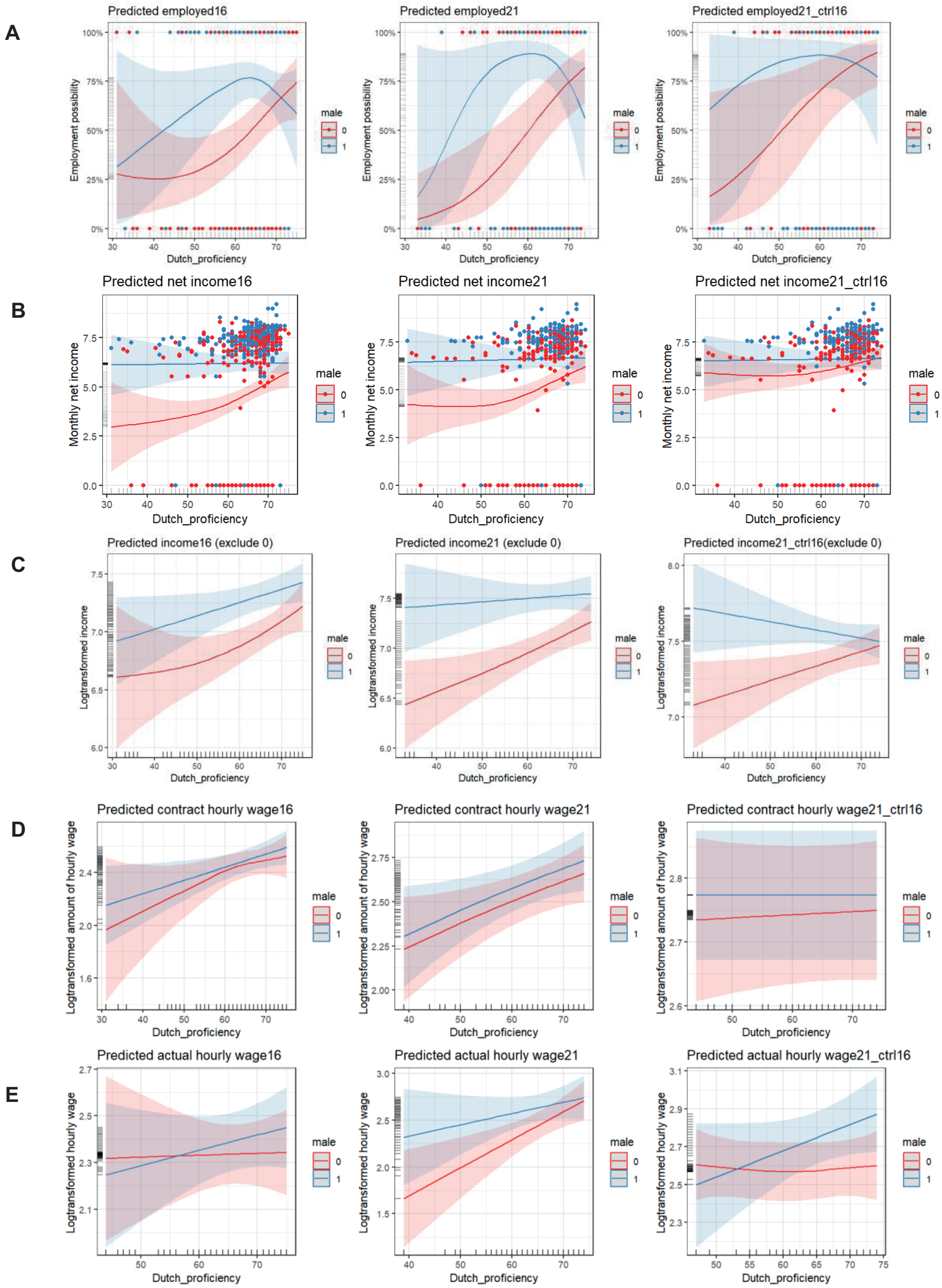


Figure 8. Examined Dutch proficiency and immigrants' (A) employment possibilities; (B) monthly net income; (C) monthly net income excluding 0; (D) contract hourly wage; (E) actual hourly wage in 2016, 2021 and 2021 while controlling for related factors and baseline conditions in 2016.

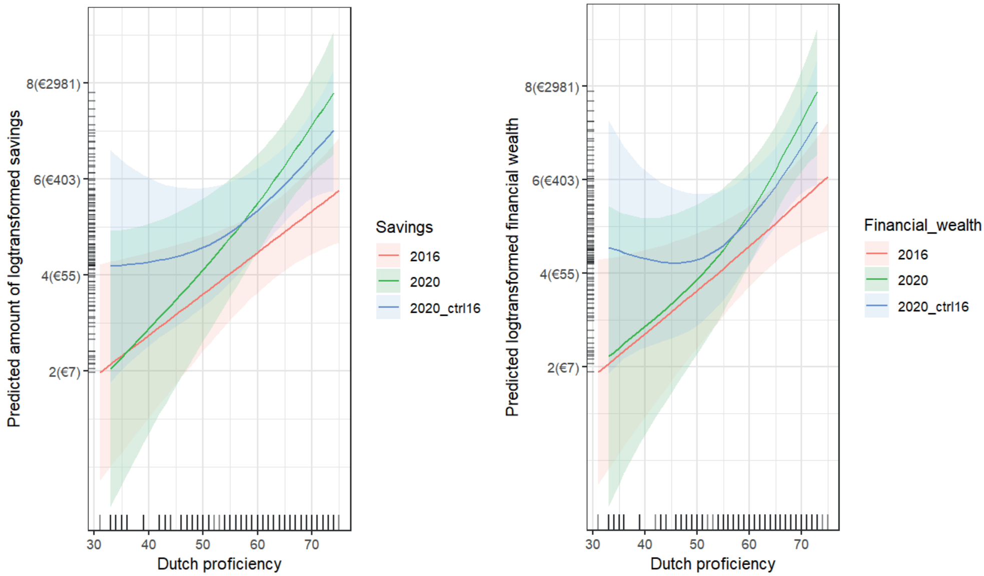


Figure 9. Immigrants' savings and financial wealth in 2016, 2020, and 2020 controlling for 2016 baseline as a function of examined Dutch proficiency (using GAM model).

Discussion

Based on surveys of Dutch immigrants, we analyse the effect of Dutch proficiency on immigrants' labour market outcomes, savings and financial wealth. We find that better Dutch proficiency predicts higher employment probabilities, higher net monthly income, and higher hourly wages, as well as more savings and financial assets both concurrently and in the future. Importantly, immigrants' Dutch language proficiency has a *causal* effect on all these aspects. Our results not only corroborate past findings of a language effect on immigrants' earnings, but also reveal that the effect of language proficiency may not be linear. Beyond such findings, we show that host-country language can persistently affect immigrants' savings and wealth in the short and long term. Such results have theoretical and policy implications across the fields of economics, linguistics, and sociology.

Past research suggests that language effects may be under- or overestimated, due to the endogeneity and measurement errors of proficiency, and thus sometimes the analysis of language effect is inconclusive (e.g., Dustmann & van Soest, 2001, 2002; Dustmann & Fabbri, 2003). In our study we have made improvements on solving both issues. First, we measured participants' IQ, patience, risk aversion, saving intention, temporal focus, financial knowledge, etc. to better capture immigrants' ability and personality in addition to controlling for standard individual characteristics. Second, instead of merely asking participants to rate their Dutch proficiency, we have conducted a Dutch placement test with all immigrant participants, which should significantly reduce measurement errors. Such improvements are also evident in the Hausman test, showing that there is no significant evidence of endogeneity of Dutch proficiency for most dependent variables (all except income). Strikingly, after such improvements, we still find a significant effect of language. In particular, to the best of our knowledge, we have shown for the first time that language proficiency can impact immigrants' savings and financial wealth concurrently and four years later. Note that in such predictions, important factors of IQ, income, financial knowledge, TFI, etc. have been controlled for, which means that the effect of language on savings and wealth may go beyond these factors and exert influence through some other unobserved aspects (e.g., cultural values and social networks affected by the linguistic advantages). Our study marks a new era in language and economics research, extending from studies on the effect of language on labour market success to more broadly based financial well-being.

This study also has crucial methodological implications in terms of measuring language proficiency in survey data. Although self-assessed language proficiency may provide some useful information, we provide empirical evidence that the self-assessment indeed underestimates the influence of language proficiency on labour market performance. For example, neither speaking Dutch nor reading Dutch is significant while the standard Dutch exam does reveal a significant effect for hourly wages. The insignificance in the self-assessed Dutch proficiency can be due to the subjective nature of the self-assessment, plus the cross-cultural and individual differences in responses to the same rating scales (Chen et al., 1995) creating additional noise. Deviating results between different Dutch proficiency measurements suggest that future studies should consider at least one standardized measurement of language proficiency (in addition to or instead of self-assessment). If we consider the effect of English proficiency apart from that of a host-country language, we had better conduct language proficiency tests of both the hosting language and English on immigrants. This will also further allow us to know the respectively role and a relative weight of each language contributing to the economics outcome.

Our results have implications for policymakers. First, as the effect of language proficiency is mostly observed in the first generation, the government should improve conditions for language learning and inform and target this immigrant group to motivate and improve their Dutch proficiency. Furthermore, based on results from self-assessed speaking and reading Dutch, the effect of language proficiency is more profound for reading. Language educators should also give more importance to reading proficiency in their instruction, as for a functional life in a foreign country immigrants need to be able to partake in literate life (online sources, forms, work literature, emails, etc.), for which they need vocabulary, including vocabulary not needed for daily informal spoken conversation. Especially, our results show that the effect of Dutch proficiency on earnings and financial wealth only becomes pronounced when immigrants' Dutch proficiency has reached a certain level (score about 50/75). The immigrant education office may consider increasing the difficulty level of the Dutch integration exam to motivate immigrants to improve their Dutch proficiency to at least an intermediate level. Furthermore, language proficiency seems to have a larger impact on females' earnings. Thus targeting females' linguistic ability particularly will help reduce the gender wage gap and improve gender equality.

One direction of future research is to consider the possible impact of the prestige of host-country languages. For example, English is an international language of prestige (Francis & Ryan, 1998). Native speakers of German who are proficient in English earn 13% higher in wages (Hahm & Gazzol, 2022). Interestingly, in Hong Kong, immigrants who are fluent in English and Mandarin rather than their native language Cantonese earn more (Jiang & Lui, 2022). However, a recent study in Switzerland shows that English is not as helpful as the host-country's languages in earning a higher wage. This seems to suggest that the effect of a host-country language can be related to global and regional contextual factors such as language policy of the region. Particularly, some countries have a bilingual or multilingual environment. For instance, Belgium uses both French and Dutch as official languages, whereas Switzerland has German, French, Italian, and Romansh. It is entirely unclear what independent and joint roles multiple official languages in a host country may play. As a first attempt, Zheng, Lin and Gu (2023) investigated whether Chinese Sign Language-Mandarin print bilingual deaf signers' language proficiency related to their occupational prestige and income. Surprisingly, results showed that only a higher sign language proficiency level but not Mandarin print proficiency predicted having a more prestigious job, and a higher sign language proficiency predicted a higher income. Therefore, the situation indeed becomes more complex when there are several languages. To gain a thorough understanding of the impact of language(s) on economic outcomes, we must consider the interaction of global language prestige and local contextual factors.

Appendix 1 Descriptive results of main variables

var	N	mean	sd	min	max	var	n	mean	sd	min	max
examDutchprf	641	65.29	6.69	31	75	logsav16	398	5.29	4.31	0	13.06
finaknowldge	644	2.12	1.06	0	3	logfinasset16	389	5.43	4.42	0	14.01
IQ	640	2.51	1.11	0	4	logsav20	290	6.46	4.14	0	13.3
highedu1	651	0.38	0.49	0	1	logfinasset20	284	6.52	4.27	0	14.18
retired	649	0.06	0.24	0	1	inc_unknown16	651	0.08	0.27	0	1
partner	651	1.39	0.49	1	2	loginc16	651	5.86	2.97	0	9.21
gene2	651	0.45	0.5	0	1	loginc21	465	6.17	2.9	0	9.47
male	651	0.47	0.5	0	1	inc_unknown21	465	0.08	0.27	0	1
age	651	45.37	11.81	25	66	speakDutch16	568	2.73	0.48	1	3
childrenum	651	0.86	1.11	0	4	readDutch16	568	2.81	0.43	1	3
married	651	0.48	0.5	0	1	employed16	634	0.65	0.48	0	1
riskaverse	642	6.12	1.93	1	9	employed21	630	0.64	0.48	0	1
selfcontrol	642	6.17	1.79	1	9	loghwagemaintot16	321	2.53	0.54	0	4.61
liveforpresent	649	4.45	2.22	1	9	loghwagemaintot21	197	2.71	0.63	0	4.62
saveintention	645	6.01	1.75	1	9	staylenth	651	34.84	15.04	1	65
aoa	651	10.53	13.12	0	52	patience	649	4.21	2.18	1	9
English	650	6.24	1.99	1	9	loghwagecontr16	323	2.57	0.46	0	4.36
Tfi	649	0.02	0.19	-0.8	0.78	loghwagecontr21	182	2.8	0.47	0	4.14

References

Angrist, J. D., Imbens, G. W., & Rubin, D. B. (1996). Identification of causal effects using instrumental variables. *Journal of the American Statistical Association*, *91*(434), 444-455.

Alderson, J. C. (2005). *Diagnosing foreign language proficiency: The interface between learning and assessment*. London: Continuum.

Bilker, W. B., Hansen, J. A., Brensinger, C. M., Richard, J., Gur, R. E., & Gur, R. C. (2012). Development of abbreviated nine-item forms of the Raven's standard progressive matrices test. *Assessment, 19*(3), 354-369.

Budría, S., Colino, A., & de Ibarreta, C. M. (2019). The impact of host language proficiency on employment outcomes among immigrants in Spain. *Empirica, 46*(4), 625-652.

Bleakley, H., & Chin, A. (2004). Language skills and earnings: Evidence from childhood immigrants. *Review of Economics and Statistics*, *86*(2), 481-496.

Chen, C., Lee, S. Y., & Stevenson, H. W. (1995). Response style and cross-cultural comparisons of rating scales among East Asian and North American students. *Psychological Science*, *6*(3), 170-175.

Chiswick, B.R., (1998). Hebrew language usage: determinants and effects on earnings among immigrants in Israel. *Journal of Population Economics*,*11*(2), 253–271.

Chiswick, B.R., & Miller, P.W., (1995). The endogeneity between language and earnings: international analyses. *Journal of Labor Economics*, *13*(2), 246–288.

De la Fuente, J., Santiago, J., Román, A., Dumitrache, C., & Casasanto, D. (2014). When you think about it, your past is in front of you: How culture shapes spatial conceptions of time. *Psychological Science, 25*, 1682-90.

Di Paolo, A., & Raymond, J. L. (2012). Language knowledge and earnings in Catalonia. *Journal of Applied Economics*, *15*(1), 89-118.

Dustmann, C. (1994). Speaking fluency, writing fluency and earnings of migrants. *Journal of Population Economics*, *7*(2), 133-156.

Dustmann, C., & Fabbri, F. (2003). Language proficiency and labour market performance of immigrants in the UK. *The Economic Journal*, *113*(489), 695-717.

Dustmann, C., & van Soest, A. (2001). Language fluency and earnings: Estimation with misclassified language indicators. *Review of Economics and Statistics*, *83*(4), 663-674.

Dustmann, C., & van Soest, A. (2002). Language and the earnings of immigrants. *ILR Review*, *55*(3), 473-492.

Francis, N., & Ryan, P. M. (1998). English as an international language of prestige: Conflicting cultural perspectives and shifting ethnolinguistic loyalties. *Anthropology & Education Quarterly, 29*(1), 25-43.

Hahm, S., & Gazzola, M. (2022). The value of foreign language skills in the German labor market. *Labour Economics, 76*, 102150. https://doi.org/10.1016/j.labeco.2022.102150

Isphording, I. E., & Otten, S. (2014). Linguistic barriers in the destination language acquisition of immigrants. *Journal of Economic Behavior & Organization*, *105*, 30-50.

Jiang, J., & Lui, H. K. (2022). Pursuing dreams in an Asian global city: Does host language proficiency matter for Asian minorities?. *Urban Studies*, 00. 1–19. https://doi.org/10.1177/0042098022109287

Johnson, J. S., & Newport, E. L. (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology*, *21*(1), 60-99.

Long, M. (2005). "Problems with supposed counter-evidence to the Critical Period Hypothesis", *IRAL*, *43*(4), 287-317.

Lusardi, A., & Mitchell, O. S. (2008). Planning and financial literacy: How do women fare? *American Economic Review*, *98*(2), 413–417.

Muhawenayo, J., Habimana, O., & Heshmati, A. (2022). Foreign language skills and labour market earnings in Rwanda. *Journal of Education and Work*, 1-16.

Mayberry, R. I., Lock, E., & Kazmi, H. (2002). Linguistic ability and early language exposure. *Nature*, *417*(6884), 38.

Miranda, A., & Zhu, Y. (2021). The effect of deficiency at English on female immigrants' wage in the UK: correcting for measurement error, endogenous treatment, and sample selection bias. *Applied Economics Letters*, *28*(5), 349-353.

Pieroni, L. d'Agostino, G., Lanari, D. & Scarlato, M. (2022): Immigrant labour market outcomes: new insights from a lack of language proficiency in Italy. MPRA Paper. https://mpra.ub.uni-muenchen.de/111991/

Raven, J.C. (1976) *Raven's standard progressive matrices test*. Texas, Harcourt Assessment.

Tam, K. W., & Page, L. (2016). Effects of language proficiency on labour, social and health outcomes of immigrants in Australia. *Economic Analysis and Policy*, *52*, 66-78.

Van Rooij, M. C., Lusardi, A., & Alessie, R. J. (2011b). Financial literacy and stock market participation. *Journal of Financial Economics*, *101*(2), 449-472.

Wong, L. (2022). The effect of linguistic proximity on the labour market outcomes of the asylum population. *Journal of Population Economics*, 1-44.

Yao, Y., & van Ours, J. C. (2015). Language skills and labor market performance of immigrants in the Netherlands. *Labour Economics*, *34*, 76-85.

Zheng, Y., Lin, H., & Gu, Y. (2023). The value of sign and print: Language proficiency predicts deaf signers' occupational prestige and income. *OSF Preprints*. https://doi.org/10.31219/osf.io/rn93w

Zuur, A.F., Ieno, E.N, Walker, N.J., Saveliev, A.A, & Smith, G.M. (2009) *Mixed effects models and extensions in ecology with R*. Springer-Verlag, New York.

Publication List

Zheng, Y., Gu, Y., & van Soest, A. (2023). Beyond financial knowledge and IQ: The effect of temporal values on pension planning and financial wealth of natives and immigrants in the Netherlands. *OSF Preprints*. https://doi.org/10.31219/osf.io/6cwk7

Zheng, Y., Gu, Y., & van Soest, A. (2023). Time to get attention: The effect of temporal focus on health, income and happiness. *OSF Preprints*. https://doi.org/10.31219/osf.io/7k4ct

Zheng, Y., Gu, Y., Backus, A., & van Soest, A. (2023). Host language proficiency has a causal effect on immigrants' income, savings and financial wealth. *OSF Preprints*. https://doi.org/10.31219/osf.io/qnfuv

Zheng, Y., Lin, H., & Gu, Y. (2023). The value of sign and print: Language proficiency predicts deaf signers' occupational prestige and income. *OSF Preprints*. https://doi.org/10.31219/osf.io/rn93w

Zheng, Y., Gu, Y., & van Soest, A. (2023). Who is taking drugs and what are the consequences?: Understanding influences of psychological and demographic factors on drug consumption and its impact on health, labour market performance and financial wealth. *OSF Preprints*. https://doi.org/10.31219/osf.io/phnyg

Zheng, Y., Gu, Y., Cozijn, R., & Swerts, M. (revision invited). Looking downward to the future: What eye movements reveal about Chinese people's conceptualisations of time. *Psychological Science*. https://osf.io/c3q5t/?view_only=c74d2cfff63243c38849d97be71b0582.

Gu, Y., Lin, H., & **Zheng, Y**. (in revision). Back to the future or the past? The effect of Chinese Sign Language (CSL) on deaf CSL-Mandarin bilinguals' spatial conceptualisation of time. *Journal of Memory and Language*. https://osf.io/y937u/?view_only=36f5136946b842f480bfb6e565034c7e.

Gu, Y., **Zheng, Y**., & Swerts, M. (2019). Which is in front of Chinese people, past or future? The effect of language and culture on temporal gestures and spatial conceptions of time. *Cognitive Science*, *43*(12), e12804. https://doi.org/10.1111/cogs.12804.

Gu, Y., **Zheng, Y**., & Swerts, M. (2019). Having a different pointing of view about the future: The effect of signs on co-speech gestures about time in Mandarin-CSL bimodal bilinguals. *Bilingualism: Language and Cognition*, *22*(4), 836-847. https://doi.org/10.1017/S1366728918000652

Curriculum Vitae

Yeqiu Zheng was born in Shandong (China) in 1989. She attended Shandong University (2007-2011) and obtained a bachelor's degree in Financial Engineering and a second bachelor's degree in English (minor). In 2011 she started a research master's programme in Finance at Shandong University. In 2012 she was awarded the Partner Scholarship between Tilburg University and Shandong University to exchange and study at Tilburg University, from which she obtained her master's degree in Quantitative Finance and Actuarial Science (Cum Laude) in 2013. Thanks to a full Koopmans Scholarship and a CentER Scholarship, she further earned a research master's degree in Economics (Cum Laude) at Tilburg University in 2015. In the same year she was awarded as the "Best Research Master Student" continuing on to PhD at the TiSEM and was awarded a grant from The Netherlands Organization for Scientific Research (NWO Research Talent) to do her PhD research in the Department of Econometrics and Operations Research, Tilburg University. In November 2015, she started her PhD project and this thesis is the main product of that research. Since September 2021, she has worked as a lecturer at the Business Information Management (BIM) section in the Department of Technology and Operations Management at the Rotterdam School of Management, Erasmus University.

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The present dissertation studies the effects of language and temporal focus on cognition, economic behaviour, and well-being. It mainly has three parts. In the first part, it investigates the direct relationship between language and temporal thinking as to whether users of different languages think about time differently. The results also show that, apart from linguistic influences, cultural and bodily experience can affect people's conceptualisation of time. In the second part, it studies the relationship between temporal thought and various economic behaviour (e.g., pension planning, retirement savings, labour market performance), a healthy lifestyle (e.g., diet, smoking, disease) and overall well-being (financial satisfaction, happiness, life expectancy, financial wealth, etc.). Thirdly, it shows how language itself can be viewed as a form of capital that has a direct causal effect on economic and financial outcomes.

The dissertation may be of interest to researchers working on applied econometrics, labour and health economics, aging, cognitive science, applied linguistics, and perception of time and well-being.

ISBN: 978 90 5668 704 5
DOI: 10.26116/ndbt-jr04

TILBURG SCHOOL OF ECONOMICS AND MANAGEMENT

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