Mechanisms of language processing in monolinguals and bilinguals: Prediction and production

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Declaration

I hereby declare:

(a) that this thesis is of my own composition, and
(b) that the work reported in this thesis has been carried out by myself, except where acknowledgement of the work of others is made in text, and
(c) that the work has not been submitted for any other degree or professional qualification except as specified in text, and
(d) that the included publications are my own composition.

The following chapters of this thesis are based on manuscripts that have been submitted to peer-reviewed journals:

Chapter 2: Yin, H., Sturt, P., & Pickering, M. J. (under review). How does speech rate affect prediction? *Quarterly Journal of Experimental Psychology*. Authorship details: Yin designed the study, ran the participants, analyzed the data, and wrote the original manuscript. Sturt and Pickering acted as supervisors, gave feedback on each of these steps, and contributed to the revision of the manuscript. The first experiment in this study originated from Yin's master thesis. As it was closely related to the other two experiments, it was included in this thesis for the sake of completeness.

Chapter 3: Yin, H., & Pickering, M. J. (under review). The role of semantics and phonology in bilingual picture naming: evidence from the phono-translation effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. Authorship details: Yin designed the study, ran the participants, analyzed the data, and wrote the original manuscript. Pickering acted as supervisor, gave feedback on each of these steps, and contributed to the revision of the manuscript.

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Huanhuan Yin

Abstract

For both monolinguals and bilinguals, language comprehension is not merely a bottom-up passive process of waiting for words, but also involves actively generating top-down predictions about what is likely to occur. For example, if a speaker says *It is raining outside, so you should take an* …, the listener may predict that the next word is likely *umbrella*. For bilinguals, this prediction process is made more complicated because they can conduct language processing in two languages. That is, they can activate both their first language (L1) and second language (L2) in parallel during comprehension and production. However, it remains unclear whether this cross-language activation, especially during bilingual production, occurs in one-language contexts (where only the target language is used). In addition, while substantial evidence shows that L1 speakers can predict many aspects of upcoming words and that L2 speakers do so less effectively, the cognitive mechanisms underlying prediction—such as whether it requires cognitive resources or whether bilinguals co-activate L1 during L2 prediction—remain poorly understood. Therefore, this thesis investigated the mechanisms of language processing in monolinguals and bilinguals, focusing on prediction and production. It first examined whether prediction is constrained by cognitive resources by having L1 Mandarin Chinese speakers listen to Mandarin Chinese sentences with varying speech rates and levels of contextual predictability (highly predictive, moderately predictive, or unpredictive of a final word). We measured how quickly participants judged whether a given letter was contained in that final word (Experiment 1), named a picture corresponding to that final word (Experiment 2), and named that final word (Experiment 3). We found that participants responded more slowly at a faster speech

rate, with greater effects in more than less predictable sentence contexts. These results suggested that a faster speech rate slows down prediction speed due to increased cognitive load, and that the detrimental effect of cognitive load is greater in more predictable contexts, where the prediction mechanism can be engaged to a larger extent. Overall, these results support the idea that prediction is cognitively demanding. Experiments 4 and 5 used a picture-word interference paradigm to investigate whether bilinguals activate their L1 during L2 production within a pure L2 context. We asked highly proficient Mandarin Chinese-English bilinguals (Experiment 4) and English native speakers who spoke no Mandarin (Experiment 5) to name pictures (e.g., *hat*, “mao zi” in Mandarin) in English while ignoring English auditory distractors that were phonologically related to the Mandarin translations of the picture names (*mouth*, phono-translation distractors). We found that both groups showed inhibition for semantically related distractors and facilitation for phonologically related distractors. Most importantly, Mandarin-English bilinguals were quicker to name pictures when just preceded by phono-translation distractors compared to unrelated distractors, but English native speakers were not. These findings suggest that information associated with words from the non-target language is activated even when that language is irrelevant to the task, but do not compete for selection. Experiments 6 and 7 directly tested whether bilinguals pre-activate L1 translations of predictable words during L2 comprehension and whether this depends on language contexts, using the visual-world paradigm. Specifically, Mandarin-English bilinguals listened to L2 English sentences containing a highly predictable word (e.g., *You should take an umbrella with you, because there will be heavy rain at three o'clock this afternoon*) while viewing a display containing a critical object and three distractors. We found that participants predictively fixated more on a competitor object whose Mandarin Chinese name was a homophone (e.g., feather [Mandarin: yu3]) of the Mandarin Chinese translation of the predictable word (e.g., rain [Mandarin: yu3]) than an unrelated object (e.g., *comb* [Mandarin: *shu*1]) when both languages were used (Experiment 7) but not when just English was used (Experiment 6). Our findings suggest that bilinguals predict across languages when both languages are contextually relevant but not otherwise.

Lay Summary

During language comprehension, both monolinguals and bilinguals actively predict what a speaker is going to say rather than passively waiting for the speech to unfold. For example, if a speaker says *It is raining outside, so you should take an …*, the listener may predict that the next word is likely *umbrella*. For bilinguals, this prediction process is more complex, as they can activate both their first language (L1) and second language (L2) during comprehension and production, though it is less clear whether this parallel activation persists when only one language is needed. Currently, the cognitive mechanisms underlying prediction—such as whether prediction is cognitively demanding or whether bilinguals activate L1 during L2 prediction—remain poorly understood. In this thesis, I first examined whether prediction is constrained by cognitive resources by having L1 Mandarin speakers listen to Mandarin sentences. I manipulated the speech rate and the predictability of the final word, and measured how quickly participants judged whether a given letter was contained in that final word, named a picture corresponding to that final word, and named that final word. Then I investigated whether bilinguals activate L1 during L2 production when only L2 was used. Mandarin-English bilinguals named pictures in English while ignoring English auditory distractors phonologically related to the Mandarin translations of the picture names. Finally, I examined whether bilinguals activate L1 translations of predictable words during L2 comprehension when both L1 and L2 were used and when only L2 was used by asking Mandarin-English bilinguals listen to English sentences containing a highly predictable word while viewing a display containing a critical object whose Mandarin Chinese name has the same pronunciation as the Mandarin translation of the predictable word.

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1. Introduction

1.1. Overview

For both monolinguals and bilinguals, language comprehension is not merely a bottom-up passive process of waiting for words, but also involves actively generating top-down predictions about what is likely to occur. For example, when hearing “It is raining heavily outside, so we should take an …”, they may predict that the speaker is going to say “umbrella”. For bilinguals, this prediction process is made more complicated because they can conduct language processing in two languages. There is good evidence that bilinguals at least sometimes process both their first language (L1) and second language (L2) in parallel during comprehension and production. However, it remains unclear whether this cross-language activation, especially during bilingual production, occurs in one-language contexts (where only the target language is used). In addition, while substantial evidence shows that L1 speakers can predict many aspects of upcoming words and that L2 speakers do so less effectively, the cognitive mechanisms underlying prediction—such as whether it requires cognitive resources or whether bilinguals co-activate L1 during L2 prediction—remain poorly understood. Therefore, this thesis investigates the mechanisms of language processing in monolinguals and bilinguals, focusing on prediction during comprehension and production.

In Chapter 2, I will examine whether predictive processing is constrained by cognitive resources. Specifically, I will investigate whether a fast speech rate (a natural factor likely to influence the cognitive resources available for prediction while also allowing for entrainment) affects listeners’ prediction speed. Additionally, I will explore whether this effect varies across contexts differing in contextual predictability. Importantly, I will distinguish between the effects of speech rate on prediction itself and its impact on bottom-up comprehension processes.

In Chapter 3, I will examine to what extent bilinguals activate information associated with the language that they are not currently using. Specifically, I will investigate whether highly proficient Chinese-English bilinguals activate their L1 Chinese when producing words in their L2 English in a one-language context where only L2 is used, using a picture-world interference paradigm. In addition, I will explore whether any effects suggesting online cross-language activation could have alternative explanations, such as a learning-based account.

In Chapter 4, I ask whether bilinguals predict in both languages, or restrict predictions to the one they are currently hearing? Also, do such predictions depend on whether or not they have recently encountered both languages? Specifically, I will investigate whether highly proficient Mandarin Chinese-English bilinguals pre-activate Chinese representations of predictable words during English comprehension in a one-language context where only English is used, and in a two-language context where both languages are contextually relevant.

The current chapter first provides an overview of findings showing prediction at different levels (semantic, syntactic, form) in L1 speakers (Section 1.2). It then reviews studies comparing predictive processing between L1 and L2 speakers, showing that L2 speakers predict more slowly and less effectively compared to L1 speakers (Section 1.3). Next, it reviews predominant prediction accounts (Section 1.4), based on which I point out possible reasons for the L1 and L2 prediction differences: (1) Prediction is cognitively demanding, and L2 speakers have fewer cognitive resources available for prediction than L1 speakers (Section 1.5), and (2)

L2 prediction is hindered by interference from L1 co-activation (Section 1.6). Specifically, Section 1.5 focuses on existing studies investigating whether prediction requires cognitive resources (Section 1.5.1) and the potential differences in cognitive resources available for prediction between L1 and L2 speakers (Section 1.5.2). In Section 1.6, I first review evidence that suggests parallel activation of L1 and L2 during bilingual comprehension (Section 1.6.1) and production (Section 1.6.2). After this, Section 1.7 reviews research suggesting L1 activation during L2 prediction at semantic level (Section 1.7.1), syntactic level (Section 1.7.2), and form level (Section 1.7.3).

1.2. Prediction at different levels in L1 speakers

For a long time, language comprehension has been regarded as a process where people incrementally integrate new information accessed from the word recognition with the established representation in a strictly bottom-up way (Gernsbacher, 1991; Kintsch & van Dijk, 1978).

A few decades later, however, more psycholinguists realize that language comprehension is not merely a bottom-up passive process of waiting for words, but also involves actively generating top-down predictions about what is likely to occur based on the preceding context (Dell & Chang, 2014; Huettig, 2015; Kuperberg & Jaeger, 2016; Pickering & Gambi, 2018). Prediction refers to the pre-activation of linguistic information related to the upcoming utterance before comprehenders encounter it in a bottom-up way. For example, people will generally guess the next word is “glasses” when presented with contexts such as “Her vision is terrible and she has to wear…” (Brothers & Kuperberg, 2021).

Such predictions have several clear benefits in facilitating people's comprehension. One such benefit is that it can help resolve ambiguity of linguistic input (e.g., *flour* vs. flower; *bin* and *bean* may be indistinguishable in noisy context), thereby reducing the processing burden, especially in adverse conditions. Another significant benefit is their contribution to short turn gaps in conversation. For example, the average gap between conversational turns is around 200 ms (Stivers et al., 2009), which is much shorter than the minimum 600 ms needed to name an isolated picture (Indefrey & Levelt, 2004). This suggests that listeners begin preparing their responses by predicting the speaker's upcoming utterance before the speaker finishes their turn, enabling smoother turn-taking in dialogue.

The ease at which to pre-activate representations of an upcoming word is affected by its predictability based on the context. The most common way of evaluating a word's predictability is to calculate its cloze probability, which is often operationalized as the proportion of people who fill a gap in a sentence with that specific word using a cloze task (Taylor, 1953). The more predictable a word is, the less processing difficulty it causes. For example, words predictable from the context are often read faster (Ehrlich & Rayner, 1981; Lowder et al., 2018; Rayner et al., 2004; Shain et al., 2024; Smith & Levy, 2013) and are more likely to be skipped (Rayner et al., 2011). In addition, Goldman-Eisler (1958) observed that speakers were more likely to pause when producing low probability words in a sentence completion task. Similarly, Staub et al. (2015) found that the response latency was shorter for higher probability words when participants produce a spoken continuation to a visually presented sentence fragment (see also Nebes & Boiler, 1983). Wlotko and Federmeier (2012) found that a word's cloze probability is inversely correlated with the associated N400 amplitudes, an index of integration difficulty during comprehension. Taken together, these studies suggest that the more predictable a word is, the greater it will be facilitated during processing.

When comprehenders make predictions about upcoming words, at which levels do these predictions occur? A substantial body of research demonstrates that L1 comprehenders can predict upcoming words at different linguistic levels: semantic, syntactic, and form. In the following sections, I review evidence supporting L1 prediction at these levels.

1.2.1. Semantic prediction

Evidence for semantic prediction in L1 speakers comes from studies using a variety of methods: the visual world paradigm, ERPs, and fMRI. For example, Altmann and Kamide (1999) recorded eye movements of L1 English speakers as they listened to English sentences (e.g., *The boy will eat the…*) while viewing a scene containing a target object (e.g., a cake) and three distractors (e.g., a balloon, a toy car, and a toy train). Participants looked at the edible object cake more than the distractors after hearing the verb *eat* but before the target word onset, suggesting that they predicted the semantic aspect (i.e., edible objects) of the upcoming word based on the verb *eat*. But note that the anticipatory looks toward the cake suggested that listeners predicted semantic features of the upcoming word that fit the context, rather than the specific concept of CAKE itself.

In an ERP study of Grisoni et al. (2017), L1 English speakers listened to high-constraint sentences ending with predictable hand-related (e.g., *I take the pen and I …write*) or face-related (e.g., *I take some grapes and I . . . eat*) verbs, as well as low-constraint contexts (e.g., *I do not take the pen and I ……write*) where the final verb was unpredictable. High-constraint contexts elicited readiness potential in sensorimotor cortex areas associated with the meaning of the predictable verbs 100 ms before the target verb onset: dorsolateral hand motor areas for hand-related words (e.g., *write*) and ventral motor cortex areas for face-related words (e.g., *eat*). In contrast, low-constraint contexts did not elicit such activity. This suggests that participants pre-activated semantic features of upcoming words following high-constraint contexts.

In another ERP study, Huang et al. (2023) had L1 Mandarin Chinese speakers read Chinese classifier-noun phrases in which a classifier precedes a noun and predicts its animacy features. EEG amplitude analysis revealed distinct neural patterns for animate versus inanimate nouns. More critically, before the target word onset, neural activity patterns following classifiers predicting animate nouns showed greater similarity compared to those predicting inanimate nouns. This suggests that participants pre-activated the semantic features of animate nouns, as animate nouns share more common features than inanimate ones.

In an fMRI study, Shao et al. (2022) had L1 Mandarin Chinese speakers listen to high-constraint Chinese contexts predicting either a tool-related noun (e.g., *hammer*) or a building-related noun (e.g., *florist's shop*) and weak-constraint contexts where the final word was unpredictable. In high-constraint contexts, enhanced activation was observed in the left anterior supramarginal gyrus for building-related nouns and their preceding verbs, while the left parahippocampal place area showed enhanced activation for tool-related nouns and their preceding verbs. This differential activation indicates that participants pre-activated semantic features of upcoming words belonging to different categories. Across all these studies, the effects associated with predictable words emerged before participants encountered them in a bottom-up way, providing clear evidence of semantic pre-activation for predictable words.

1.2.2. ***Syntactic prediction***

Evidence for syntactic prediction in L1 comprehension comes from studies using the visual world paradigm and ERPs. For example, in an ERP study, Wicha et al. (2004) asked L1 Spanish speakers to read high-constraint Spanish contexts (e.g., *Caperucita Roja cargaba la comida para su abuela en…* "Little Red Riding Hood carried the food for her grandmother in…") that continued with a gender-marked article (*una/un*) and a noun that was either highly expected (e.g., *canasta*, "basket") or unexpected (e.g., *corona*, "crown"). An enhanced positivity was observed at 500-700 ms after the onset of articles that did not match the gender of the following nouns, suggesting that comprehenders pre-activated the syntactic gender of the upcoming words.

Van Berkum et al. (2005) had L1 Dutch speakers listen to Dutch stories (e.g., *De inbreker had geen enkele moeite de geheime familiekluis te vinden. Deze bevond zich natuurlijk achter een…* "The burglar had no trouble locating the secret family safe. Of course, it was situated behind a . . .") ending with a predictable (*schilderij*$_{neuter}$, painting) noun. The noun was preceded by a gender-marked adjective that either matched (e.g., *groot*$_{neuter}$, big) or mismatched (e.g., *grote*$_{common}$, big) the gender of the predictable noun. ERPs showed that mismatched adjectives elicited a positivity 50-250 ms after the adjective compared to matched adjectives, suggesting that participants pre-activated the syntactic information of the predictable word. However, this effect was not replicated in Nieuwland et al. (2020).

In a visual world paradigm study, Arai and Keller (2013) had L1 English speakers listen to English sentences containing transitive verbs (e.g., *Surprisingly, the nun punished the artist*), intransitive verbs followed by a preposition (e.g., *Surprisingly, the nun disagreed with the artist*), or intransitive verbs followed by a conjunction "*and"* (e.g., *Surprisingly, the nun disagreed and the artist threw the kettle*), while viewing a display containing three objects (e.g., a nun, an artist, and a kettle). Participants showed more predictive looks toward the target object (artist) after hearing transitive verbs (e.g., *punish*) compared to intransitive verbs with a preposition (e.g., *disagree*), and more predictive looks after intransitive verbs with a preposition than those with a conjunction (e.g., *disagreed and*) before the target object was mentioned. These findings suggest that participants predicted the syntactic structure of the upcoming input using verb-specific information.

1.2.3. ***Form prediction***

Compared to semantic and syntactic prediction in L1 comprehension, there is also robust evidence for form prediction. In an ERP study, DeLong et al. (2005) had L1 English speakers read highly predictable sentences (e.g., *The day was breezy so the boy went outside to fly...*) that ended with either a predictable noun phrase (e.g., *a kite*) or an unpredictable one (e.g., *a plane*). Larger N400 amplitudes were observed not only for the unexpected noun "airplane" compared to the expected "kite", but also for the article "an" preceding "airplane*"* compared to "a" preceding "kite*"*. These findings suggest that participants pre-activated the form of predictable words, although this effect was not replicated in (Nieuwland et al., 2018).

Similarly, Ito et al. (2020) had L1 Italian speakers read high-constraint Italian sentences ending with either an expected noun preceded by a phonologically-matched article (e.g., *un*-Masculine *incidente*-Masculine; 'accident') or with an unexpected noun of a different gender, requiring an article that was phonologically mismatched with the expected noun but matched with the unexpected noun (e.g., *uno*-Masculine *scontro*-Masculine; 'collision'). Phonologically mismatched articles elicited greater negativity at left posterior channels between 250–800 ms compared to expected articles, suggesting that participants pre-activated the phonological information of the predictable words.

In a magnetoencephalography (MEG) study, Dikker et al. (2010) presented L1 English participants with contexts predicting either a noun category (e.g., *the tasteless* ___) or a verb participle category (e.g., *the tastelessly* ___), followed by a noun whose orthography was either typical (e.g., *soda*) or atypical (e.g., *infant*) of the noun category's visual form properties. Typical nouns elicited enhanced activity in the visual cortex between 100 and 130 ms after noun onset when presented in a verb-biasing context compared to a noun-biasing context, but no difference was observed for atypical nouns between these contexts. These findings suggest that participants predicted the syntactic category of the upcoming word based on context and, importantly, they pre-activated the typical visual form associated with the noun category[1].

More evidence for form prediction comes from studies using the visual world paradigm. Kukona (2020) had L1 English speakers listen to highly constraining English sentences (e.g., *In order to have a closer look, the dentist asked the man to open his* . . .) while viewing a visual display containing a target object (e.g., mouth),

[1] Although the effect in this study was found after the target word, it still occurred due to pre-activation of the target word rather than the integration, because this effect occurred after 100-130 ms following the target word but the visual word recognition process typically takes 130-150 ms (Carreiras et al., 2014; Sereno & Rayner, 2003), which excluded the integration possibility.

an object whose English name was phonologically similar to the target word (e.g., mouse), and two unrelated distractors (e.g., socks and bone). Participants fixated more on the phonological competitor than on the unrelated objects before hearing the target word, suggesting that L1 speakers pre-activate the phonological representation of predictable words. Similar findings have been reported in other studies using the same paradigm (Ito et al., 2018; Ito & Husband, 2017; Ito & Sakai, 2021; Li et al., 2022; Shen et al., 2021; Zhao et al., 2024; but see Ito & Husband, 2017; Ito & Sakai, 2021).

1.3. Prediction differences between L1 and L2 speakers

We can see from the above studies that L1 speakers can predict various aspects of upcoming words, but what about L2 speakers? Do they predict to the same extent as L1 speakers? Overall, there is good evidence that L2 speakers can predict, but do so more slowly and less effectively than L1 speakers.

1.3.1. ***Difference in time course***

A substantial body of evidence shows that L2 speakers generate predictions more slowly than their L1 counterparts (Chun & Kaan, 2019; Dijkgraaf et al., 2017, 2019; Ito et al., 2018; H. Kim & Grüter, 2021a; Koch et al., 2021; Lew-Williams & Fernald, 2010; Momenian et al., 2024). For example, Dijkgraaf et al. (2017) had Dutch-English bilinguals and L1 English speakers listen to either constraining (e.g., *Mary reads a letter*) or neutral (e.g., *Mary steals a letter*) English sentences while viewing a display containing four objects (e.g., car, letter, school bag, and wheelchair). Although both groups fixated more on a target object (e.g., letter) in constraining sentences before the target word onset, the predictive looks occurred later for L2 speakers. Chun and Kaan (2019) had Chinese-English bilinguals and L1

English speakers listen to English sentences containing a semantically biased or neutral verb (e.g., *I know the friend of the dancer that will open / get the present*) while viewing a visual display in which only one object can serve as a proper theme. Both L1 and L2 speakers showed predictive looks towards the target object in the semantically biased condition compared to the neutral condition, but L2 speakers' anticipatory looks began 180 ms later than those of L1 speakers.

1.3.2. ***Difference in prediction levels***

In addition to predicting more slowly, L2 speakers also make fewer predictions than L1 speakers, with syntactic (Hopp, 2015; Lew-Williams & Fernald, 2010; Mitsugi & Macwhinney, 2016; Molinaro et al., 2017) and form-level (Amos et al., 2022; Ito, et al., 2018; Martin et al., 2013) predictions often evident only in L1 speakers, not in L2 speakers.

In a visual world study, Lew-Williams and Fernald (2010) had L1 Spanish speakers and English-Spanish bilinguals listen to Spanish sentences containing an article-noun phrase (e.g., *Encuentra la pelota* "find the ball") while viewing a display containing two pictures whose names had either the same or different grammatical genders. L1 speakers quickly shifted their gaze to the target object after hearing gender-marked articles (e.g., *la*) when the pictures' names had different genders, while L2 learners did not show such predictive eye movements. This suggests that L2 speakers were less effective in using gender information from articles to predict the upcoming nouns.

In another VWP study, Hopp (2015) had L1 German speakers and English-German bilinguals listen to German sentences where case marking on determiners indicated whether the first noun was a subject (e.g., *Der Wolf tötet gleich den Hirsch*

"TheNOM wolf kills soon theACC deer") or an object (e.g., *Den Hasen frisst gleich der Fuchs* "TheACC hare eats soon theNOM fox"), allowing participants to predict the role of the second noun. Participants viewed a display containing objects corresponding to the first noun (e.g., the wolf), a potential agent (e.g., the hunter), a potential patient (e.g., the deer), and a distractor (e.g., the mountain). In sentences with a Subject-Verb-Object (SVO) order, L1 speakers fixated more on the patient than the agent after the verb but before the target word, while in Object-Verb-Subject (OVS) sentences, they fixated more on the agent. L2 learners, however, showed anticipatory looks toward the patient regardless of sentence type, suggesting that they failed to use morphosyntactic cues, such as case marking, for syntactic prediction.

Mitsugi and Macwhinney (2016) had L1 Japanese speakers and intermediate L2 learners listen to Japanese sentences with different word orders: canonical, scrambled, and accusative. In the canonical and scrambled orders, a sequence of nominative noun and dative noun indicates that an accusative noun is likely to follow, while in the accusative condition, a sequence of nominative noun and accusative noun indicates that a sentence-final verb is expected. Participants viewed a display containing an agent, a recipient, a theme, and a distractor. L1 Japanese speakers showed predictive looks toward the theme object in both canonical and scrambled conditions, but not in the accusative condition, while L2 learners did not show such predictive eye movements, suggesting that L2 learners were not able to use case-marking information to predict the upcoming syntactic structure as L1 speakers.

The clearest difference between L1 and L2 prediction appears to relate to form, as no study has found form prediction in L2 comprehension. For example, in an ERP study, Martin et al. (2013) had L1 English speakers and Spanish-English bilinguals read highly constraint English sentences (e.g., *He was very tired so he sat on ...*) with a predictable or unpredictable final noun, which were preceded by an article either congruent (e.g., *a chair*) or incongruent with the predictable noun (e.g., *an armchair*) (as in DeLong et al., 2005). L1 English speakers, but not L2 speakers, showed an increased N400 amplitude effect for articles incongruent with the predictable nouns, suggesting that unlike L1 speakers, L2 speakers did not pre-activate the phonological representation of predictable words. However, since the mean cloze probability of the expected nouns differed between L1 and L2 speakers, it remains unclear whether L2 speakers predict less than L1 speakers under comparable cloze probability conditions (see also Amos et al., 2022; Ito et al., 2018).

Together, the studies reviewed thus far demonstrate that L1 speakers can predict various aspects of upcoming words, whereas L2 speakers do so more slowly and to a less extent. What may account for these differences? To address this, we must first understand the mechanisms underlying prediction during comprehension. While L1 comprehenders can predict various aspects of upcoming words, this does not necessarily mean that predictions are always cost-free and ubiquitous. So, how do people predict upcoming words during comprehension? The following section reviews some dominant accounts of prediction during comprehension.

1.4. Prediction mechanism

Some researchers argue that prediction is integral to language comprehension, considering it a spontaneous computational process where comprehenders incrementally update their probabilistic beliefs about upcoming words at multiple levels of representation upon encountering new input (Dell &

Chang, 2014; Federmeier, 2007; Fitz & Chang, 2019; Kuperberg & Jaeger, 2016; Levy, 2008; Lupyan & Clark, 2015), while others consider it an optional process impeded by resources limitations (Chang et al., 2006; Dell & Chang, 2014; Federmeier, 2007; Huettig & Mani, 2016; Pickering & Gambi, 2018; Pickering & Garrod, 2013). Currently, this debate remains unresolved. Since resolving this debate is beyond the scope of this thesis, I will focus on the optional-based account, which is more directly relevant to my research.

One such optional-based account argues that people make predictions using their production system (e.g., Pickering & Gambi, 2018). To predict what a speaker is going to say, comprehenders first listen to the speakers' linguistic input and covertly imitate it, transforming comprehension representations into production representations. Based on these linguistic representations and nonlinguistic context (e.g., shared visual context and background knowledge), comprehenders derive the speaker's intention underlying the utterance. Then they run it through their production mechanisms and predict by reproducing the representations of the upcoming word in the order of semantics, syntax, and form, mirroring the actual word production process, except without overt articulation. The production-based accounts propose that making predictions through such a system is cognitively demanding, meaning that under time and resources constraints, comprehenders may predict only at lower levels (e.g., semantics and syntactics) but not at the level of form.

Prediction-by-production accounts have gained much empirical support. For example, in an ERP study, Martin et al. (2018) manipulated participants' production system availability by having them either produce a syllable, perform tongue tapping, or listen to a syllable while comprehending sentences containing expected or unexpected noun phrases. Unexpected articles before predictable nouns elicited larger N400 amplitudes compared to expected articles, but this effect was reduced when the production system was occupied, suggesting that prediction relies on the production system. Similarly, Lelonkiewicz et al. (2021) found that participants processed predictable words faster than unpredictable ones in high-constraint contexts, and importantly, this facilitation effect was stronger when participants read contexts aloud than silently, suggesting that involving the production system enhances prediction.

Rommers et al. (2020) presented participants with sentences word-by-word, and then had them read the sentence-final word either aloud or silently. Memory improvements from producing words were smaller for predictable words compared to unpredictable words, suggesting that prediction involves covert production processes per se. Neuroimaging studies also support the prediction-by-production accounts. In an ERP study, Gastaldon et al. (2020) found similar patterns of alpha and beta desynchronization in participants who listened to high-constraint contexts followed by either naming a picture (production) corresponding to a predictable word or simply listening to the predictable word (prediction). Together, these findings suggest that comprehenders engage their production systems to generate predictions.

1.5. The role of cognitive resources in predictive processing

In the previous section, I reviewed evidence supporting accounts that propose that comprehenders use their production systems to generate predictions, with prediction being an optional process in comprehension due to its cognitive resource demands. If prediction is indeed constrained by cognitive resources, a likely explanation for why L2 speakers predict less effectively than L1 speakers is their relatively limited cognitive resources available for prediction. In Section 1.5.1, I review existing studies investigating whether prediction is limited by cognitive resources and in Section 1.5.2, I review research suggesting potential differences in the cognitive resources available for prediction between L1 and L2 speakers.

1.5.1. ***Existing research on prediction and cognitive resources***

A wealth of studies has examined whether prediction relies on cognitive resources by investigating the correlation between individuals' working memory (WM) capacity and their predictive processing. Much evidence suggests that higher WM capacity is linked to stronger prediction effects (Huettig & Janse, 2016; Huettig & Mani, 2016; Li & Qu, 2024; Otten & Van Berkum, 2009). For instance, Otten and Van Berkum (2009) found that while Dutch speakers with both high- and low-WM capacities showed an early negative deflection (200-600 ms) to unexpected gender-marked determiners followed by a predictable word in high-constraint sentences, low-WM readers also showed a late negativity (900-1500 ms). This suggests that WM capacity influences how comprehenders process information inconsistent with their predictions. Li and Qu (2024) had L1 Chinese speakers listen to high-constraint Chinese sentences containing a predictable word (e.g., *放学了, 我把铅笔盒和本子装进了书包里准备 回家* "After school, I packed my pencil case and notebooks into my schoolbag and prepared to go home") while viewing a scene. Participants with higher WM capacity made earlier predictive looks toward a semantic competitor (e.g., *rubber*) than those with lower WM capacity, suggesting that greater WM capacity facilitates prediction.

There is also evidence suggesting that populations with fewer domain-general executive resources, such as children (Gambi et al., 2018; Mani & Huettig, 2012), older adults (Dave et al., 2018; Federmeier et al., 2010, 2010; Federmeier & Kutas, 2019; Wlotko & Federmeier, 2012) and L2 speakers (Lew-Williams & Fernald, 2010; Martin et al., 2013; Mitsugi & Macwhinney, 2016), have weaker predictive abilities compared to young adults.

Other studies have investigated the influence of cognitive resources on prediction by manipulating comprehenders' cognitive load. For example, Ito et al. (2018) had L1 and L2 English speakers listen to high-constraint sentences (e.g., *The lady will fold/find the* *scarf*) where the verb could predict one of four objects (e.g., *scarf*, *high heels*, *violin*, and *piano*) shown in a display. Both groups showed predictive looks toward the target object before hearing the target word. However, when participants were engaged in a concurrent word-remembering task, this predictive effect was delayed by 800 ms, suggesting that increased cognitive load impairs prediction (see also Schuckart et al., 2024).

Although these studies suggest that greater cognitive load impairs predictive processing, they all used a dual-task paradigm, where speech comprehension is performed concurrently with a secondary task. A limitation of this approach is that the observed effects may arise from attention shifts between the primary task and secondary tasks (Mattys et al., 2014; Mitterer & Mattys, 2017). In other words, impaired predictive processing could be due to divided attention (processing both prediction during comprehension and the secondary task) rather than a depletion of cognitive resources (a reduction in the mental capacity available to support prediction during comprehension).

One factor that can be naturally used to investigate the cognitive load effect on prediction is a fast speech rate. Some studies suggest that fast speech rates interfere with prediction. Wlotko and Federmeier (2015) had participants read two-sentence passages (e.g., *They wanted to make the hotel look more like a tropical resort. So along the driveway they planted rows of ...*), where the final word was predictable (e.g., *palms*), categorically related (e.g., *pines*), or unrelated (e.g., *tulips*). At a 500 ms SOA, categorically related words elicited reduced N400 amplitudes compared to unrelated words, but the effect diminished at a 250 ms SOA, suggesting that a faster presentation rate may disrupt prediction. However, this effect occurred after the final word was encountered, possibly reflecting ease of integration rather than prediction (see Pickering & Gambi, 2018).

In two experiments, Ito et al. (2016) had participants read high-constraint sentences (e.g., *Living alone is too expensive, so the students will share a ...*) followed by a predictable, semantically related, form-related, or unrelated word at 500 ms or 700 ms SOAs. At 700 ms SOA, reduced N400 effects were observed for both semantically related and form related words, whereas at 500 ms SOA, this effect was only found for semantically-related words. These findings suggest that comprehenders may predict less at a faster presentation rate. However, they may also suggest a faster presentation rate makes the integration of form-related words more difficult, rather than reducing prediction itself.

In a visual-world study, Huettig and Guerra (2019) had Dutch speakers preview a scene with a target object (e.g., a bicycle) and three distractors for a short or long time before listening to Dutch sentences spoken at a slow or normal rate (e.g., *Kijk naar de afgebeelde fiets* “Look at the displayed bicycle”). The gender of the determiner matched only the target object but not distractors, thus allowing prediction. Participants showed predictive looks to the target object at both speech rates after a long preview but only at the slow rate after a short preview, suggesting that a faster rate may impair prediction. However, since the target picture had a different gender from the other three pictures, participants might have figured out that it would be the target before hearing the determiner.

However, some studies suggest that fast speech rates may not impair prediction. Fernandez et al. (2020) had participants listen to short stories (e.g., *One day a wolf and a deer were sleeping near a cave. The wolf became crazed and the wolf attacked the deer. A hawk watched as the deer escaped*) followed by a "*wh*-movement" comprehension probe (*Point to who the wolf was attacking near the cave*) while viewing four objects (e.g, a wolf, a deer, a hawk, and a cave) mentioned in the story. They manipulated the speech rate (3.5, 4.5, 5.5, 6.0 syllables per second) of the stories and found that both young and older adults showed more anticipatory eye movements to the target object after encountering the verb at 4.5 than 3.5 syllables/second (Experiment 1). This finding suggests that as speech rate increases, speakers seem to become more able to use top-down syntactic information to predict upcoming information and form such "filler-gap" dependencies.

In another study, Kukona (2023) had participants listen to high-constraint sentences (e.g., *What the man will ride, which is shown on this page, is the bike*) while viewing a visual array (e.g., a bike and a kite), and asked them to use a mouse to select the referenced object. Participants moved their mouse cursor to the predictable object (the bike) before hearing it not only at a natural speech rate (~3 syllables/second) but also at faster rates (~6 and ~9 syllables/second). This suggests that comprehenders' prediction does not seem to be impaired at a faster pace.

Overall, existing findings on whether prediction requires cognitive resources are mixed, particularly in studies using speech rate to manipulate cognitive load. While some studies suggest that higher cognitive load impairs compreheners' prediction, others do not provide evidence that it affects prediction.

1.5.2. ***Greater cognitive load in L2 comprehension and production***

In contrast to the mixed findings on whether prediction demands cognitive resources, research has consistently shown that L2 speakers experience greater cognitive load than L1 speakers during both comprehension and production.

Language comprehension involves complex processes such as word recognition, meaning retrieval, syntactic parsing, and inference-making, all requiring cognitive resources (Caplan & Waters, 1999; In'nami et al., 2022; Just & Carpenter, 1992; Perfetti & Stafura, 2014). For L1 speakers, processes such as lexical access and syntactic parsing are largely automatic and resource-efficient. However, for L2 speakers, comprehension is more resource-intensive due to limited grammatical and lexical knowledge, leading to processing challenges (Morishima, 2013). For example, L2 learners often struggle with lexical access due to weaker lexical representations (Li & Clariana, 2019), have less efficient semantic searches (Ardila, 2003), encounter real-time syntactic processing difficulties (Roberts, 2007), and face challenges in constructing discourse-level representations (Horiba, 1996; Walter, 2004).

These difficulties are also evident in ERP studies. For instance, L2 learners typically show P600 responses to word category and case violations but lack the early left-lateralized anterior negativity (LAN) seen in L1 speakers (Clahsen & Felser, 2006; Hahne, 2001; Isel et al., 2000; Mueller et al., 2005). Since the P600 is often linked to controlled processes and the LAN to automatic ones (Friederici, 2002), these findings suggest reduced automaticity in semantic and syntactic processing of L2 speakers.

Similarly, language production also requires cognitive resources (Karimi et al., 2019), and higher WM capacity is associated with better language production performance (Abu-Rabia, 2003; Bergsleithner, 2010; Kim et al., 2021). Compared to L1 speakers, L2 speakers have weaker word-concept associations (Jiang, 2000), require more attentional resources to monitor speech (Kormos, 2000), and exhibit slower retrieval and less effective use of gender information (Grüter et al., 2012). An fMRI study by Liu et al. (2010) showed that during picture naming, L2 speakers activated the left inferior frontal gyrus and brain areas related to articulo-motor processing more than L1 speakers, suggesting greater cognitive demands in lexical retrieval and articulatory processing in L2 speakers.

The reduced efficiency in both comprehension and production for L2 speakers means these processes require more cognitive resources than they do for L1 speakers, limiting cognitive resources available for prediction and impairing it. For example, L2 speakers may be slower in extracting sentence meaning necessary for prediction or less effective in pre-activating lexical representations of predictable words through their production systems (Ito & Pickering, 2021). Thus, differences in prediction between L1 and L2 speakers may stem from the disparity in cognitive resources available for prediction, assuming prediction is indeed a cognitively demanding.

1.5.3. *Conclusion*

In sum, the evidence on whether prediction is constrained by cognitive resources remains inconclusive. While some indirect findings suggest that populations with greater WM capacity predict more effectively, consistent evidence is lacking on whether increased cognitive load during comprehension directly impairs prediction, especially under natural load manipulations such as faster speech rates. To explore whether L2 speakers predict less than L1 speakers due to less available cognitive resources, it is important to first establish whether prediction is impaired under greater cognitive load. Therefore, Experiments 1-3 in this thesis (Chapter 2) investigated how speech rate affects listeners' prediction speed across contexts of different predictability.

The following sections discuss another likely explanation for reduced prediction in L2 speakers: L1 co-activation during L2 prediction. In Section 1.6, I review evidence suggesting parallel activation of both languages during comprehension and production. In Section 1.7, I review evidence suggesting that L1 co-activation affects L2 prediction.

1.6. Parallel activation of L1 and L2 during bilingual comprehension and production

Compared to monolinguals, bilinguals manage two mental lexicons, and are constantly faced with the challenge of selecting words from the appropriate language. Extensive evidence suggests that words from both languages are activated in parallel during comprehension and production—a phenomenon known as non-selective lexical access. However, a substantial body of research has also shown that this non-selective access can be influenced by language context—whether participants have recently encountered only the target language word (one-language context) or both languages (two-language context).

The co-activation of L1 during L2 comprehension likely influences L2 predictive processing in two ways. First, L2 speakers may co-activate the L1 counterparts of L2 contextual segments (e.g., critical verbs or syntactically marked articles) that serve as predictive cues for upcoming words. Second, since prediction likely engages the production system (Pickering & Gambi, 2018), L2 speakers may pre-activate lexical representations of predictable words in both L1 and L2, similar to bilingual lexical activation in actual production. Next, I review studies on lexical access in bilingual comprehension (Section 1.6.1) and production (Section 1.6.2).

1.6.1. ***Parallel activation in bilingual comprehension and language context***

Evidence for parallel activation of L1 and L2 during comprehension mainly comes from studies on cognates, interlingual homograph / homophone, phoneme monitoring, interlingual orthographic neighbours, and translation equivalents.

1.6.1.1. Cognates

Cognates—words that share both form and meaning across languages—are processed faster than non-cognates in tasks such as L2 lexical decision (Dijkstra et al., 1998; Lemhöfer & Dijkstra, 2004; Schröter & Schroeder, 2015; Van Hell & Dijkstra, 2002) and progressive demasking (Dijkstra et al., 1999; Lemhöfer et al., 2008). The standard explanation for the cognate facilitation is that the target-language word activates its cognate in the non-target language, and this combined activation facilitates comprehension.

However, there are alternative explanations for cognate facilitation. For instance, cognates often contain higher-frequency syllables than non-cognates, because the shared syllables are activated whenever the cognate is used in either language (Costa et al., 2000; Gollan & Acenas, 2004). Thus, the cognate facilitation effect may not necessarily reflect non-specific lexical selection. Another explanation for the cognate effect is that bilinguals tend to learn cognates more effectively than non-cognates, hence making cognates more accessible (Costa et al., 2017; Mitchell et al., 2024; Sanahuja & Erdocia, 2024).

Critically, the cognate facilitation effect appears to be influenced by language context. For example, Titone et al. (2011) found that English-French bilinguals showed cognate facilitation in low- but not high-constraint L1 contexts. However, when L2 filler sentences were included (two-language context), cognate facilitation was observed for both low- and high-constraint sentences, suggesting that a two-language context increases cross-language activation. However, Dijkstra et al. (2015) found no effect of language context on cognate facilitation, reporting facilitation in a L2 lexical decision task, regardless of whether cognates were preceded by Dutch (two-language context) or English sentences (one-language context).

1.6.1.2. Interlingual homographs

Interlingual homographs—words that share form but not meaning across languages—are processed more slowly than non-homographs in lexical decision tasks (Dijkstra et al., 1998; Dijkstra et al., 2000; Lameira et al., 2023). For example, Dijkstra et al. (2000) observed slower responses to interlingual homographs when Dutch-English bilinguals were asked to press one button for English words and another for Dutch words, or when they responded to words in only one of the two languages. This suggests that readings of homographs in both languages are activated (see also Dijkstra et al., 1999).

Like cognate facilitation, interlingual homograph interference is affected by language context. For instance, in Dijkstra et al.'s (1998) English lexical decision task, there was no response time difference between interlingual homographs and English control words when only English words or nonwords that were orthographically legal in English were used (one-language context). However, when Dutch filler items were added (two-language context), response times for homographs were longer than for English control words, suggesting increased non-target language activation in a two-language context. Similarly, in a L2 lexical decision task, Dijkstra et al. (2000) observed response time difference between homographs and controls only after L1 words were introduced in the second half of the experiment. Likewise, in an English lexical decision task, Studnitz and Green (2002) found that proficient German-English bilinguals responded more slowly to interlingual homographs than to control words, but with greater interference when German words were included in the stimuli. In addition, when no German words were included, interference was smaller when participants were informed about the presence of interlingual homographs at the start of the experiment than when informed before the second phase.

Relatedly, Elston-Güttler et al. (2005) presented German-English bilinguals with English sentences (e.g., *The woman gave her friend an expensive gift*/item) ending with either an interlingual homograph (*gift*, meaning “poison” in German) or a control word (e.g., *item*), followed by target words corresponding to the L1 homograph meaning (e.g., *poison*) in an English lexical decision task. Participants who had viewed a German movie before the experiment responded faster and showed N200 and N400 modulations for homograph-related words compared to control words in the first block—an effect not observed for those who watched an English movie (see also Elston-Güttler & Gunter, 2009). These findings suggest that cross-language activation is influenced by language context.

But not all studies have found a language context effect on interlingual homograph interference. For example, De Bruijn et al. (2001) had Dutch-English bilinguals respond "yes" if all words in a triplet were valid in either English or Dutch, and "no" if any were non-words in either language. In critical trials, the first item was either an English word (e.g., *HOUSE*) or a Dutch word (e.g., *ZAAK*), followed by an interlingual homograph (e.g., *ANGEL*) and a third item related to the English homograph meaning (e.g., *HEAVEN*). Semantic priming effects occurred regardless of the language of the first item, suggesting that the English meaning of interlingual homographs was activated independently of language context.

1.6.1.3. Phoneme monitoring

Further evidence of cross-language activation comes from phoneme monitoring tasks. Colomé (2001) had Catalan-Spanish bilinguals judge whether a given phoneme was in the Catalan name of a picture. Participants were slower to reject a phoneme (e.g., /m/) present in the Spanish translation ("mesa") than one (e.g., /f/) absent from both the Catalan ("taula") and Spanish names ("mesa"). This led the authors to conclude that both languages were activated: if both the Catalan name "taula" and the Spanish name "mesa" are activated, /m/ is also activated, causing slower rejection than /f/. Conversely, if only the Catalan name were activated, no difference in rejection times would be expected.

However, the phoneme monitoring effect is also influenced by language context. Hermans et al. (2011) had Dutch-English bilinguals judge if a phoneme was in the English name of a picture. Participants were slower to reject phonemes from Dutch names than ones absent from both Dutch and English names when filler pictures with cognate names were included (two-language context), but this effect disappeared with non-cognate fillers (one-language context). This again suggests that language context affects cross-language activation.

1.6.1.4. Orthographic neighbourhood density

In progressive demasking and lexical decision tasks, Van Heuven et al. (1998) found that Dutch-English bilinguals responded slower to English words with more Dutch orthographic neighbours, but faster with more English neighbours. In contrast, L1 English speakers responded faster to words with more English neighbours but were unaffected by Dutch neighbours. This suggests that bilinguals activate words from both languages in parallel during L2 comprehension. This orthographic neighbourhood effect was replicated by Dirix et al. (2017) who showed that response times in L2 lexical decision tasks increased with more interlingual orthographic neighbours in L1(see also Midgley et al., 2008).

1.6.1.5. Cohort members

Evidence supporting non-selective lexical access also comes from studies involving lexical cohort members. In an eye-tracking study, Marian and Spivey (1999) had Russian-English bilinguals listen to instructions in either Russian or English (e.g., *Poloji marku nije krestika, "*Put the stamp below the cross*"*) while viewing a display containing a target object (e.g., *stamp*), a cross-language competitor whose name in the alternate language was phonologically overlapped with the name of the target object (e.g., *marker*), and two filler objects. Bilingual participants fixated more on the cross-language competitor than on filler objects, suggesting that the non-target language is co-activated. However, this study was conducted in a two-language context: participants were aware the experiment was about bilingualism and were tested by bilingual experimenters, and completed both Russian and English experimental sessions.

Using a similar paradigm, Marian & Spivey (2003) later tested Russian-English bilinguals in a strictly one-language context (i.e., only one language was used throughout the experiment; the experimenter was monolingual). Although participants still showed cross-language activation effects, the magnitude was smaller, suggesting that the language context modulates the extent of cross-language activation.

1.6.1.6. Unconscious Translation

A final key source of evidence for parallel activation of L1 and L2 comes from studies on the unconscious translation of L2 words into L1 during L2 comprehension. In an ERP experiment, Thierry and Wu (2007) had Chinese-English bilinguals judge the semantic relatedness of English word pairs, and found smaller N400 amplitudes for English word pairs (e.g., *train – ham*) whose Chinese translations (e.g., *huo che – huo tui*) shared a character compared to those whose Chinese translations did not. They interpreted these results in terms of unconscious activation of Chinese translations during English comprehension (see also Wu & Thierry, 2010; Zhang et al., 2011). In auditory word recognition, Wang et al. (2017) showed that Chinese-English bilinguals listening to English words (e.g., *rain, "*yu3*"* in Chinese) fixated more on a competitor object whose Chinese name was a homophone of the Chinese translation of the target word (e.g., *feather*, *"yu3"* in Chinese) than an unrelated object, suggesting cross-language activation. However, Costa et al. (2017) argued that these findings might reflect remnants of L2 learning rather than online cross-language activation.

The unconscious translation effect was also influenced by language context. Cheng and Howard (2008) presented Mandarin -Taiwanese bilinguals with pairs of Mandarin sentences that either both included code-switched Taiwanese words (two-language context) or were entirely in Mandarin (one-language context) and had them judge if two sentences were semantically synonymous in Mandarin. Participants showed a switch cost (i.e., slower to respond) for language-switching pairs when they believed that only Mandarin would be used in the experiment, but such switch cost disappeared when they expected that both Mandarin and Taiwanese would be involved in the experiment.

In an eye-tracking study, Olson (2017) had Spanish-English bilinguals read a target word in English following a context that was entirely in English, entirely in Spanish, or consisted of some English words followed by some Spanish words. Relative to the English-only context, participants had more difficulty with a context entirely in Spanish but did not have difficulty with the mixed language context, suggesting that the non-target language is activated to a larger extent in a two-language context than in a one-language context (see also Declerck & Grainger, 2017; Kheder & Kaan, 2019). In another eye-tracking study, Hoversten and Traxler (2020) had Spanish-English bilinguals read low-constraint English sentences (e.g., *We saw that his _ had a horrible scar*) containing a critical word in English (*hand*), Spanish (*mano*), or a pseudoword (*erva*). Eye movements revealed that overtly presented Spanish words (two-language context) caused early reading disruptions compared to English words, though less than pseudowords, suggesting that code-switched words were less accessible but not fully treated as pseudowords. However, when code-switched words were presented covertly using the gaze-contingent boundary paradigm (one-language context), they were processed like pseudowords (see also Hoversten & Martin, 2023), thus in a one-language context Spanish had the same status as nonwords – it was not activated.

In sum, there is much evidence to suggest that the bottom-up lexical access in language comprehension is non-selective but influenced by language context, as proposed by Bilingual Interactive Activation plus model (BIA +) (Dijkstra & Heuven, 2002) and localist-connectionist model (Multilink) (Dijkstra et al., 2019). These models distinguish between a bottom-up, language non-selective word identification system and a task/decision system, and assume that while the word identification system operates in a bottom-up, non-selective way, the decision system—guided by the non-linguistic factors such as instructions and task demands—modulates its output before a response is made.

1.6.2. ***Parallel activation in bilingual production and language context***

Evidence for parallel activation of L1 and L2 during production comes from studies on speech errors, cognates, the picture-word-interference effect, and switch costs.

1.6.2.1. Speech errors

In a corpus analysis, Poulisse and Bongaerts (1994) analysed spontaneous L2 speech by Dutch-English bilinguals and found frequent L1 intrusion errors, where L1 equivalents or parts of them were morphologically or phonologically bended with L2 words (e.g., *zit* for the intended English word *sit*). Similar intrusion errors have also been reported in bilinguals with Alzheimer's disease (Gollan et al., 2017). These findings suggest that parallel activation of two languages occurs very occasionally.

1.6.2.2. Cognates

As in comprehension, bilinguals produce cognates faster than non-cognates (Costa et al., 2000; Hoshino & Kroll, 2008; for review, see Costa et al., 2005). For instance, Costa et al. (2000) showed that Catalan-Spanish bilinguals named pictures with cognate names faster than non-cognates, with stronger facilitation effect in L2 than in L1, suggesting phonological activation in the non-target language.

But as in language comprehension, cognate facilitation in production is also influenced by language context. Li and Gollan (2021) had Spanish-English bilinguals name pictures in isolation, or pictures embedded in low-constraint Spanish and English sentences, replacing a target word. Participants named the pictures in either Spanish or English based on a cue. The switch costs were smaller for cognates than for non-cognates, suggesting that non-target language is co-activated. Importantly, switch costs were larger in sentence contexts compared to isolated picture naming. These results suggest that language context modulates cross-language activation.

1.6.2.3. Picture-word-interference paradigm

The picture-word-interference (PWI) paradigm provides further evidence for parallel activation of L1 and L2 during production. Hermans et al. (1998) had Dutch-English bilinguals name pictures (e.g., a mountain) in English while displaying distractors (e.g., *bench*) phonologically related to the Dutch translations of the picture names (phono-translation distractor). An interference effect was observed for phono-translation distractors compared to unrelated distractors when the distractors were in Dutch (two-language context), but no such effect was found when the distractors were in English (one-language context). This suggests that the non-target language is activated in a two-language context but not in a one-language context. Several more recent studies have used this paradigm to investigate bilingual lexical selection process. Some observed interference effects but they were also conducted in two-language contexts (Boukadi et al., 2015; Costa et al., 2003; Klaus et al., 2018). Other studies reported facilitation (Costa et al., 2008; Deravi, 2009; Goh & Chen, 2017; Hoshino et al., 2021), and still others found no significant effects (Boukadi et al., 2015; Goh & Chen, 2017; Hoshino et al., 2021; Klaus et al., 2018). In sum, the findings are mixed and sometimes contradictory, as discussed in more detail in Chapter 3.

1.6.2.4. Switch costs

Other evidence for cross-language activation in bilingual language production comes from studies showing switch costs. For example, Meuter and Allport (1999) had bilinguals name numerals in L1 or L2 based on a colour cue. Participants responded slower on switch trials (where the response language differed from the previous trial) compared to non-switch trials (where the response language was the same as the previous trial), and the switch costs were larger when switching from L2 to L1 than vice versa. This has been interpreted as evidence that both languages are activated during production and bilinguals use an inhibitory mechanism to suppress the activation and competition of the non-target language. Larger switch costs when switching to L1 are thought to result from the stronger inhibition required to supress the more dominant and highly activated L1 (Green, 1998). However, there are alternative explanations for these effects (Finkbeiner et al., 2006; Philipp et al., 2007), with some proposing that language switch costs may arise from task-switching rather than language switching (Philipp et al., 2007).

Language switch costs have also been observed in fMRI and ERP studies. For example, ERP studies have shown that the N2 component, associated with inhibitory control and occurring around 200 ms after stimulus onset, exhibits larger amplitudes for switch trials compared to non-switch trials (Jackson et al., 2001; Verhoef et al., 2010; Zheng et al., 2020). Additionally, the N400 component, which reflects lexical and semantic integration, shows greater amplitudes in switch trials, suggesting increased processing costs to lift inhibition of the previously used language (Pellikka et al., 2015). Furthermore, time-frequency analysis by Liu et al. (2017) revealed that bilinguals with low L2 proficiency but high inhibitory control showed larger theta rhythms (4-7 Hz), linked to inhibitory control, when switching to L1 compared to L2 in picture naming tasks.

Language switch costs in production are also influenced by language context. In an fMRI study, Abutalebi et al. (2008) had German-French bilinguals name pictures in a blocked paradigm, either entirely in L1 or L2 (one-language context) or randomly switching between L1 and L2 (two-language context). Naming pictures in L1 during the two-language context elicited greater activation in the left caudate and anterior cingulate cortex—areas associated with inhibition, compared to naming in L1 during the one-language context (see also Guo et al., 2011). This suggests that the non-target language is more strongly activated in a two-language context than in a one-language context.

In another cued picture naming study, Olson (2016) had bilinguals name pictures in a one-language context (95% of tokens in L1, 5% in L2 or 95% of tokens in L2, 5% in L1) and a two-language context (50% of tokens in L1, 50% in L2). Asymmetrical switch costs were observed in the one-language context but disappeared in the two-language context. This suggests that inhibition applied to the non-target language is more balanced in the two-language context, which implies that the non-target language is less strongly inhibited compared to the one-language context. Together, these findings suggest that the degree of activation of the non-target language varies based on the language context.

1.6.3. ***Conclusion***

The evidence reviewed in this section suggests that both L1 and L2 are activated in parallel during language comprehension and production when bilingual encounter words from both languages, supporting the notion of language non-selective lexical access. However, the degree of cross-language activation in bilingual language comprehension and production is likely context-sensitive. Grosjean (1998, 2001, 2008) argues that bilinguals' two languages are always somewhat activated, with specific activation levels depending on the language context. In a two-language context where both languages are required (bilingual mode), both languages are activated, while in a one-language context where only one language is needed (monolingual mode), primarily the target language is activated. Currently, it remains unclear whether this cross-language activation occurs in a one-language context. Therefore, Experiments 4-5 in this thesis (Chapter 3) investigates this issue in further detail, before further exploring cross-language activation in top-down prediction in Experiment 6-7 (Chapter 4). The following sections review evidence suggesting that bilinguals co-activate their L1 during L2 prediction.

1.7. Evidence on L1 co-activation during L2 prediction

The parallel activation of L1 and L2 during comprehension and production supports the possibility of L1 co-activation during L2 prediction, potentially explaining differences between L1 and L2 predictive processing. Indeed, much evidence suggests that bilinguals co-activate their L1 during L2 prediction. When the activated L1 counterparts completely overlap with their L2 equivalents, this co-activation can facilitate L2 prediction. Conversely, when L1 and L2 counterparts differ in semantic, syntactic, or form-related features, co-activation may interfere with L2 prediction. Section 1.7.1, Section 1.7.2, and Section 1.7.3 review evidence of L1 activation affecting L2 prediction at the semantic, syntactic, and form levels, respectively.

1.7.1. ***L1 activation affecting L2 semantic prediction***

Two studies suggest that L1 semantic activation interferes with L2 prediction. Using the visual-world paradigm, van Bergen and Flecken (2017) investigated whether German-Dutch and English / French-Dutch bilinguals could use L2 Dutch placement verbs to predict upcoming words. German and Dutch placement verbs specify its position (i.e., they distinguish "put into a standing position" from "put into a lying position"), while French and English verbs do not (i.e., they just have "put"). Participants listened to Dutch sentences (e.g., *de jongen zette kort geleden een bal op de tafel* "the boy put.stand recently a ball on the table") with placement verbs while viewing scenes with objects in various positions. L1 German speakers made predictive eye movements toward objects whose position was compatible with the verb, while L1 English and French speakers did not. This may suggest that L1

English and French speakers co-activated their L1 verbs, leading them to predict objects without considering their position.

Similarly, Ito et al. (2024a) had heritage speakers of Vietnamese in Germany listen to Vietnamese sentences (e.g., *Mai mặc một chiếc áo* "Mai wears a shirt"), where the constraints of Vietnamese verbs differ from their German equivalents (e.g., German *tragen* allows clothing and accessories as its objects, while Vietnamese *mặc* only allows clothing) while viewing a scene. After hearing the verb *mặc* but before the target noun, L2 speakers were distracted by objects (e.g., earrings) compatible with German verb constraints but not Vietnamese ones. This likely occurred because Vietnamese heritage speakers co-activated L1 German verbs (*tragen*), which interfered with L2 semantic prediction.

However, L1 activation can facilitate L2 semantic prediction when the activated L1 translation have complete semantic overlap with their L2 counterparts. In a VWP study, Ito et al. (2024b) had low- and high-proficient L1 Spanish learners of English listen to English sentences (e.g., *The girl will adopt a dog*) containing either cognate or non-cognate verbs that predicted target objects while viewing a scene with a target object and three distractors. Lower-proficient L1 Spanish group showed greater and faster predictive fixations towards target objects when the verbs were cognates than non-cognates. This finding suggests L1 activation of cognate verbs facilitated L2 prediction.

1.7.2. ***L1 activation affecting L2 syntactic prediction***

Some studies suggest that L1 activation can interfere with L2 prediction when activated L1 syntactic features differ from those of L2, or are realized differently. In an ERP study, Alemán Bañón and Martin (2021) had Swedish-English and Spanish-

English bilinguals read English stories featuring two characters (e.g., *Julia's niece* and *Albert's sister*) that biased participants to expect *his sister* (referring to Albert's sister) rather than *her niece* (referring to Julia's niece) as the upcoming possessive construction. In both Swedish and English, possessive pronouns indicate the natural gender of the possessor noun, while in Spanish, a possessive pronoun marks the syntactic gender of the possessed noun. The Swedish-English bilinguals showed increased N400 amplitudes for unexpected possessives pronoun (e.g., *her*) that mismatched the expected possessor noun's natural gender, compared to expected possessives (e.g., *his*), but the Spanish-English group did not show such an effect[2]. This suggests that Spanish-English bilinguals pre-activated the L1 Spanish equivalent *su hermana* (his/her sister), which interfered with L2 syntactic predictive processing.

In a visual-world experiment, Dussias et al. (2013) had L1 Spanish speakers, English-Spanish, and Italian-Spanish bilinguals listen to Spanish sentences containing gender-marked articles, which could serve as predictive cues for an object in a two-picture visual scene. Like Spanish, Italian has grammatical gender, whereas English does not. Italian-Spanish bilinguals quickly made nativelike predictive eye movements toward the target object upon hearing gender-marked articles. Highly proficient English-Spanish bilinguals also showed predive processing after hearing articles, while less proficient English-Spanish bilinguals did not. This may be

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[2] Instead, the Spanish-English group showed a P600 effect for unexpected possessives relative to expected possessives, suggesting integrating difficulty for the unexpected possessives.

because less proficient English-Spanish bilinguals co-activated non-gendered English articles, which, being gender-neutral, interfered with using Spanish articles to predict noun gender.

Similar effects were found by Hopp and Lemmerth (2018). Both Russian and German mark gender on adjectives through suffixes, but differ in noun gender marking: Russian directly marks gender on noun suffixes and lacks articles, while German uses prenominal articles. Two groups of advanced and high-intermediate Russian-German bilinguals listened to L2 German sentences in which gender-marked articles (e.g., *der/die/das*) or adjectives (e.g., *kleiner/s*) allow participants to predict upcoming nouns while viewing a scene. Advanced learners of German showed predictive gender processing for both adjectives (syntactically congruent) and articles (syntactically incongruent), similar to L1 speakers, while high-intermediate learners showed gender prediction for adjectives, but only did so for articles when noun genders in Russian and German were congruent. This suggests that high-intermediate learners co-activate L1 lexical gender, with incongruent genders interfering with L2 syntactic prediction, modulated by L2 proficiency.

But some studies suggest that the influence of L1 activation on L2 prediction is not modulated by lexical gender congruency. Both Norwegian and Greek have grammatical gender and mark nouns' gender on prenominal indefinite articles, while Russian has a gender system but lacks articles, and Turkish has neither gender nor articles. Using the visual-world paradigm, Johannessen et al. (2024) had L2 learners of Norwegian from Greek, Russian, and Turkish L1 backgrounds listen to Norwegian sentences containing gender-marked indefinite articles that are predictive of the following nouns, while viewing a scene with a target and a competitor. Low proficient L2 learners in all groups did not show predictive gender processing. But High proficiency L2 learners with L1 Greek and Russian backgrounds showed more predictive looks toward the target object than the competitor before the target word onset, whereas high proficiency Turkish learners did not show this predictive fixation bias. Moreover, no lexical congruence effect was found. This lack of predictive processing in L1 Turkish speakers likely stems from L1 activation, where non-gendered L1 representations interfere with establishing syntactic gender agreement in L2, hindering predictive processing of L2 articles.

There is also evidence suggesting activation of L1 syntactic structure during L2 prediction. English and German allow ditransitive verbs in both prepositional-object (PO) structures in which the verb is followed by the theme and then the recipient, and in double-object (DO) structures in which the order is reversed. In contrast, Turkish follows a fixed theme-recipient order, similar to the English PO structure. Şafak and Hopp (2023) had German and Turkish learners of English listen to English sentences containing verbs biased toward either PO or DO structures while viewing a scene. L1 German speakers quickly made more predictive looks to the theme after hearing verbs biased toward PO structures compared to those biased toward DO structures. Turkish learners, however, showed no such differential predictive looks, suggesting that Turkish learners activated L1 verb structure information (i.e., the fixed theme-recipient order), which interfered with their L2 syntactic prediction.

1.7.3. ***L1 activation affecting L2 form prediction***

To date, three studies have investigated whether L1 form is activated during L2 prediction, but none have found evidence to support this. In an ERP study, FitzPatrick and Indefrey (2010) had Dutch-English bilinguals listen to high-constraining English sentences ending with semantically incongruent words, predictable words, or words phonologically related to the Dutch translations of predictable words (e.g., *My Christmas present came in a bright-orange* *doughnut*"; doughnut had initial overlap with *doos*, meaning "box"). There was no difference in the N400 peak or onset latency between phonologically related words and incongruent words (though they did differ from predictable words), thus providing no evidence that the L1 phonological representations of the predictable words were activated during L2 prediction.

In a visual world paradigm study, Ito et al. (2018) had Japanese-English bilinguals listen to sentences containing a highly predictable word (e.g., *The tourists expected rain when the sun went behind the cloud*) while viewing a display of four objects. They found no difference in fixations between an object whose Japanese name was phonologically related to the Japanese translation of the predictable word (*bear*; kuma) and an unrelated object (*globe*; tikyuugi), nor between an English phonological competitor (*clown*) and an unrelated object before the target word onset. Thus, there was no evidence that L2 speakers pre-activated phonological representations of either predictable words or their L1 translations. Using the same design, Amos et al. (2022) found similar results for French-English translators or interpreters who listened to English sentences and translated them into French.

Although these studies did not find evidence of L1 phonological pre-activation, we cannot be certain that L1 phonological representations of predictable words are not activated during L2 comprehension. Even in L1 comprehension, phonological prediction effects are small (see Ito, 2024). In Ito et al. (2018), Japanese competitors and Japanese translations of predictable words shared only 2.6 out of 4.9 phonemes (53%), which may be insufficient to trigger activation of phonologically related words, and the study had low power (96 observations per condition in Ito et al., 2018), as did Amos et al. (2022) (192 per condition).

1.7.4. ***Summary***

To summarize, much evidence suggests that L1 speakers predict upcoming words across semantic, syntactic, and phonological levels, while L2 speakers predict more slowly and primarily at the semantic level, with limited prediction at syntactic, and no prediction, at the form level. I pointed out two possible explanations for L1 and L2 prediction differences. This thesis aims to investigate the mechanisms of language processing in monolinguals and bilinguals by focusing on these two explanations. Specifically, L2 speakers may predict less than L1 speakers because: (1) prediction is constrained by cognitive resources, and L2 speakers generally have fewer resources available due to reduced automaticity in comprehension (2) L1 co-activation during L2 comprehension interferes with L2 prediction.

Before examining the first explanation, however, it is necessary to determine whether prediction is indeed cognitively demanding. To address this, Experiments 1-3 (Chapter 2) examined whether greater perceptual load impairs prediction by investigating the effect of fast speech rates on listeners' prediction speed. Participants listened to sentence contexts presented at fast or slow speech rates that either were or were not highly predictive of a final word. Prediction speed was assessed by measuring how quickly participants judged whether a given letter was contained in that final word (Experiment 1), named a picture corresponding to that final word (Experiment 2), and named that final word (Experiment 3).

Before exploring whether L2 prediction is affected by L1 activation, it is important to first determine whether cross-language activation occurs in one-language contexts—typical scenarios in which L2 prediction takes place. Thus, Experiments 4-5 (Chapter 3) addressed this question using a picture-word-interference paradigm. Highly proficient L2 speakers and L1 English speakers were asked to name pictures in L2 while ignoring L2 auditory distractors, allowing us to determine whether L2 speakers activated L1 representations during L2 production, even when L1 was irrelevant.

Finally, Experiments 6-7 (Chapter 4) directly investigated whether L2 speakers pre-activate L1 translations of predictable words during L2 comprehension using a visual-world paradigm. Experiment 6 used a two-language context, while Experiment 7 used a one-language context, offering insight into the role of language context in cross-language prediction.

2. How Does Speech Rate Affect Prediction?

Chapter 2 of this thesis is based on a manuscript that was submitted to a peer-reviewed journal:

Yin, H., Sturt, P., & Pickering, M. J. (under review). How does speech rate affect prediction? *Quarterly Journal of Experimental Psychology*. Authorship details: Yin designed the study, ran the participants, analyzed the data, and wrote the original manuscript. Sturt and Pickering acted as supervisors, gave feedback on each of these steps, and contributed to the revision of the manuscript. The first experiment in this study originated from Yin's master thesis. As it was closely related to the other two experiments, it was included in this thesis for the sake of completeness.

Note: The reference list is not included in this chapter but is brought together with other references in this thesis.

2.1. Introduction

During language comprehension, people often make predictions based on the preceding context to facilitate their processing. That is, they pre-activate linguistic representations associated with predictable words and use those representations to aid comprehension (Altmann & Kamide, 1999; Federmeier, 2007; Wicha et al., 2003). Although it is generally accepted that prediction is cognitively demanding and that an increased cognitive load reduces predictive processing, the impact of fast speech rate (a natural factor likely to influence the cognitive resources available for prediction while also allowing for entrainment), is less straightforward and not fully clear. Our study addressed this by examining how speech rate influences listeners' prediction speed in three experiments using Mandarin Chinese.

Comprehenders predict upcoming words at various levels of representation (for reviews, see Huettig, 2015; Kuperberg & Jaeger, 2016; Pickering & Gambi, 2018). For example, Altmann and Kamide (1999) found that comprehenders looked at an edible object (cake) more than inedible objects (ball, toy train, toy car) after hearing *the boy will eat the…*, indicating that they predicted reference to an edible object. In an event-related potential (ERP) study, Wicha et al. (2004) had native Spanish speakers read high constraint Spanish sentences (e.g., *Caperucita Roja cargaba la comida para su abuela en…* "Little Red Riding Hood carried the food for her grandmother in…") that continued with a gender-marked article (*una/un*) and a noun that was either expected (e.g., *canasta*, "basket") or unexpected (e.g., *corona*, "crown"). The unexpected articles elicited an enhanced positivity 500-700 ms after an article onset, suggesting that comprehenders pre-activated the syntactic gender of the predictable word. Ito et al. (2018) had native English speakers listen to sentences containing a highly predicable word (e.g., *The tourists expected rain when the sun went behind the cloud...*) while viewing a visual scene. They were more likely to look at a picture of a clown (whose name is phonologically related to *cloud*) than a globe (whose name is phonologically unrelated), before they heard *cloud*, indicating that they predicted the sound of the predictable word.[3]

A word's predictability, which is often operationalized as the proportion of people who fill a gap in a sentence with that specific word (Taylor, 1953), is a critical factor that affects predictive processing in several ways. For example, many studies (Ehrlich & Rayner, 1981; Lowder et al., 2018; Smith & Levy, 2013) have shown that lexical predictability influences reading times: When a word can be predicted from the preceding context, readers tend to spend less time on it than when it cannot. Staub et al. (2015) had participants produce a spoken continuation to a sentence fragment and found that the response latency was shorter for higher probability words, indicating that higher probability words are faster to predict.

Despite studies showing that comprehenders can predict upcoming words at various levels, prediction is generally regarded as a cognitively demanding process, and as such, it is impeded by resources limitations (Chang et al., 2006; Dell & Chang, 2014; Federmeier, 2007; Huettig & Mani, 2016; Pickering & Gambi, 2018; Pickering & Garrod, 2013). According to one account (Pickering & Gambi, 2018), comprehenders predict using their production mechanisms. After they have comprehended what they encounter, they covertly imitate the speaker and derive the

[3] Evidence for prediction of sound in studies using event-related potentials is controversial (compare DeLong et al., 2005 with Nieuwland et al., 2018).

speaker's intention based on the linguistic context and their background knowledge. They can then run this derived intention through their production system so that the linguistic representations of the upcoming word can be activated in the same order as in actual production (e.g., Levelt et al., 1999): from meaning, to syntax, and to sound, but without articulation. The extent to which an upcoming word is predicted depends on time and resources, just as in actual production. Therefore, any factor that reduces the cognitive resources available for prediction should impair prediction. One such factor is likely to be a fast speech rate, which can strain the cognitive resources needed for effective predictive processing but can influence comprehension in two ways.

2.1.1. ***Effects of speech rate on bottom-up processing during comprehension***

Research shows that fast speech can tax cognitive resources and reduce people's bottom-up comprehension ability (Müller et al., 2019; Winn & Teece, 2021; Yang, 2019). Zhang (2017) told native English speakers that they would listen to English sentences (e.g., *The kite is on the left of the ball, the stone is on the right of the ball, where is the kite in relation to the stone?*) given at five different speech rates, and that they would be rewarded if they answered the sentence-final question correctly. Participants' cognitive effort, indicated by their peak pupil dilation, was larger as the speech rate and reward increased, which was also accompanied by longer response time and decreased accuracy. In a combined EEG and eye-tracking study, Müller et al. (2019) had participants match a picture to an auditory sentence at two speech rates while recording their pupil sizes and tracking their neural responses. They observed that at a faster rate participants processed speech faster, as indicated by the earlier occurrence of the P2crosscorr, a marker of processing difficulty. But there were larger peak-pupil dilations for fast speech compared to slow speech, suggesting that fast speech rate increased comprehenders' listening effort. Yang (2019) had professional and trainee simultaneous interpreters interpret texts spoken at three rates and found that both professional and trainee interpreters showed an increased count of fixations and saccades, a larger pupil diameter, and poorer interpreting quality when the speech rate of the source text became faster. Winn and Teece (2020) had listeners with cochlear implants first listen to predictable (e.g., *Let's decide by tossing a coin*) or unpredictable (e.g., *He wants to talk about the risk*) sentences at two rates and then repeat the whole sentence with their pupil size being recorded throughout the whole process. After the sentences offset, participants showed greater recovery towards the baseline pupil size for slower-rate sentences, indicating less cognitive effort for slower-rate speech. But speech rate did not show a statistically significant effect on participants' sentence intelligibility score.

In addition to more cognitive resources required by increasing speech rate, listeners entrain to ongoing speech rate and form predictions about the timing of upcoming input. Entrainment was shown by Jungers and Hupp (2009), who had participants listen to a fast or slow prime sentence describing a picture and then describe a new picture. They produced picture descriptions more quickly after hearing a prime sentence presented more quickly than after hearing it presented more slowly. Schultz et al. (2016) found that participants' speech rates converged with their partners over the course of dialogues. Corps et al. (2020) presented participants with questions in which the context (e.g., *Do you have a…*) was fast or slow relative to the final word (e.g., *dog?*). The response latency was shorter following the fast than the slow context, suggesting that listeners entrained to the speech rate and then used the speech rate information to time the initiation of a response, and a fast speech rate allowed them to initiate their responses earlier.

2.1.2. ***Effects of speech rate on prediction***

At this point, we have evidence that increasing speech rate leads to greater cognitive effort for bottom-up comprehension processes and that a faster speech rate leads to entrainment and prediction of timing, thereby enabling listeners to initiate earlier responses, but it is unclear what to expect about the effects of speech rate on prediction.

Some studies provide evidence that fast speech rate interferes with prediction. Wlotko and Federmeier (2015) had participants read two-sentence passages (e.g., *They wanted to make the hotel look more like a tropical resort. So along the driveway they planted rows of …*) in which a final word was predictable (*palms*), categorically related to the predictable word (*pines*), or unrelated (*tulips*). Each word was presented at 500 ms or 250 ms SOAs, in two blocks. Categorically related words elicited reduced N400 amplitudes compared to unrelated words at 500 ms SOA. This finding provides some evidence for prediction (and replicates Federmeier & Kutas, 1999), but the effect occurred after the final word was encountered and may therefore be due to ease of integration rather than prediction (see Pickering & Gambi, 2018). At 250 ms, this effect of semantic similarity diminished; if the effect is due to prediction, then speeded written language interfered with it.[4]

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[4]An analysis by block order suggested that semantic similarity effect did not occur at 250 ms when this block came first, but did occur when it came after the 500 ms

In two experiments, Ito et al. (2016) had participants read high-cloze sentence contexts (e.g., *Living alone is too expensive, so the students will share a ...*), followed by a predictable word (*flat*), a word semantically related to the predictable word (*wall*), a word phonologically related to the predictable word (*flag*), or an unrelated word (*bell*), at a rate of 500 ms or 700 ms SOA. They found an N400 reduction for semantically related words at both SOAs, but an N400 reduction for form-related words only at 700 ms and only in very high-cloze sentences. In addition, they found a post-N400 enhanced positivity for form-related words in comparatively lower cloze sentences at the 700 ms but not the 500 ms SOA, suggesting that listeners could detect the form conflict between form-related words and predictable words in such contexts only at a slower presentation rate. These results suggested that comprehenders predicted less when the presentation rate was fast compared to slow.

In a visual-world study, Huettig and Guerra (2019) had Dutch speakers view a target object (e.g., a bicycle) and three unrelated distractors for a short or a long time and then listen to Dutch sentences presented at a slow or normal rate (e.g., *Look at the displayed bicycle*). The determiner was compatible in gender with the target object but none of the distractors, thus allowing prediction. Participants looked predictively at the target object in both speech-rate conditions when they had a long preview (Experiment 1), but only at the slow rate condition when they had a short preview (Experiment 2). Thus, the slower rate appeared to enhance prediction. But the target picture had a different gender from the other three pictures, and so

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block.

participants might have worked out that it would be the target before hearing the determiner.

Using an question-answer sequence from spontaneous conversational corpora, Hoogland et al. (2023) found that a faster speech rate in questions was associated with longer response latencies before answers, which contradicts Corps et al. (2020) who found that participants responded more quickly after speeded questions. The mixed results suggest that the effect of speech rate on prediction may be complex.

Similar to Corps et al. (2020), other studies provide some evidence that fast speech rate does not impair prediction. Kukona (2023) had participants view visual arrays containing two objects (e.g., *a bike* and *a kite*) while listening a predictive sentence (e.g., *What the man will ride, which is shown on this page, is the bike*) and used a mouse to click on the object referred to in the sentences. They moved their mouse cursor to the predictable object (the bike) before hearing it. Importantly, this prediction effect was found not only at a natural speech rate (~3 syllables/second), but also at rates twice (~6) or three times (~9) as fast as the natural rate, with predictions occurring even earlier at faster rates. This suggests that comprehenders' prediction does not seem to be impaired at a rapid pace.

Fernandez et al. (2020) had participants listen to short stories (e.g., *One day a wolf and a deer were sleeping near a cave. The wolf became crazed and the wolf attacked the deer. A hawk watched as the deer escaped*) followed by a "*wh-*movement" comprehension probe (*Point to who the wolf was attacking near the cave*) while viewing four objects (wolf, deer, hawk, cave) mentioned in the story. They manipulated the speech rate (3.5, 4.5, 5.5, 6.0 syllables per second) of the stories and found that both young and older adults showed more anticipatory eye movements to the target picture after encountering the verb at 4.5 than 3.5 syllables/second (Experiment 1). This finding, again, suggests that as speech rate increases, speakers seemed to become more able to use top-down syntactic information to predict upcoming information and form such "filler-gap" dependencies. However, the two groups showed decreased anticipatory looks to the target picture at the fastest speech rate (6.0 syllables/second).

2.1.3. ***The present study***

As we can see, the current evidence regarding the effect of speech rate on comprehenders' prediction is mixed, with some studies relating to the prediction of timing rather than content (e.g., Dilley & Pitt, 2010) and others potentially measuring integration rather than prediction (e.g., Wlotko & Federmeier, 2015). Another limitation of previous research is the failure to distinguish between the effects of speech rate on prediction and its impact on bottom-up comprehension processes. It is plausible that a faster speech rate affects other aspects of comprehension without altering prediction, and the observed effects on prediction might actually stem from changes in other aspects of comprehension process. To accurately assess the impact of speech rate on prediction, it is essential to separate its effects on prediction and on other aspects of comprehension. Therefore, our study conducted a thorough examination of how speech rate influences prediction speed across three experiments, explicitly designing one experiment to separate the impact of speech rate on prediction from that on other aspects of comprehension. The first experiment used a letter judgment task, focusing on how speech rate affects prediction within highly predictable contexts. The second used a picture naming task, aiming to determine if the effects of speech rate on predictable sentences were attributable to prediction process rather than to other aspects of comprehension, by isolating the impact of speech rate on bottom-up processes in comprehension from that on prediction. The third experiment involved a word naming task, investigating how the speech rate effects might vary with the level of contextual predictability.

In all experiments, our primary dependent measure was response latency – the time to make the judgment or initiate naming. Since prediction is assumed to be cognitively demanding, we hypothesized that speeded speech should slow down comprehenders' prediction speed.

As well as prediction speed, our second and third experiments also manipulated contextual predictability – whether the sentence context made the target word more or less predictable. We expected less-predictable contexts should slow down comprehenders' prediction speed than more-predictable contexts. We also expected an interaction between speech rate and contextual predictability. Specifically, we expected that a faster speech rate should increase response latency to a greater extent for more predictable than less predictable sentence contexts. This expectation is based on the assumption that prediction is cognitively demanding, so the more a comprehender predicts, the greater the effect of speech rate should be, so its effect should be greater for more predictable than less predictable contexts.

Following evidence of speech rate entrainment in production (Corps et al., 2020; Jungers & Hupp, 2009) and perception (Dilley & Pitt, 2009), we expected shorter response durations in the fast-rate than the slow-rate conditions, and shorter response latencies in the fast-rate than the slow-rate condition for unpredictable sentences (in Experiment 2 and 3). In addition, we anticipated shorter response latencies in more predictable contexts than less predictable ones. Such effects would demonstrate the efficacy of our manipulations.

In an ERP study, Brothers et al. (2017) found that top-down goals influence lexical prediction mechanism during comprehension (see also Huettig & Guerra, 2019, Experiment 3). They observed larger lexical prediction effects, as indicated by the N400 and by post-N400 positivity, when participants were instructed to actively predict the predictable word during reading than when they were told only to read sentences for comprehension. Based on these findings, in all three experiments we instructed participants to actively predict the final word of each sentence while they were listening in order to enhance lexical prediction.

2.2. Experiment 1

In Experiment 1, we had participants listen to high-cloze sentences truncated before the final word, presented at a fast or slow speech rate, and participants were told to actively predict what they thought the final word would be. They then were asked to judge, after the offset of the recording, whether a given letter was contained in the Pinyin of the predictable word (and then typed the word they had predicted). On half of the trials, the letter was included in the word (positive trials); on the other half, it was not (negative trials). Pinyin is a phonetic system that represents Chinese characters using the Latin alphabet based on their pronunciation. (It uses 25 of the 26 letters of the Latin alphabet and some are pronounced the same as English). As it is an integral part of learning the pronunciation of characters, Pinyin is generally familiar to Mandarin Chinese speakers such as our participants.

We expected that participants would predict the high-cloze final word regardless of speech rate. The key dependent measure was the time participants took to make a response, because we hypothesized that the response latency would reflect the time needed to pre-activate the predictable word. To make a judgment about whether a letter is contained in a predictable word, we assumed that comprehenders would first have to pre-activate this word. Since prediction takes resources and a faster speech rate will tax the comprehension system and leave fewer cognitive resources for prediction, we expected comprehenders to take more time to pre-activate a word at a fast than slow speech rate. Thus, they should take longer to respond in the fast than the slow condition (again, on both positive and negative trials).

Data availability

The code and data associated with this paper are available from https://osf.io/wtbfg/.

2.2.1. ***Method***

2.2.1.1. Participants

One hundred and twenty Chinese undergraduates (54 males and 66 females) aged 18-28 (M = 20.82 years, SD = 1.97) who were recruited online took part in the experiment. All were native Mandarin Chinese speakers and gave informed consent. Each participant was paid ¥15 (about US$2) for participation. The experiment was conducted online via Testable and was approved by the Ethics Committee of the Department of Psychology, University of Edinburgh.

2.2.1.2. Design

We used a 2 (Speech Rate: fast vs. slow) × 2 (Trial Type: positive vs. negative) within-participants design. On positive trials, the letter to be judged occupied the final position of the Pinyin of the predictable word. The reason why we asked participants to judge the last letter was that it would maximize the effect of speech rate on prediction speed because we reasoned that comprehenders would be likely to pre-activate all the letters before making a judgment. On negative trials, the letter to be judged did not occur in the Pinyin of the predictable word. Speech rate was blocked, and was counterbalanced between participants (i.e., half the participants encountered fast speech first, and half encountered slow speech first).

2.2.1.3. Materials

We constructed 120 items (from a candidate set of 140 items) in Mandarin Chinese that consisted of a highly constraining sentence context and the highly predictable word at the end of the sentence. A separate group of 37 undergraduates were recruited via online social platforms to perform a cloze probability test. All were Mandarin Chinese native speakers and were paid ¥ 12 (about US$ 1.80) for their participation. They were presented with 140 sentences truncated before the final word and were asked to complete the sentence with the first noun that came to mind. The cloze probability of a word was defined as the percentage of participants who used the word to complete the sentence. We excluded items if the predictable word had a cloze probability of less than 70%. Selected items had a mean cloze value of 90.00 % (range 75.68–100%); see Table 1 for example stimuli, and Appendix for the complete set. We converted the sentence fragments to speech using Voice Maker (a commercial online text to speech converter). The fast version was 50% faster than Voice Maker's normal rate and the slow version was 50% slower than it. The mean speech rates were 6.37 and 2.46 syllables per second in the fast and slow version, respectively. The same fast and slow rates were consistently used across all three of our experiments. Both the fast and the slow version were comprehensible, as judged by two native Mandarin Chinese speakers.

Table 1

Example sentence contexts from Experiment 1

Sentence Context	Target Word
艾米莉今年拿到了驾照，打算明年给自己买一台_	车
Ai Mili Jin Nian Na Dao Le Jia Zhao, Da Suan Ming Nian Gei Zi Ji Mai Yi Tai_	che
(Emily got her license this year, so next year she is going to buy herself a_)	(car)
夏天天气变化非常快，我们出门最好带一把_	伞
Xia Tian Tian Qi Bian Hua Fei Chang Kuai, Wo Men Chu Men Zui Hao Dai Yi Ba_	san
(The weather changes very quickly in summer, so when we go out we'd better take an_)	(umbrella)

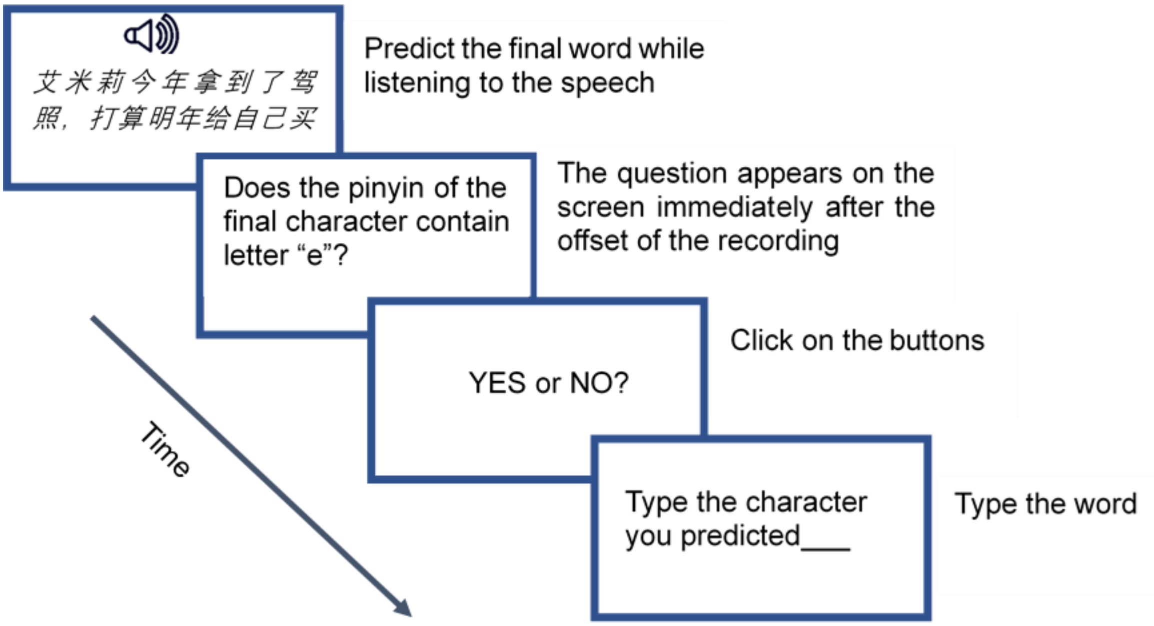
The four conditions in this experiment were: (1) Positive trial, Fast speech rate; (2) Positive trial, Slow speech rate; (3) Negative trial, Fast speech rate; (4) Negative trial, Slow speech rate. The positive and negative trials used the same letters for judgment. On the positive trials, the proportions of individual letters were *a* (18.33%), *n* (6.67%), *e* (13.33%), *i* (12.50%), *g* (15.83%), *u* (15.00%), *o* (18.33%); on negative trials, the proportions were *a* (8.46%), *n* (22.31%), *e* (8.46%), *i* (17.69%), *g* (11.54%), *u* (14.62%), *o* (15.38%). The 120 items were first divided into four counterbalanced lists, such that each list contained 30 items from each condition and one version of each item. Each list was divided into two further lists, one in which the fast-rate speech block came first, and one in which the slow-rate speech block came first. The order of the sentences within each block was randomized for each participant.

2.2.1.4. Procedure

Participants were randomly assigned to one of the eight lists. They sat in front of a computer screen and the stimuli were presented in two blocks of 60 sentences, with a five-minute break between the blocks. An overview of the experimental paradigm is shown in Figure 1.

Figure 1

An example of a trial in Experiment 1



Participants were informed that they would hear sentences that were missing the final word and were instructed to actively predict the final word of each sentence while they were listening. Immediately after the offset of the penultimate word, they were asked to judge whether a letter was contained in the Pinyin of the predictable word. The participants responded by clicking a "YES" or "NO" button on the screen, and the time to respond was recorded. The question remained on the screen until participants pressed a button. After the button press, they were instructed to type the word they had predicted. They then clicked on "Next" to begin the next trial. No feedback was given during the experiment. The experiment began with two practice trials that were used for familiarizing the participants with the procedure, and it took approximately 30 minutes.

2.2.2. ***Data analysis***

Trials in which participants did not type a word that was consistent with the word from the cloze norm test, or where response latencies were greater than 3000 ms (18.43%) were excluded before analyzing the effects of speech rate and trial type on letter judgement accuracy. Further, trials in which participants did not make a correct judgement (3.45%) and trials in which response latencies deviating more than 2 standard deviations from a participant's conditional mean (2.78%) were excluded before analyzing the effects of speech rate and trial type on response latency.

We used the lme4 package (version 1.1.26; Bates et al., 2015) in the statistical software R (version 4.0.5; R Core Team, 2021) to analyze the effects of speech rate and trial type (positive or negative) on letter judgment accuracy and response latency. The effects of speech rate and trial type on judgment accuracy were analyzed in a generalized linear mixed effects model, using a binomial link function, and the effects of speech rate and trial type on response latency were analyzed in a linear mixed effects model. The effects of speech rate and trial type in both models used sum contrast coding (Speech Rate: slow was set to -1, fast to 1; Trial Type: negative was set to -1, Positive to 1). In both models, as fixed effects, we entered speech rate and trial type (with interaction term) into the model. As random effects, we specified the maximal random effects structure in both models, for both participants and items, and if the maximal model did not converge, complexity was removed in the order of removing random correlations, interactions of random effects, and random slopes corresponding to main effects until models converged as suggested in Barr et al. (2013) (Final model on response latency: lmer(RT ~ SpeechRate * TrialType + (SpeechRate +TrialType | ID) + (SpeechRate | item), control = lmerControl (optimizer = "bobyqa")); Final model on Judgement Accuracy: glmer(JudgementAccuracy~SpeechRate * TrialType + (SpeechRate + TrialType | ID) + (SpeechRate | item), family = "binomial", control = glmerControl ("bobyqa"))). Significance was calculated using the lmerTest package (Kuznetsova et al., 2017).

2.2.3. ***Results***

We analyzed the effects of speech rate and trial type on comprehenders' response latency and letter judgement accuracy.

2.2.3.1. Response latency

Table 2 lists the means and standard deviations of response latency and judgement accuracy aggregated over participants in Experiment 1. There was an effect of speech rate (B = 30.04, SE = 10.81, t = 2.78, p = .006): Participants took longer to make a response when the speech rate was fast than slow. There was also an effect of trial type on response latency (B = -15.70, SE = 6.33, t = -2.48, p = .015), with a tendency for shorter responses in the positive than the negative conditions.

There was no interaction between speech rate and trial type (*B* =1.097, *SE* = 3.84, *t* = 0.28, *p* = .776).

Table 2

Means (and standard deviations) aggregated over participants for response latency and judgement accuracy in Experiment 1

Condition	Response latency (In milliseconds)	Judgement accuracy (%)
	Mean (SD)	Mean (SD)
Fast-Positive	1783 (323)	89.8 (13.9)
Fast-Negative	1818 (325)	94.1 (11.2)
Slow-Positive	1720 (310)	90.9 (12.7)
Slow-Negative	1759 (316)	94.8 (11.5)

2.2.3.2. Judgment accuracy

There was an effect of speech rate on response accuracy (*B* = -0.17, *SE* = 0.06, *z* = -3.07, *p* = .002): Participants were more accurate when the speech rate was slow than fast. There was also an effect of trial type (*B* = -0.47, *SE* = 0.05, *z* = -9.52, *p* < .001): Participants were more accurate in the positive than the negative conditions (i.e., participants were more likely to respond YES than NO). There was no interaction between speech rate and trial type (*B* = 0.01, *SE* = 0.04, *z* = 0.33, *p* = 0.74), suggesting that fast speech rate reduced comprehenders' prediction accuracy regardless of trial type.

2.2.4. ***Discussion***

The results of Experiment 1 showed that participants responded slower and less accurately at a faster speech rate, we interpreted this as evidence that faster speech rate slowed down comprehenders' prediction speed. (The judgment-accuracy data indicated that there was no speed-accuracy trade-off in the response-time data.)

However, the longer response latency at a faster rate in Experiment 1 may not necessarily result from slowed prediction speed. An alternative explanation is that the rapid speech rate impairs other aspects of comprehension, such as bottom-up processing in language comprehension, including word recognition, rather than prediction itself. To rule out this possibility, we needed an experiment that could disentangle the effects of speech rate on prediction from its effects on other aspects of comprehension.

To address this, we designed Experiment 2 in which we had participants listen to fast- or slow-rate sentence fragments that either had a predictable ending (high-cloze) or did not (low-cloze) and then asked them to name a sentence-final picture corresponding to the final word. In the low-cloze condition, the unpredictable sentence contexts prevented listeners from relying on the prediction system to anticipate the final word, engaging primarily bottom-up comprehension processes. Additionally, the experimental design directed participants' focus towards the picture naming task, further minimizing the role of top-down predictive process during listening. This setup ensures that in the low-cloze condition, the influence of prediction was minimal, providing a baseline to contrast with the high-cloze condition, in which prediction mechanism was heavily engaged. By comparing the two conditions, we could isolate the impact of speech rate on prediction from its broader effects on comprehension.

2.3. Experiment 2

As in Experiment 1, we had participants listen to sentences truncated before the final word, presented at a fast or slow speech rate. But this time the sentences either had a predictable ending (high-cloze) or did not (low-cloze). Participants were still instructed to actively predict what they thought the final word would be during listening and then name a sentence-final picture that matched the predictable word (i.e., in the high-cloze condition). We assumed that the mechanism of picture naming would be facilitated if participants predicted the predictable words (in the high-cloze condition), and therefore that the amount of facilitation to response latency would depend on the extent and speed of participants' prediction.

In the low-cloze condition, in which the final word was unpredictable and thus relied primarily on bottom-up comprehension processes, any difference in response latency between fast and slow speech rates would reflect the effect of speech rate on bottom-up comprehension. A longer response latency at a fast rate, compared to a slow rate, would suggest that the speeded speech rate slows down bottom-up comprehension processes. Conversely, if response latency remains unaffected or even decreases at a faster rate (potentially due to speech rate entrainment, as indicated by shorter response durations at faster rates), it would indicate that bottom-up comprehension is not additionally taxed by increased rate.

In the high-cloze condition, where sentences were predictable, both bottom-up comprehension and prediction processes were involved, with response latency reflecting the net effect of speech rate on the two processes. If analysis of the low-cloze condition reveals that a fast speech rate does not impair bottom-up comprehension and primarily induces speech rate entrainment (evidenced by earlier response latency and shorter response duration), then longer response latency but shorter response duration (evidence for entrainment) at a faster rate in the high-cloze condition would indicate that the increased cognitive demands of prediction by the faster rate outweighs advantages of faster latency due to speech rate entrainment. This would provide clear evidence that the longer latency observed for predictable sentences at a faster rate in Experiment 1 was due to prediction rather than other aspects of comprehension, supporting the view that prediction is a cognitively demanding process and that increased speech rates hinder comprehenders' prediction speed.

Alternatively, if no significant latency difference is observed between fast and slow rates in the high-cloze condition, but response duration is shorter at a faster speech (indicating speech rate entrainment), it would suggest that any advantages of faster latency due to speech rate entrainment are offset by the increased cognitive demands of prediction by the faster rate. This would also support the view that prediction is cognitively demanding. We also expected shorter response latencies in the high- than the low-cloze conditions, and shorter response durations in the fast- than the slow-rate conditions.

2.3.1. ***Method***

2.3.1.1. Participants

One hundred and twenty undergraduates from Chinese universities (43 males and 77 females) aged 18-24 (M = 19.78 years, SD = 1.52), who were recruited online, took part in the experiment. All were native Mandarin Chinese speakers and gave informed consent. Each participant was paid ¥15 (about US$2). The experiment was conducted online via Testable and was approved by the Ethics Committee of the Department of Psychology, University of Edinburgh.

2.3.1.2. Design

We used a 2 (Speech Rate: fast vs. slow) × 2 (Cloze Probability: high cloze vs. low cloze) within-subjects and within-item design.

2.3.1.3. Materials

The experimental stimuli consisted of 96 pairs of high- and low-constraint sentence fragments matched with a target picture. To create the stimuli, we first constructed 120 sentence fragment pairs in written Chinese, with each pair consisting of a sentence fragment that we judged to be high constraint and sentence fragment that we judged to be low constraint (see Table 3). Forty additional participants from the same participant pool were paid ¥ 10 (about US $1.50) to fill in the missing final (target) word for these fragments. The pairs were divided into two lists of 120 sentences containing one version of each pair (60 high-constraint and 60 low-constraint fragments). Twenty participants were asked to complete each list with the first word that came to mind. The cloze probability of a word was defined as the percentage of participants who used the exact word to complete the sentence. We selected 96 sentence fragment pairs for the main experiment and paired them with a target word (which was the most frequent completion in the high-constraint condition). This word had a mean cloze value of 94.80% (range 81.25–100%) in the high-constraint condition, and a mean cloze value of 4.38% (range 0–24%) in the low-constraint condition; see Table 3 for example stimuli and Appendix for the compete set.

Table 3

Example sentence fragments used Experiment 2

Close Probability	Sentence Context	Target Word
High Cloze	男朋友送了她一枚戒指，上面镶嵌着一颗闪闪发光的_ Nan Peng You Song Le Ta Yi Mei Jie Zhi, Shang Mian Xiang Qian Zhe Yi Ke Shan Shan Fa Guang De _ (The boyfriend gave her a ring studded with a sparkling _)	钻石 Zuan Shi diamond
Low Cloze	小偷趁主人不在家入室盗窃，偷走了放在保险柜里的_ Xiao Tou Chen Zhu Ren Bu Zai Jia Ru Shi Dao Qie, Tou Zou Le Fang Zai Bao Xian Xiang Li De_ (Thieves, taking advantage of the owner's absence, broke into the safe and stole the_)	钻石 Zuan Shi diamond

These sentence fragments were generated the same as in Experiment 1 at both a fast speech rate and a slow speech rate, thus both the fast and the slow version were comprehensible. In addition, there were six practice trials and eighteen fillers similar to the experimental sentences (e.g., "There is no bridge over the river, so you will have to take a boat") followed by a comprehension question (e.g., "To go across the river, do we have to take a boat?"), with half fillers requiring a "Yes" answer, and half a "No" answer. The fillers were to ensure that participants paid close attention to the recording.

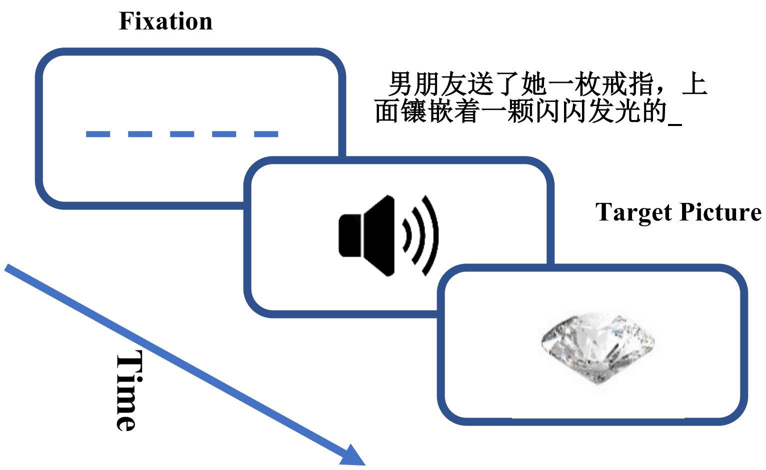
Each pair of sentences was matched with a picture whose target name corresponded to the predictable word in the high-cloze fragment. The pictures were taken from Zhou and Chen (2017), who investigated naming latencies and norms in Mandarin Chinese for 435 images. We used this study because they included color and texture information, which can facilitate object processing and improve name agreement (Rossion & Pourtois, 2004), and the data were collected quite recently (in 2017). For all pictures that we selected, name agreement was at least 0.87, and two further Chinese native speakers both agreed they were easy to identify.

2.3.1.4. Procedure

An overview of the experimental paradigm is shown in Figure 2. The experiment was conducted online and participants were asked to do it in a quiet room on a computer.

Figure 2

An example of a trial in Experiment 2



Participants were first instructed to listen to each sentence fragment. After the offset of each recording, a picture corresponding to the target word appeared on the screen and they were asked to name the picture as quickly as possible. Each picture remained on the screen until the voice key detected a response. No feedback was given during the experiment. Stimuli were presented in two blocks of 60 trials each, with each block beginning with three practice trials, and a five-minute break between the blocks. Speech rate was blocked and the block order of speech rate (fast vs. slow first) was counterbalanced between participants. The order of the sentences within each block was randomized for each participant and the whole experiment took approximately 30 minutes.

2.3.2. ***Data Analysis***

Two participants were removed from further analyses for trials because more than 60% of the responses were wrong (0.80% of the data). Trials on which participants did not name the pictures correctly (4.08%) or response latencies were longer than 2000 ms (1.68%) were eliminated. Further, trials in which response latencies deviating more than 2 standard deviations from a participant's condition mean were excluded before further analysis (6.49%). Response durations for each trial were manually calculated using Audacity, an open-source audio software.

We used the lme4 package (version 1.1.26; Bates et al., 2015) in the statistical software R (version 4.0.5; R Core Team, 2021) to analyze the effects of speech rate and cloze probability (high or low) on response latency and response duration. The effects of speech rate and cloze probability on response latency and voice response duration were analyzed in two linear mixed effects models. The effects of speech rate and cloze probability in both models used sum contrast coding (Speech Rate: fast was set to -1, slow to 1; Cloze Probability: low was set to -1, high to 1). As response duration had right-skewed distributions, we applied log transformations to these variables in our models. In both models, as fixed effects, we entered speech rate and cloze probability (with interaction term) into the model. As random effects, we specified the maximal random effects structure in both models, and if the maximal model did not converge, the model was progressively simplified in the order of removing random correlations, interactions of random effects, and random slopes corresponding to main effects, until the models converged (final model on response latency: lmer (RT ~ SpeechRate * Cloze + (SpeechRate + Cloze | ID) + (SpeechRate + Cloze | item), control = lmerControl (optimizer = "bobyqa")); final model on response duration: lmer (log (duration) ~ SpeechRate * Cloze + (SpeechRate + Cloze | ID)+(SpeechRate + Cloze | item), control = lmerControl (optimizer = "bobyqa")). Significance was calculated using the lmerTest package (Kuznetsova et al., 2017). The analysis of response latency and response duration was adjusted for the family-wise error rate (FWER) using the Holm-Bonferroni method a significance threshold set at at $p < 0.05$.

2.3.3. ***Results***

2.3.3.1. Response Latency

Table 4 lists the means and standard deviations of response latency and response durations aggregated over participants in Experiment 2. For latency, there was an effect of cloze probability (B = -105.76, SE = 6. 12, t = -17.29, p < .001): Participants responded faster in the high- than the low-cloze condition. There was no effect of speech rate (B = 6.28, SE = 6.10, t = 1.03, p = 0.408). However, there was an interaction between speech rate and cloze probability (*B* = -11.36, *SE* = 2.45, *t* = -4.65, *p* < .001). Additional analyses indicated that participants responded faster when the speech rate was fast than slow in the low-cloze condition (*B* = 35.3, *SE* = 13.2, *t* = 2.67, *p* = .012) but that there was no difference between fast and slow speech rate in the high-cloze condition (*B* = -10.2, *SE* = 13.2, *t* = -0.78, *p* = .500).

Table 4

Means (and standard deviations) for response latency and response duration in Experiment 2

Condition	Response latency (in milliseconds)	Response duration (in milliseconds)
	Mean (SD)	Mean (SD)
High Cloze-Fast Speech	886 (215)	587 (149)
Low Cloze-Fast Speech	1073 (191)	602 (140)
High Cloze-Slow Speech	875 (227)	667 (166)
Low Cloze-Slow Speech	1108 (189)	679 (150)

2.3.3.2. Duration of responses

To determine whether there was speech rate entrainment, we further analyzed the effect of speech rate and cloze probability on response durations. There was an effect of speech rate (*B* = 0.06, *SE* = 0.01, *t* = 7.77, *p* < .001): The response duration was shorter when the speech rate was fast than slow. There was also an effect of cloze probability (*B* = -0.01, *SE* = 0.00, *t* = -4.16, *p* < .001): The response duration was shorter when sentences were predictable than unpredictable. But there was no interaction between speech rate and cloze probability ($B = 0.00$, $SE = 0.00$, $t = 0.36$, $p = .716$).

2.3.4. ***Discussion***

Experiment 2 did not reveal an overall effect of speech rate on participants' response latency. However, we observed an interaction between speech rate and cloze probability. Specifically, participants responded faster to unpredictable sentences in the low-cloze condition when presented at a fast rate than at a slow speech rate. But there was no difference in response latency to predictable sentences in the high-cloze condition, whether they were presented at a fast or a slow speech rate. As expected, we also found that participants' response duration was shorter when the speech rate was fast than slow and when sentences were predictable than unpredictable.

In the low-cloze condition, in which sentences were unpredictable and engaged primarily bottom-up comprehension processes, the reduced response latency at a faster speech rate indicates that the increased rate did not impair the bottom-up comprehension. Instead, the primary effect of the fast speech rate was speech rate entrainment, as evidenced by the shorter response duration at this quicker rate. This finding provides a baseline for understanding the effect of faster speech rates on bottom-up comprehension alone, which then allows for comparison with conditions involving both bottom-up comprehension and prediction processes.

In the high-cloze condition, in which both bottom-up comprehension and prediction systems were engaged, the latency reflects the combined impact of speech rate on these processes. We believed that the lack of a significant effect of speech rate on latency in this condition could be due to two counteracting effects: a faster rate facilitated shorter response latencies through speech rate entrainment, while the increased cognitive demands of prediction at the faster rate caused longer latencies. The absence of a significant latency difference suggests that these opposing influences balanced each other, consistent with the view that prediction is a cognitively demanding process. Notably, the descriptive pattern in the high-cloze condition, showing a slight increase in latency (11ms longer) at a faster rate, suggesting that the increased cognitive load from a faster speech rate was of a broadly similar magnitude as the benefits of reduced latency through entrainment.

The design of Experiment 2 may have led participants to focus on the picture naming itself (as a bottom-up task), neglecting the active top-down prediction process, even in highly-predictable contexts. This could have reduced the engagement of the prediction mechanism in predictable sentences, making it harder to observe the effect of speech rate on prediction speed. Instead, the effect of speech rate might be easier to observe when the experimental task itself fully engages participants with the prediction process. Thus, we conducted Experiment 3, in which we presented participants with sentence fragments and asked them to produce a final word as quickly as possible – a task that allows for the full engagement of the prediction mechanism and provides a more direct test of speech rate effect on prediction speed.

2.4. Experiment 3

We again had participants listen to a sentence fragment that was presented at a fast or slow rate. To further investigate how contextual predictability modulates the effect of speech rate on prediction speed, the sentences had either a highly predictable (high-cloze) or a less predictable (medium-cloze) ending, and participants were told to produce what they thought the final word would be while listening. We used medium- rather than low-cloze sentences because our design required participants to produce a particular word on a large fraction of trials - something that would happen in medium-cloze sentences but not in low-cloze sentences. Our main claims relate to trials on which participants did produce this word. We expected that the response latency for the predictable word should be longer in the fast- than the slow-rate condition, and this effect should be greater in the high- than the medium-cloze condition. We also expected shorter response durations in the fast- than the slow-rate condition.

2.4.1. ***Method***

2.4.1.1. Participants

One hundred and twenty Chinese undergraduates (55 males and 65 females, aged 18-24, *M* = 20.17 years, *SD* = 1.4) recruited from the same pool as in Experiment 2 took part in the experiment. All were native Chinese speakers and gave informed consent. Each participant was paid ¥ 15 ($ 2.26) for participating in the experiment. Like Experiment 1 and Experiment 2, Experiment 3 was also conducted online via Testable and was approved by the Ethics Committee of the Department of Psychology, University of Edinburgh.

2.4.1.2. Materials

In Experiment 3, we added some medium cloze (35%-65%) sentence contexts to the materials used Experiment 2. We first constructed 120 medium-cloze sentence fragments whose highest-frequency continuations correspond to the target words of the 120 high-cloze sentence fragments used in the first experiment. Then we recruited a group of 20 undergraduates from different Chinese universities to perform the cloze probability test. All these undergraduates were Chinese native speakers and each of them was paid ¥ 10 (about US$ 1.5) for the cloze probability task. They were presented with the 120 sentence fragments and were asked to complete the sentence with the first word that came to their mind. The cloze probability of a word was defined as the percentage of participants who used the word to complete the sentence. We excluded items if this word was not the target word, or if it had a cloze probability of greater than 65% or lower than 35% (and note that the target word was always the highest-frequency word).

In total, 84 sentence fragment pairs were used in the second experiment, with each pair consisting of a high-cloze sentence fragment (i.e., 84 of the sentence fragments used in Experiment 2) and a medium-cloze sentence fragment. The words in the high constraint sentence fragments had a mean cloze value of 91% (range 81–100%), and the words in the medium constraint sentence fragments had a mean cloze value of 51% (range 35–65%); see Table 5 for example stimuli and Appendix for the compete set. These sentence fragments were recorded via Voicemaker at two speech rates the same way as in Experiment 1 and Experiment 2, and thus both the fast and the slow version were comprehensible.

Table 5

Example sentence fragments used in Experiment 3

Cloze Probability	Sentence Context	Target Word
High Cloze	夏天天气变化非常快，我们出门最好带一把_	伞

	Xia Tian Tian Qi Bian Hua Fei Chang Kuai, Wo Men Chu Men Zui Hao Dai Yi Ba_ (Summer weather changes quickly, so we'd better take an _)	San umbrella
Medium Cloze	无论春夏秋冬，我每次出门都会随身携带_ Wu Lun Chun Xia Qiu Dong, Wo Mei Ci Chu Men Dou Hui Sui Shen Xie Dai_ (Whenever I go out, I will always carry an _)	伞 San umbrella

2.4.1.3. Design

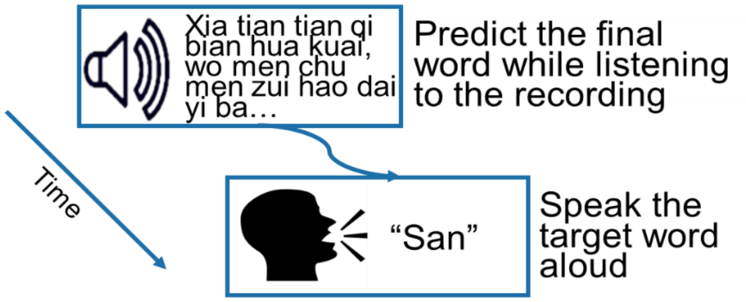
We used a 2 (Speech Rate: fast vs. slow) × 2 (Cloze Probability: High Cloze vs. Medium Cloze) within-subjects and within-item design.

2.4.1.4. Procedure

Stimuli were presented in two blocks of 46 trials each. The first four trials in each block were practice trials. Participants were instructed to listen to sentence fragments and were told to actively predict the final word of the sentences while listening. After the offset of the recording, they were asked to speak the final word aloud as soon as possible, and the time to initiate a response was recorded. After they finished speaking the final word, the next trial began automatically. The experiment took about 30 minutes. An overview of the experimental paradigm is shown in Figure 3.

Figure 3

An example of a trial in Experiment 3



2.4.2. ***Data analysis***

Three participants were excluded from analyses because their recordings had loud audio noise (2.50%). Then we listened to each voice response and manually classified these responses into three categories: target responses, non-target responses, and errors. Target responses were responses in which participants produced the target word. Non-target responses were responses in which participants produced a different word. Errors were responses which were missing or unrecognizable. We excluded error trials (4.57%), trials in which response latencies were longer than 2000 ms (9.66%), and trials in which response latencies were more than 2 SD away from a participant's conditional mean (2.40%). The response duration in each trial was calculated using seewave package (Sueur et al. 2008) in R. Trials in which response durations were more than 2 SD away from a participant's conditional mean (4.54%) were excluded from the analysis of response duration.

We used the lme4 package (version 1.1.26; Bates et al., 2015) in the statistical software R (version 4.0.5; R Core Team, 2021) to analyze the effects of speech rate and cloze probability on response latency and response duration in two linear mixed-effects models. Both effects in both models used sum contrast coding (Speech Rate: fast was set to -1, slow to 1; Cloze Probability: medium was set to -1, high to 1). As the distributions of response latency and response duration were right-skewed, we applied a log transformation to the dependent variable in our models. In our model, as fixed effects, we entered speech rate and cloze probability (with interaction term) into the model. As random effects, we specified the maximal random effects structure in both models, and if the maximal model did not converge, complexity was removed in the order of removing random correlations, interactions of random effects, and random slopes corresponding to main effects until models converged (Final model on dominant response proportion: glmer(Dominant~ SpeechRate * Cloze + (SpeechRate + Cloze | ID) + (Cloze | item) family = "binomial", control = glmerControl(optimizer = "bobyqa")); Final model on response latency:lmer(log(RT)~ SpeechRate * Cloze + (SpeechRate * Cloze | ID)+(SpeechRate + Cloze | item), control = lmerControl(optimizer = "bobyqa")); Final model on response duration: lmer(log(duration)~ SpeechRate * Cloze + (SpeechRate + Cloze | ID) + (SpeechRate | item), control = lmerControl(optimizer = "bobyqa")). Significance was calculated using the lmerTest package (Kuznetsova et al., 2017). The analyses of response latency and duration was based on different datasets, hence no adjustment for the family-wise error rate (FWER) was made.

2.4.3. ***Results***

We analyzed the effects of speech rate and cloze probability on three dependent variables: proportion of target responses, response latency, and response duration.

2.4.3.1. Proportion of target responses

Table 6 lists the means and standard deviations of target response proportions aggregated over participants across different conditions. There was no effect of speech rate on the proportion of target responses (B = -0.07, SE = 0.04, z = -1. 69, p = .091), but there was a main effect of cloze probability (B = 1.62, SE = 0.13, z =

12.80, $p < .001$), with a higher proportion in the high-cloze condition than the medium-cloze condition. There was no interaction between speech rate and cloze probability ($B = 0.03$, $SE = 0.04$, $z = .65$, $p = .518$). Note that the mean values are similar to the mean values in the pre-test.

Table 6

Means (and standard deviations) aggregated over participants for target response proportion in Experiment 3

Condition	Proportion of Target Response (%)	
	Mean	SD
High Cloze - Fast Speech	86.9	15.7
Medium Cloze - Fast Speech	47.8	19.6
High Cloze - Slow Speech	88.1	16.6
Medium Cloze - Slow Speech	46.8	19.4

2.4.3.2. Response latency

We conducted two separate analyses of responses latencies. The primary analysis considered trials on which participants produced the target word, because such responses were the same across conditions[5]. Table 7 lists the means and

[5] However, we also considered trials in which participants produced non-target responses. Since there were so few non-target responses in the high-cloze condition, we analyzed the non-target responses in only the medium-cloze condition. The mean

standard deviations of response latencies as well as response durations aggregated over participants for trials in which participants produced the target word. There was an effect of speech rate on response latency (*B* = -0.07, *SE* = 0.02, *t* = -4.38, *p* < .001), with longer latencies in the fast- than the slow-rate condition. There was also an effect of cloze probability (*B* = -0.12, *SE* = 0.02, *t* = -5.97, *p* < .001), with longer latencies in the medium- than the high-cloze condition. In addition, there was an interaction between speech rate and cloze probability (*B* = -0.02, *SE* = 0.01, *t* = -3.77, *p* < .001), indicating that fast speech rate had a larger effect in high-cloze contexts (94 ms) than medium-cloze contexts (81 ms).

Table 7

Means (and standard deviations) aggregated over participants for response latency and response duration when participants spoke a target word in Experiment 3

Condition	Response latency (in milliseconds)	Response duration (in milliseconds)
	Mean (SD)	Mean (SD)
High Cloze-Fast Speech	716 (207)	403 (147)
Medium Cloze- Fast Speech	900 (210)	400 (145)
High Cloze-Slow Speech	622 (232)	453 (151)

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response latencies in the fast and slow conditions were 1587 and 1528 ms, respectively. For these non-target responses, we did not find an effect of speech rate (*B* = -0.02, *SE* = 0.02, *t* = -0.86, *p* = .39).

Medium Cloze-Slow Speech	819 (282)	444 (139)

2.4.3.3. Response duration

We conducted an analysis of response duration for trials in which participants produced the target word. There was an effect of speech rate (B = 0.06, SE = 0.01, t = 4.88, p < .001), with longer durations in the slow- than the fast-rate condition. But there was no effect of cloze probability (B = 0.01, SE = 0.01, t = 1.45, p = .149) and no interaction (B = 0.01, SE = 0.00, t = 1.31, p = .191) between speech rate and cloze probability.

It is possible that participants took longer to initiate a response at the faster speech rate because they needed longer to plan the shorter-duration words that tended to occur in this condition (though we do not know of any evidence for this claim). To investigate this possibility, we included response duration as a covariate in the model on the effects of speech rate and cloze probability on response latency (Final model: lmer (log(RT) ~ speechrate * cloze + duration + (speechrate * cloze + duration| ID) + (1 | item), control = lmerControl (optimizer = "bobyqa")). However, we did not find an effect of response duration on response latency (B = 0.00, SE = 0.00, t = 1.33, p = .184), and there was still an effect of speech rate on response latency (B = -0.08, SE = -0.02, t = -5.22, p < .001) when response duration was included. Thus, the longer initiation time in the fast-rate condition did not appear to be due to the longer preparation time when articulation was fast.

2.4.4. ***Discussion***

As in Experiment 1, response latencies were longer in the fast- than the slow-rate condition, and more importantly, the effect of speech rate was greater in the high- than the medium-cloze condition. We also found that participants were more likely to produce a target response in the high- than medium-cloze condition (and the results were similar to the pre-test), but speech rate had no effect on the proportion of target responses. Participants responded earlier in the higher than the medium cloze condition, suggesting that highly predictable words are more quickly pre-activated than less predictable words. Response durations were also shorter in the fast- than the slow-rate condition, consistent with the results of Experiment 2.

The analysis of the target responses showed that participants exhibited a longer response latency to name a predictable word when they heard its context being presented at a fast than a slow speech rate. Thus, the results are compatible with Experiment 1 and 2, which also revealed that a fast rate lengthened time-to respond. Participants also responded earlier in the higher than the medium cloze condition, suggesting that highly predictable words are more quickly pre-activated than less predictable words. More importantly, there was an interaction between speech rate and cloze probability, with the faster speech rate increasing response latency to a greater extent for more predictable than for less predictable sentence contexts.

2.5. General Discussion

We investigated how comprehenders' prediction speed is affected by speech rate and contextual predictability using three different experimental paradigms: a letter-judgment task to first determine the effect of a fast speech rate on prediction (Experiment 1), a picture naming task to distinguish whether the observed fast speech rate effect in highly predictable contexts were due to prediction or other aspects of comprehension (Experiment 2), and a word naming task to investigate how the effect of a fast speech rate on prediction was modulated by contexts of different predictability (Experiment 3).

We found that a fast speech rate led to longer response latency as compared to a slow speech rate in Experiment 1 and Experiment 3. Experiment 2 did not replicate this effect of speech rate in predictable contexts, but it did show that speech rate had an effect in unpredictable contexts—a faster rate led to a shorter response latency. This indicates that this fast rate does not impair bottom-up comprehension but instead primarily induces speech rate entrainment, thereby suggesting that the slowed response latency at a faster speech rate observed in Experiment 1 was due to impaired prediction rather than issues with bottom-up processing. Together, our results suggest that a fast speech rate reduced listeners' prediction speed, and most importantly, we found that this effect was greater for more than less predictable contexts in Experiment 3.

Despite the different experimental paradigms across our three experiments, they provide a compatible set of findings. In Experiment 1, participants were presented with sentence fragments which all had a highly predictable word. After hearing the sentences, they were asked to judge whether a given letter was contained in the Pinyin of the predictable word (and then typed the word they had predicted so that we can be sure that they have indeed predicted the target word). This task required participants to pre-activate the word, and the response latency was taken as an indicator of prediction speed. But the slowed latency at a faster speech rate for those highly predictable sentences may not necessarily be due to impaired prediction. Instead, it may be due to impaired bottom-up comprehension processing.

In Experiment 2, participants were presented with sentence fragments containing either a predictable or unpredictable ending and were then asked to name a picture corresponding to the predictable word as quickly as possible. This experiment allowed us to separate the effect of speech rate on prediction and bottom-up comprehension. The unpredictable sentences prevented the prediction process from facilitating the picture naming task. In addition, the experimental setup ensured that participants could name the pictures regardless of whether they had actively predicted the target word, minimizing the influence of the prediction system in the low cloze condition.

Experiment 2 showed an interaction between speech rate and cloze probability. Specifically, in unpredictable contexts where comprehenders could not regularly predict the word corresponding to the target picture, a faster speech rate led to shorter response latencies, suggesting that the primary effect of the fast speech rate on bottom-up comprehension was speech rate entrainment (as indicated by shorter response durations after a faster speech rate). Conversely, in predictable contexts, where participants could easily predict the word and therefore both the bottom-up comprehension and prediction systems were engaged, no significant differences in latency were observed between fast and slow speech rates. This lack of difference suggests that the shorter response latency due to speech rate entrainment may have been offset by the longer latency caused by higher cognitive costs from the prediction system at the fast speech rate. This finding confirmed that the slowed response latency at a faster speech rate for highly predictable sentences in Experiment 1 was due to impaired prediction rather than other aspects of comprehension, suggesting that prediction is very cognitively demanding, and that increased speech rate, like other types of cognitive load, impairs prediction.

In Experiment 3, participants were presented with sentence fragments containing either highly predictable (high-cloze) or less predictable (medium-cloze) endings and were instructed to speak the final word aloud as quickly as possible. This task is actually an online cloze task, and just like the letter judgment task in Experiment 1, it unequivocally ensured that participants engaged their prediction system and provided a direct test of the effect of speech rate on prediction speed in contexts of different predictability. As in Experiment 1, a fast speech rate led to longer response latency than a slow speech rate, and more importantly, there was an interaction between speech rate and contextual predictability: the speech rate effect was greater following more predictable contexts (high cloze) than less predictable contexts (medium cloze). Also, Experiment 3 showed that more predictable contexts led to shorter response latencies compared to less predictable contexts. This suggests that a more predictable context make it easier and therefore faster to predict an expected word than a less predictable context.

The finding that the effect of speech rate on response latency was larger after a highly predictable context (a faster rate slowed down response latency more) than a less predictable context is consistent with the findings of Schuckart et al. (2024) who used a secondary task to manipulate cognitive load and found that the cognitive load effect was larger in more predictable contexts. This finding is compatible with our assumption that prediction takes cognitive resources and listeners' prediction mechanism is engaged more in highly predictable contexts than less predictable contexts. That is, since the possibility of making accurate predictions is greater in a highly predictable context than a less predictable context, the prediction mechanism is likely to be engaged more in a highly predictable context than a less predictable context. Consequently, any effect of speech rate on predictive processing is expected to be greater in highly predictable contexts than less predictable contexts. Since prediction requires resources, then the effects of speech rate should be further enhanced in high-cloze contexts because fast speech rate reduces resources available for prediction.

We also found that participants' word-response durations were shorter when they heard its context being presented at a fast speech rate relative to a slow speech rate in Experiments 2 and 3.This finding aligns with previous research (Cohen Priva et al., 2017; Dilley & Pitt, 2010; Jungers & Hupp, 2009; Schultz et al., 2016), suggesting that listeners entrain to the speech rates of speakers. Entrainment to a faster speech rate causes listeners to initiate earlier response latencies, contrasting with the longer latencies due to increased cognitive load from prediction. These two opposing effects might sometimes cancel each other out, explaining the lack of significant latency differences between fast and slow speech rates for highly predictable contexts in Experiment 2.

We assume that these two effects cancel each other out in highly predictable sentences in Experiment 2 but not in Experiment 1 and 3, due to differences in the experimental paradigms. In both Experiment 1 and 3, participants had to engage their prediction systems to complete the tasks. In Experiment 2, however, participants could complete the tasks without making predictions, making it possible for them to listen passively without fully engaging their prediction systems. This reduced engagement in Experiment 2 may mean that the cognitive costs of making predictions at a faster speech rate were similar to the facilitation benefits from speech rate entrainment, resulting in a non-significant net effect. Consequently, longer response latencies from increased cognitive load may have been balanced by shorter response latencies due to entrainment. In Experiment 1 and 3, the prediction mechanism was more engaged, leading to higher cognitive load from making predictions at a faster speech rate. This increased cognitive load may have exceeded the facilitation benefits from fast speech rate entrainment, resulting in longer response latencies overall. Thus, according to this idea, in Experiments 1 and 3, a faster speech rate led to slower response latencies, while in Experiment 2, no significant latency difference was found between fast and slow speech rates.

Taken together, our results from the three experiments support the idea that prediction is cognitively demanding (Chang et al., 2006; Dell & Chang, 2014; Federmeier, 2007; Huettig & Mani, 2016; Pickering & Gambi, 2018; Pickering & Garrod, 2013), and that greater engagement of the prediction mechanism in highly predictable contexts requires more cognitive resources. We interpret this finding in terms of Pickering and Gambi's (2018) production-based prediction account. According to their account, comprehenders first covertly imitate speakers to derive their intention underlying the utterance, and then run this intention through their production system to produce the representations of the predictable word in the order of meaning, syntax, and form. Predicting using such a mechanism takes time and resources and therefore is optional. Depending on the available time and resources, comprehenders vary in the extent of predictions made through this mechanism. When there are not sufficient time or resources, comprehenders will not complete all stages of prediction. A fast speech rate, taxes comprehension and hence reduces resources that can be allocated to the prediction mechanism, and the more a comprehender predicts, the greater the effect of speech rate should be. Therefore, our finding that fast speech rate reduced comprehenders' prediction speed, and the effect was greater for more predictable than less predictable contexts provides support for this production-based prediction account (Pickering & Gambi, 2018), which posits that prediction is a cognitively demanding process independent of comprehension. This interpretation also aligns with previous studies showing that the availability of cognitive resources can affect comprehenders' predictions (Federmeier et al., 2010; Huettig & Janse, 2016; Ito et al., 2018).

Although speeded speech appeared to slow down comprehenders' prediction speed, it is important to note that our findings are not informative about the sub-processes through which the prediction process was slowed down by the fast speech rate. For instance, it is conceivable that the increased speech rate might impede the pre-activation of the semantic aspects of a predictable word, while leaving the pre-activation of the word's syntactic or form aspects unaffected. Conversely, it could potentially influence all stages of the prediction process. To gain more clarity, future research could investigate whether the impact of speech rate encompasses all these processes or selectively targets individual sub-processes.

2.6. Conclusion

We reported three experiments that investigated how comprehenders' prediction speed was affected by fast speech rate. We found that participants slowed down their responses latency at a faster speech rate, and the fast speech rate slowed down participants' latency to a larger extent for more predictable than less predictable contexts. These findings suggest that a faster speech rate slows down comprehenders' prediction speed, supporting the idea that prediction takes up resources.

3. Study 2 Experiments 4-5: The Role of Semantics and Phonology in Bilingual Picture Naming: Evidence from the Phono-Translation Effect

Chapter 3 of this thesis is based on a manuscript that was submitted to a peer-reviewed journal:

Yin, H., & Pickering, M. J. (under review). The role of semantics and phonology in bilingual picture naming: evidence from the phono-translation effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. Authorship details: Yin designed the study, ran the participants, analyzed the data, and wrote the original manuscript. Pickering acted as supervisor, gave feedback on each of these steps, and contributed to the revision of the manuscript.

Note: The reference list is not included in this chapter but is brought together with other references in this thesis.

3.1. Introduction

If you speak two (or more) languages, then you have to make sure that you produce words in the intended (or target) language. Understanding how bilinguals manage to do this is a central concern of the field of bilingual language production. In particular, researchers have asked whether lexical representations in the non-target language are activated and considered for selection. In this paper, we address this question by investigating whether information associated with Chinese-English bilinguals' first language, Chinese, is activated in a purely English experimental setting. We conducted two picture-word interference experiments in which participants named pictures in English while ignoring English auditory distractors that were phonologically related to the Chinese translations of the picture names (phono-translation distractors).

Much evidence suggests that both the target and non-target languages are activated when bilinguals intend to produce words in only one language, though some of this evidence comes from studies conducted in a two-language context (Colomé, 2001; Colomé & Miozzo, 2010; Costa et al., 2000; Guo & Peng, 2006; Hoshino & Kroll, 2008; Koranda et al., 2022; Rodriguez-Fornells et al., 2005). For instance, bilinguals tend to name pictures with cognate names—words that share both meaning and similar form across languages—more quickly than those with non-cognate names (Costa et al., 2000; Hoshino & Kroll, 2008; Koranda et al., 2022). The standard explanation for such cognate facilitation is that the word in the target language activates its cognate in the non-target language in a one-language context, and their combined activation facilitates production. An alternative explanation is that cognates are learned better than other words (by cross-language activation during early learning), and so cognate facilitation can occur without activation of the non-target language (Costa et al., 2017). For the purposes of the introduction, we assume on-line activation, though return to a learning-based account in the General Discussion.

While researchers generally agree on the activation of words from both languages, they disagree on whether words from the non-target language compete for selection. Language-specific accounts (Costa et al., 1999; Costa & Caramazza, 1999; Roelofs, 1998) propose that lemmas (syntactic representation of lexical words) and lexemes (phonological representation of lexical words) from both languages are activated, but only those from the target language are considered for selection during speech production. Conversely, language-nonspecific accounts (Abutalebi & Green, 2007; Colomé, 2001; Green, 1986, 1998; Hermans et al., 1998) propose that lemmas and lexemes from both languages compete for selection, even in contexts where the non-target language is entirely irrelevant.

A widely used method to investigate whether lexical selection is language specific or non-specific is picture-word interference (PWI). In typical PWI experiments, participants name a target picture while ignoring a distractor word that is semantically or phonologically related to the target name. Participants using their native language (L1 speakers) take longer to name a picture (e.g., *apple*) when it is paired with a semantically related word (e.g., *pear*) than an unrelated word (e.g., *shoes*) (Glaser & Düngelhoff, 1984; Hantsch et al., 2005; La Heij, 1988; Lupker, 1979). This semantic interference effect is standardly explained by competition at the lemma level, and typically occurs when the distractor word precedes (e.g., SOA -150 ms) or is presented simultaneously (SOA 0 ms) with the target picture (Caramazza &

Costa, 2000; Damian & Bowers, 2003; for review, see Bürki et al., 2020); note that some studies did not find this effect with auditory distractors at SOA 0 ms (e.g., Damian & Martin, 1999; Schriefers et al., 1990).

In contrast, participants are quicker at naming a picture that is paired with a phonologically related distractor than an unrelated distractor. This phonological facilitation effect occurs when distractors are presented simultaneously with (SOA 0 ms) or shortly after (e.g., SOA +150 ms) the target pictures (Abel et al., 2009; Damian & Bowers, 2009; De Zubicaray & McMahon, 2009; Lupker, 1979; Meyer & Schriefers, 1991; Pisoni et al., 2017; Schriefers et al., 1990; Starreveld & La Heij, 1996). It also occurs when distractors precede (e.g., SOA -150 ms) the pictures (Abel et al., 2009; Damian & Martin, 1999; Jescheniak & Schriefers, 2001; Meyer & Schriefers, 1991; Starreveld, 2000; Ventura et al., 2007; Wilshire et al., 2016; H. Zhao et al., 2012), though it is important to note that not all studies have found such early facilitation (e.g., Schriefers et al., 1990; Zhang et al., 2009).

Many researchers argue that early and late phonological facilitation have different explanations. The late effect is believed to occur at the lexeme level: The phonologically related distractor activates phonological segments shared with the target word, thereby facilitating retrieval of its lexeme (Hansen et al., 2017; Meyer & Schriefers, 1991; Schriefers et al., 1990; Starreveld, 2000). In contrast, the early effect is attributed to activation at the lemma level (Jescheniak & Schriefers, 2001; Roelofs et al., 1996; Starreveld, 2000): The phonologically related distractor facilitates the selection of the target lemma via feedback from the activated shared phonological segments.

Semantic interference and phonological facilitation are also observed in L2 speakers, with the time course of these effects largely mirroring those in L1 speakers. For example, semantic interference in L2 speakers is commonly found at early SOAs, such as SOA -150 ms (Hermans, 2000; Hermans et al., 1998) and SOA 0 ms (Hermans et al., 1998; Hoshino & Thierry, 2011). Similarly, phonological facilitation in L2 speakers is often observed at both early SOAs (e.g., SOA -150 ms) (Hermans, 2000; Hermans et al., 1998) and late SOAs (e.g., SOA 0 ms and +150 ms) (Boukadi et al., 2015; Hermans, 2000; Hermans et al., 1998; Hoshino & Thierry, 2011).

3.1.1. ***Cross-language identity effect***

Alongside the patterns of semantic and phonological activation, two key PWI effects—the cross-language identity effect and, more importantly for this study, the phono-translation effect—play a crucial role in assessing whether bilingual lexical selection is language specific or nonspecific. The cross-language identity effect refers to facilitation when a picture is paired with a distractor word that is the translation of the picture name. Costa et al. (1999) had Catalan-Spanish bilinguals name pictures (e.g., a table as *taula*) in Catalan while ignoring their written Spanish translations (e.g., *mesa*). If lexical selection is language-nonspecific, naming would be inhibited, because the lexical node of the Spanish translation (here, *mesa*) receives activation from both the picture *table* and the distractor word *mesa*, making *mesa* a stronger competitor than an unrelated Spanish distractor, which only receives activation from the distractor itself. But if lexical selection is language-specific, naming would be facilitated, because the target word (here, *taula*) receives additional activation from the Spanish distractor *mesa* (through the shared semantic representation), and this additional activation facilitates the selection of the target lemma *taula* (as *mesa* itself is not considered), compared to an unrelated distractor.

In support of the language-specific account, Costa et al. (1999) observed such facilitation, as did subsequent studies (Dylman & Barry, 2018; Roelofs et al., 2016; Tomoschuk et al., 2021).

3.1.2. ***Phono-translation effect***

While the cross-language identity effect supports the language-specific account, the data relating to the phono-translation effect is far less clear. The phono-translation effect occurs when bilinguals name pictures in the target language while being presented with a distractor word (either in the non-target or target language) that is phonologically related to the picture's name in the non-target language – that is, the translation of the picture's name in the target language.

In the first report, Hermans et al. (1998, Experiment 1) had Dutch-English bilinguals name pictures in English (e.g., a mountain as *mountain*; the Dutch name is *berg*) while hearing an English distractor (*bench*). They assumed that lexical selection is language non-specific and predicted interference. The logic behind this prediction was as follows: the phono-translation distractor (*bench*) would activate not only the lexeme of the picture's translation (*berg*) because of their shared phonological segments, but also the translation's lemma via feedback from shared phonological segments. Therefore, both the lemma and lexeme of the Dutch translation (*berg*) are more activated than when the picture is paired with an unrelated distractor. The lemma activation should slow down the target English lemma selection, assuming language non-selectivity. Alternatively, the naming response may also be slowed down because the additionally activated Dutch lexeme makes it harder to retrieve the target word lexeme.

To determine whether any phono-translation interference effect occurs at the lemma or lexeme level, Hermans et al. (1998) also paired pictures with semantically and phonologically related distractors. They hypothesized that if the effect occurs at the same SOAs as semantic interference (which is assumed to occur at the lemma level), this would suggest that this (interference) effect also occurs at the lemma level, and hence indicate that the lemma of the picture's translation in the non-target language is activated and competes for selection. In contrast, if the (interference) effect from the phono-translation distractor occurs at SOAs where phonological facilitation but not semantic interference is observed, it would imply that the phono-translation (interference) effect is localized at the lexeme level, and indicate that the lexeme of the picture's translation is activated, but it would not, in and of itself indicate whether word selection is language specific or non-specific.

However, Hermans et al. (1998) made no predictions regarding the language-specific accounts, which suggest that target picture naming should be facilitated. The reasoning is as follows: The phono-translation distractor activates the picture's translation, which in turn additionally activates the target word through its semantic representation. This additional activation should facilitate the selection of the target word relative to contexts with an unrelated distractor, when only words from the target language are considered for selection.

Hermans et al. (1998, Experiment 1) found phono-translation interference only at 0 ms SOA (significant only in the by-participant analysis), and also found semantic interference and phonological facilitation at this SOA (in comparison to an unrelated distractor). The authors attributed the weak phono-translation effect to the limited phonological overlap between English distractors and Dutch picture names, and therefore conducted Experiment 2 using Dutch distractors. In Experiment 2, they found phono-translation interference at -150 ms and 0 ms SOAs, semantic interference at -150 ms SOA, but no phonological facilitation at either of the two SOAs. This led the authors to conclude that only lemmas, but not lexemes, of words in the non-target language were activated. The direction of the phono-translation effect—interference rather than facilitation also led the authors to believe that lexical selection is language non-specific.

Several more recent studies have used this paradigm to investigate bilingual lexical selection process. As Table 8 indicates, some experiments found interference

Table 8

Studies Using Picture-Word Interference to Investigate the Effects of a Distractor Word Phonologically Related to the Picture Name in the Non-Target Language

Study	Experiment No.	Language pair	L2 proficiency	Language context	Observations per condition	Semantic (ms)				Phonological (ms)				Phono-translation (ms)			
						-300	-150	0	+150	-300	-150	0	+150	-300	-150	0	+150
Hermans et.al. (1998)	Experiment 1 (audio distractors in L2, response in L2)	Dutch–English	Five years of English education	One-Language	384	44 (*)	19 (* by subject, *ns* by item)[6]	31 (*)	-10 (ns)	-19 (* by subject, *ns* by item)	-24 (* by subject, *ns* by item)	-31 (*)	-64 (*)	14 (ns)	5 (ns)	28 (*by subject, *ns* by item)	5 (ns)
	Experiment 2 (audio distractors in L1, response in L2)	Dutch–English	Five years of English education	Two-Language	384	17 (ns)	37 (*)	19 (ns)	13 (ns)	8 (ns)	5 (ns)	10 (ns)	-35 (*)	30 (*)	38 (*)	35 (*)	7 (ns)
Costa et.al. (2003)	Experiment 1 (audio distractors in L1, response in L2)	Spanish-Catalan	Highly-proficient	Two-Language	384	NA	28 (*)	29 (*)	15 (*)	NA	-28 (*)	-34 (**)	-31 (**)	NA	24 (.)	21 (.)	17 (.)
	Experiment 2 (audio distractors in L1, response in L2)	Spanish-Catalan	Highly-proficient	Two-Language	384	NA	25 (*)	-7 (ns)	14 (.)	NA	-1 (ns)	-40 (**)	-20 (*by subject, *ns* by item)	NA	4 (ns)	10 (ns)	20 (*)
Costa et al. (2008)	Experiment 2 (visual distractors in L1, response in L2)	Catalan-Spanish	Highly-proficient	Two-Language	384	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-15 (.)	NA
Deravi (2009)	Experiment 1 (visual distractors in L1, response in L2)	Persian-French	Highly proficient and balanced	Two-Language	168	-23 (ns)	-27 (ns)	-5 (ns)	-33 (*)	1 (ns)	-40 (*)	-45 (*)	-88 (*)	-1 (ns)	-21 (ns)	-28 (ns)	-44 (*)
	Experiment 2 (audio distractors in L1, response in L2)	Persian-French	Highly proficient and balanced	Two-Language	184	-15 (*)	13 (ns)	-4 (ns)	11 (ns)	-22 (*)	16 (ns)	-15 (ns)	14 (ns)	36 (*)	31 (*)	-15 (ns)	27 (ns)
	Experiment 3 (audio distractors in L2, response in L1)	Persian-French	Highly proficient and balanced	Two-Language	161	-59 (*)	-28 (*)	-18 (*)	36 (*)	-60 (*)	-17 (*)	-25 (*)	-36 (*)	-24 (*)	-42 (*)	19 (ns)	14 (*)
Hoshino & Thierry (2011)	Experiment 1 (visual distractors in L1, response in L2)	Spanish-English	Proficient	One-Language	988	NA	NA	35 (**)	NA	NA	NA	27 (*)	NA	NA	NA	22 (*)	NA

[6] The significance levels for the effects reported by Herman et al. (1998) and Deravi (2009) were not specified, so we assumed a significance level of $p < .01$ (*) if the authors indicated significance without explicitly stating the level.

Boukadi et al. (2015)[7]	Experiment 1 (audio distractors in L2, response in L2)	Arabic-French	Moderately-proficient	One-Language	161	NA	NA	-17 (ns)	NA	NA	NA	-20 (**)	NA	NA	NA	2 (ns)	NA
	Experiment 2 (audio distractors in L1, response in L2)	Arabic-French	Moderately-proficient	Two-Language	528	NA	NA	19 (*)	NA	NA	NA	18(**)	NA	NA	NA	24 (***)	NA
Goh & Chen (2017)	Experiment 1 (audio distractors in L2, response in L1)	English-Chinese	Highly-proficient	Two-Language	528	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.1 (ns)	NA
	Experiment 1 (audio distractors in L2, response in L1)	English-Chinese	Low-proficient	Two-Language	348	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.8 (ns)	NA
	Experiment 1 (audio distractors in L1, response in L2)	English-Chinese	Highly proficient	Two-Language	348	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	53 (**)	NA
	Experiment 1 (audio distractors in L1, response in L2)	English-Chinese	Low proficient	Two-Language	348	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-38 (*)	NA
Klaus et al. (2018)	Experiment 1 (audio distractors in L2, response in L1)	Dutch-English	Acquired English in high school (10.1 years of experience)	Two-Language	348	NA	NA	NA	NA	NA	NA	NA	NA	NA	22 (***)	25 (ns)	NA
	Experiment 2 (audio distractors in L2, response in L1)	Dutch-English	8.9 years of experience	Two-Language	672	NA	NA	NA	NA	NA	NA	NA	NA	NA	17 (ns)	15 (ns)	NA
	Experiment 3 (audio distractors in L2, response in L1)	Dutch-English	9.9 years of experience	Two-Language	672	NA	NA	NA	NA	NA	NA	NA	NA	NA	39 (.)	NA	NA
Hoshino et al. (2021)	Experiment 1 (audio distractors in L1, response in L2)	Spanish-English	Living in the L2 environment	Two-Language	672	NA	NA	37 (**)	NA	NA	NA	-27 (*)	NA	NA	NA	-48 (***)	NA
	Experiment 2 (audio distractors in L1, response in L2)	Japanese-English	Living in the L2 environment	Two-Language	768	NA	NA	5 (ns)	NA	NA	NA	-8 (ns)	NA	NA	NA	-7 (ns)	NA

Note. The symbols (ns), (.), (*), (**), (***) following values indicate the statistical significance levels of the effects. Specifically, (ns) indicates no statistical significance by F1 or F2 or linear mixed effects models; (.) indicates marginal significance (.05 < p < .1) by F1 or F2 or linear mixed effects models; (*) indicates significance at p < .05 by F1 and F2, or linear mixed effects models; (**) indicates significance at p < .01 by F1 and F2, or linear mixed effects models; (***) indicates significance at p < .001 level by F1 and F2, or linear mixed effects models; NA indicates that some SOAs were not used in certain experiments and therefore no effects were applicable for those specific SOAs

[7] Although Boukadi et al.'s (2015) study used three SOAs (-150 ms, 0 ms, +150 ms), they did not report the effects at -150 and +150 ms SOA.

from a phono-translation distractor (Boukadi et al., 2015; Costa et al., 2003; Hermans et al., 1998; Hoshino & Thierry, 2011; Klaus et al., 2018), but other experiments found facilitation (Costa et al., 2008; Deravi, 2009; Goh & Chen, 2017; Hoshino et al., 2021), and still others found no significant effect (Boukadi et al., 2015; Goh & Chen, 2017; Hoshino et al., 2021; Klaus et al., 2018). Interestingly, researchers have focused on explaining the interference effect – there has been little interest in explaining facilitation.

Most researchers have followed Herman's (1998) language non-specific selection explanation, which posits that words from both languages compete for selection. Therefore, for L1 Dutch-L2 English bilinguals, naming a picture (e.g., of a mountain) in English would be slowed down by a Dutch distractor (e.g., *berm*, meaning verge). This slowing occurs because *berm* phonologically overlaps with the picture's Dutch name (*berg*), thereby additionally activating this translation. However, this interpretation cannot explain the cross-language identity effect discussed above – that is, the facilitation effect observed with cross-language identity distractors (i.e., translations), as has been noted by some researchers (Costa et al., 2008; Dylman & Barry, 2018). For example, if naming a picture of a mountain in English is slowed down by the Dutch distractor *berm* due to its phonological overlap with *berg*, then naming should be inhibited further by the distractor *berg* itself. But this is not the case, as discussed above: The cross-language identity effect is facilitatory, not inhibitory (Costa et al., 1999).

This paradox challenges Herman et al.'s (1998) interpretation and raises questions about the reliability of these two effects. To explore this further, Costa et al. (2008) investigated the cross-language identity effect and the phono-translation effect using a Stroop task in which Spanish-Catalan bilinguals read L1 Spanish words and named the colour of the ink in their L2 Catalan. In critical conditions, the Spanish distractor words were the Spanish translations of the colour names or phonologically related to the Spanish translation of the colour names. They found cross-language identity facilitation, but no phono-translation interference effect – in fact, there was statistically marginal facilitation. However, because this paradigm is very different from the PWI paradigm, we cannot be sure what is causing the lack of phono-translation interference effect.

It is of course possible that the extent to which a non-target language is activated and engages in selection may depend on whether it is contextually relevant or not. We can contrast a one-language context when the session is entirely in one language (i.e., the stimuli are in one language, participants respond in that language, and any instructions or pre-tests for participants are in that language) with a two-language context, where both languages are involved (i.e., the stimuli, instructions, or pre-tests are in one language, but participants respond in a different language).

Cross-language activation may be very different in one- and two-language contexts. In a one-language context, only the target language is used in the experimental session (or real-world situation). In a two-language context, both languages are used. Grosjean (1998, 2001, 2008) argued that bilinguals' language activation levels and processing mechanisms depend on the context. In a two-language context[8], they activate both languages, but in a one-language context, they do not.

Thus, bilingual processing can be very different in a one- and a two-language

[8] Grosjean (1998, 2001, 2008) used the term "bilingual context" for a "two-language context" and "monolingual context" for a "one-language context".

context. In other words, lexical selection can be language non-specific in a two-language context but language-specific in a one-language context. Therefore, using a one-language context is crucial for the strongest test of language selective versus non-selective accounts, ensuring that stimuli, instructions, or any procedural elements do not inadvertently activate the non-target language. Currently, most phono-translation experiments (14 out of 17) were conducted in a two-language context (see Table 8). The findings from them, as argued above, may not reflect the bilingual language processing process in a one-language context.

In sum, we cannot be certain about the existence of the phono-translation effect or whether it is facilitatory or inhibitory. Given its importance to theories of language production in bilinguals, further research is clearly needed. A major concern is that previous studies appear to have been considerably underpowered (see Table 1): They all fall well short of the recommended minimum of 1600 observations per condition in reaction time experiments with repeated measures (Brysbaert & Stevens, 2018). Clearly, inadequate power would go some way to explaining the highly inconsistent pattern of results in these studies.

3.1.3. ***The present study***

We therefore conducted a large-scale phono-translation experiment (Experiment 4) within a one-language context involving highly proficient Chinese-English bilinguals, and included a control experiment (Experiment 5). The primary goal of the study was to investigate whether there is cross-language activation and competition in bilingual language production in a one-language context that minimizes non-target language activation. If cross-language activation and competition are observed, it would strongly suggest that activation and selection are inherently non-specific. Conversely, if no cross-language activation or competition is found, it would suggest that activation and selection can be contextually selective. A secondary goal of our study was to compare patterns of facilitation and interference in L1 and L2 speakers, given the paucity of direct comparisons between bilinguals and monolinguals.

In Experiment 4, we asked 120 Chinese-English bilinguals to name pictures in English while ignoring English distractors which were semantically related (e.g., *gloves*), phonologically related (e.g., *ham*), or unrelated (e.g., *bell*, baseline condition) to the English name of the picture (e.g., *hat*), or (in the critical phono-translation condition) phonologically related to the Chinese name of the picture (e.g., *mouse*, related to *mao zi*), at three SOAs (-150 ms, 0 ms, +150 ms).

Both the language specific and non-specific accounts predict early interference from the semantically related distractor relative to the unrelated distractor and phonological facilitation relative to the unrelated distractor. But they differ with respect to the phono-translation condition. According to the language-specific account, a phono-translation distractor word activates the lemma and lexeme of the target's Chinese translation, which activates the semantic representation (that is shared between the target and the Chinese translation), and this semantic representation in turn activates the lemma and lexeme of the target word. Since only words from the target language are considered for selection, the additional activation of the target word should facilitate naming. But for this to take place, this activation must occur before the speaker has selected the target lemma, and so the account predicts facilitation is most likely when the distractor is presented early – that is, just before the target picture.

According to the language-nonspecific account, a phono-translation distractor word activates the lemma and lexeme of the target's Chinese translation, and this extra activation makes the translation word highly activated because it receives activation from both the picture and the phono-translation distractor. Since words from both languages compete for selection, the highly activated Chinese translation word will interfere with the selection of the target English word (compared to unrelated distractors). As in Hermans et al. (1998), if this interference effect is observed at the same SOAs as semantic interference, we would infer it occurs at the lemma level. In contrast, if the interference effect is observed at SOAs where only phonological facilitation but not semantic interference is present, we would infer it occurs at the lexeme level.

Any effects in Experiment 4 might conceivably be due to irrelevant characteristics of the stimuli in the phono-translation condition relative to the other conditions (e.g., relations between the target picture name and the distractor word). We therefore conducted Experiment 5, in which we repeated Experiment 4 but with L1 English speakers who did not know Chinese (and who were monolingual). Clearly, such participants should show no phono-translation effect, as this effect depends on activation of the Chinese translation of the target name. However, we expected early semantic interference and broad phonological facilitation in Experiment 5, just as in Experiment 4, assuming that L2 participants produce language in a roughly similar manner to L1 participants (except, of course, for cross-language activation).

As previous studies showed highly inconsistent effects (see Table 1), we decided not to conduct a power analysis based on those studies. Instead, we followed the guidelines of Brysbaert and Stevens (2018), who advised assuming a typical small effect size (*d* = .1) in reaction time experiments and collecting a minimum of 1,600 observations per condition in a repeated measures design (which is considerably greater than any experiment in Table 1). In our study, we exceeded the recommended minimum by including 40 participants and 44 items per condition, resulting in 1,760 observations per condition.

3.2. Experiment 4

L1 Chinese speakers were asked to name pictures in L2 English, while ignoring distractor words also presented in English.

3.2.1. ***Method***

In this and the subsequent experiments, we provide full details on participant selection, manipulations, measures, and data exclusions. All relevant materials, data, and analysis scripts are accessible at https://osf.io/2aew8/. The experiments' designs and the analyses were not preregistered.

3.2.1.1. Participants

One hundred and twenty Chinese students (17 males, 101 females, and 2 others) aged 18-31 (*M* = 22.92 years, *SD* = 2.40) at the University of Edinburgh took part in this experiment. All of them met the following criteria: (1) Mandarin Chinese was their first language and English was their second language, (2) they had studied English for at least 10 years, and (3) they had lived in the UK for at least 6 months and were currently studying in the UK. Each participant was paid £6. We excluded an additional 21 participants who missed out more than 15% of the trials. Participants' language history and English proficiency are given in Table 9. The study was approved by the Ethics Committee of the Department of Psychology, University of Edinburgh.

Table 9

The Language History and Proficiency of the Chinese-English Participants in Experiment 4

Measure	Mean
English self-rating (5-point scale)	3.43 (0.62)
English proficiency test (LexTALE score)	63.50 (9.79)
Daily English usage (hours)	4.86 (3.38)
Age of English acquisition (years)	7.27 (2.77)
Length of immersion (months)	16.21 (19.56)

Note. Standard deviations are in parentheses.

3.2.1.2. Design

In this experiment, we manipulated SOA and type of distractor. SOA was a between-participant factor with three levels: -150 ms, 0 ms, and +150 ms. Type of distractor was a within-participant factor with four levels: phonologically related, semantically related, phono-translation, and unrelated.

3.2.1.3. Stimuli

The target picture stimuli consisted of 88 colored pictures (44 experimental pictures and 44 filler pictures) taken from Zhou and Chen (2017), who investigated naming norms and latencies for 435 images in Mandarin Chinese. We chose pictures from this study because they incorporated texture and color details, which can facilitate objects recognition and improve their name agreement (Rossion & Pourtois, 2004). For all selected pictures, name agreement was at least 0.87, and two further L1 Chinese speakers agreed they were easy to identify. In addition, ten pictures selected from the same pool were used as practice items. None of the pictures had names that were cognates with their Chinese counterparts (e.g., 披萨/*pi1sa4*/ and *pizza*, both meaning pizza).

Each experimental picture (e.g., a hat) was presented 4 times and each time with a different distractor word: a phonologically related word (e.g., *ham*), a semantically related word (e.g., *gloves*), a word phonologically related to the Chinese translation of the target name (e.g., *mouse*), and an unrelated word (e.g., *bell*). The distractors across the four conditions were matched on a range of lexical properties including lemma frequency (4.59, 4.33, 4.29, and 4.41, in terms of the Zipf scale[9] of word frequencies), number of letters (4.95, 5.39, 5.20, and 4.91), number of phonemes (3.91, 4.57, 4.52, and 4.07), and number of syllables (1.39, 1.61, 1.55, and 1.52). We used the Zipf frequency measure because its interpretation does not depend on the size of the corpus and it provides a better prediction of word processing times than measures from corpora such as BNC and CELEX (van Heuven et al., 2014). The phoneme and syllable counts were derived from the IPA transcription.

In the semantically-related condition, distractors were from the same semantic category as the picture names and were not phonologically or orthographically related to the picture names or their translations. In addition, we ensured that the semantically related distractor words were not associatively related

[9] The Zipf scale, a measure of word frequencies on a logarithmic scale, was obtained from the SUBTLEX-UK (van Heuven et al., 2014) which collected British English word frequencies based on television subtitles. This scale ranges from 1 to 7. Words with Zipf values of 3 or lower are considered low-frequency, while those with Zipf values of 4 and higher are considered as high-frequency words. A Zipf value of 4 corresponds to words that occur 10 times per million words.

to the picture names. Twenty-four L1 English speakers, recruited from the online participant pool platform Prolific, rated how related the meanings of 44 semantically related distractor words and their accompanying picture names (plus 44 unrelated fillers) were on a 1-7 scale (1 = "unrelated" to 7 = "very related"). The mean relatedness rating in the semantically related condition was 5.76. In the phonologically related condition, distractors and targets shared at least the first two phonemes.

To disguise the relationship between the experimental pictures and the distractors, we included 44 filler trials. These filler trials corresponded to 44 new pictures, each paired with an English distractor that was (semantically or phonologically) unrelated to the picture. Each filler picture was presented only once.

The pronunciations of the English distractor words were generated using Voicemaker (an online text to speech converter, https://voicemaker.in/) into MP3 format with the synthesized voice "Neural US_MadisonAI3Voice" (Jadhav, 2020). These converted stimuli were judged as comprehensible and natural by two further Chinese-English bilinguals from the same population as the experimental participants.

Stimuli were presented to participants in five blocks of 44 trials each. Item order was fixed, with a minimum of 20 trials before any repeated presentation of the same picture and no more than two trials from the same experimental condition in a row. A total of ten orders were created, and the same set of ten orders was used across all three SOAs. For each SOA, participants were randomly assigned to one of the ten orders, with each order being allocated to four participants. To familiarize participants with the task, each order began with five additional practice trials in which filler pictures were paired with unrelated distractor words. In total, there were 220 experimental trials, including 176 critical trials and 44 filler trials.

3.2.1.4. Procedure

Participants were tested individually in a laboratory at The University of Edinburgh. They were first exposed to all the pictures alongside their English printed names, and were told to use only these printed names to name the pictures during the experiment. After participants indicated that they had remembered all the names of the pictures, they were presented with all the pictures again, but this time without the printed names, and were instructed to name each picture. An experimenter told them whether they used the correct name. Pictures that were named incorrectly were re-presented until all of them were named correctly.

During the experiment, participants were instructed to sit in front of a computer screen at a distance of about 60 cm and to remain this distance throughout the experiment. Each trial began with a centered fixation cross for 500 ms, followed by a blank screen for 500 ms, and a centered picture for 2000 ms. The onset of the auditory distractor preceded the presentation of the picture by 150 ms (SOA -150 ms), coincided with the picture onset (SOA 0 ms), or followed the onset of the picture by 150 ms (SOA +150 ms). The experiment was run by the experimental software Testable (Rezlescu et al., 2020) and took about 15 minutes.

After the experiment, participants were given the LexTALE test (a “Yes” or “No” vocabulary test; Lemhöfer & Broersma, 2012) as a measure of their English proficiency; it took about 3.5 minutes. Finally, they completed a L2 history questionnaire that asked about age of acquisition, self-assessed L2 proficiency, daily L2 usage, and duration of immersion in an L2-speaking country (see Appendix B).

3.2.2. ***Data analysis***

Naming latencies were measured from picture onset to vocal response. If a participant did not respond within 2000 ms, the experiment moved to the next trial. In addition, there was a pause of 1000 ms at the end of each trial. Each trial lasted 4 seconds. Before analyzing data, we first transcribed the responses. For experimental trials, we removed responses that did not use the expected picture name, responses that contained speech disfluencies (such as stuttering and utterance repairs), responses that participants did not make within 2000 ms (8.05% of the data), and correct responses that were less than 200 ms (0.07%) or were more than 2 standard deviations from the participant's mean by condition (4.73%).

We used linear and generalized linear mixed-effects models in the lme4 package (version 1.1.26; Bates et al., 2015) of R (v. 4.2.2; R Core Team, 2021) to analyze the naming latencies and accuracy respectively. We analyzed the main effects of distractor type and SOA on naming latency and accuracy. We also analyzed the effect of distractor type on naming latency and accuracy for each of the three SOAs (-150 ms vs. 0 ms vs. 150 ms). For both naming latency and accuracy, by-participant and by-item random effects were included in our models, and we specified the maximal random effects structure in all models from the beginning. If the maximal models did not converge, the models were progressively simplified in the order of removing random correlations, interactions of random effects, and random slopes corresponding to main effects, until the models converged. Significance was calculated using the lmerTest package (Kuznetsova et al., 2017), and we used the bobyqa optimizer.

3.2.3. ***Results***

In the following analyses we considered only responses to the experimental trials. Table 10 provides an overview of the mean naming latency[10] and accuracy for each distractor type at each SOA separately.

Table 10

Experiment 4: Mean Naming Latencies (NL, in ms), Standard Deviations (SD, in ms), and Mean Accuracy (A, in %) for Each Distractor Type and Picture-Word Stimulus Onset Asynchrony (SOA) for Bilingual Speakers

Distractor type	SOA							
	-150		0		+150		Mean	
	NL (SD)	A	NL (SD)	A	NL (SD)	A	NL (SD)	A
Phonological	1000 (123)	92.8	950 (161)	94.2	856 (132)	92.7	935 (151)	93.2
Semantic	1035 (109)	90.8	983 (151)	91.4	882 (149)	91.2	967 (150)	91.1
Phono-translation	1001 (98.8)	92.4	967 (130)	91.6	869 (124)	89.4	946 (130)	91.1

[10] In this experiment, we also conducted an analysis to explore correlations between participants' naming latencies and their English proficiency, age of English acquisition, and duration of immersion in an English environment in the different distractor type conditions and SOAs. No significant correlations were found between these factors and participants' naming latencies across all experimental conditions and SOAs (all *ps* > .05).

Unrelated	1016 (108)	92.7	971 (156)	92.3	871 (139)	92.0	953 (148)	92.3
Mean	1013 (108)	92.2	968 (147)	92.4	870 (135)	91.3	950 (209)	92.0

3.2.3.1. Naming accuracy for bilingual speakers

The analysis of accuracy revealed that the main effect of SOA was not significant ($\chi^2(2) = 1.81$, $p = .404$). There was a main effect of distractor type ($\chi^2(3) = 24.38$, $p < .001$), but no interaction between the two factors ($\chi^2(6) = 10.12$, $p = .120$). Further analysis showed that, compared to unrelated distractors, semantically related distractors led to lower naming accuracy ($B = -0.19$, $SE = 0.08$, $z = -2.28$, $p = .023$), and phonologically related distractors led to higher naming accuracy ($B = 0.23$, $SE = 0.09$, $z = 2.45$, $p = .014$). Phono-translation distractors had no impact on naming accuracy ($B = -0.14$, $SE = 0.10$, $z = -1.41$, $p = .159$).

3.2.3.2. Naming latencies for bilingual speakers

The latency analysis showed a main effect of SOA ($F(2, 119.85) = 12.27$, $p < .001$) and a main effect of distractor type ($F(3, 140.99) = 24.73$, $p < .001$), but there was no interaction between SOA and distractor type ($F(6, 162.93) = 1.35$, $p = .240$). Subsequent analysis revealed that compared to the 0 ms SOA, naming latency was shorter at +150 ms SOA ($B = -98.05$, $SE = 29.23$, $t = -3.36$, $p = .001$). There was no difference in naming latency between 0 and -150 ms SOA ($B = 44.29$, $SE = 29.30$, $t = 1.51$, $p = .133$).

Importantly, further analyses showed that irrespective of SOA, semantically related distractors led to longer naming latencies than unrelated distractors ($B =$

12.83, $SE = 3.28$, $t = 3.91$, $p < .001$), and phonologically related distractors led to shorter naming latencies than unrelated distractors ($B = -18.39$, $SE = 3.85$, $t = -4.78$, $p < .001$). Most interestingly, phono-translation distractors led to shorter naming latencies than unrelated distractors ($B = -7.77$, $SE = 3.50$, $t = -2.22$, $p < .05$).

We then conducted separate analyses at each SOA. At -150 ms SOA, compared with unrelated distractors, semantically related distractors led to longer naming latencies ($B = 18.21$, $SE = 5.31$, $t = 3.43$, $p < .001$). Phonologically related distractors led to shorter naming latencies ($B = -17.14$, $SE = 5.28$, $t = -3.25$, $p = .001$). Phono-translation distractors also led to shorter naming latencies ($B = -15.55$, $SE = 5.29$, $t = -2.94$, $p = .003$).

At 0 ms SOA, compared with unrelated distractors, semantically related distractors led to longer naming latencies ($B = 11.21$, $SE = 5.58$, $t = 2.01$, $p = .044$). Phonologically related distractors led to shorter naming latencies ($B = -21.98$, $SE = 5.54$, $t = -3.97$, $p < .001$). There was no difference in naming latency between phono-translation distractors and unrelated distractors ($B = -4.27$, $SE = 5.59$, t = -0.77, $p = .444$).

At +150 ms SOA, there was no difference in naming latency between semantically related distractors and unrelated distractors ($B = 9.66$, $SE = 5.60$, $t = 1.73$, $p = .09$). Phonologically related distractors led to shorter naming latencies than unrelated distractors ($B = -15.64$, $SE = 5.63$, $t = -2.78$, $p = .008$). There was no difference in naming latency between phono-translation distractors and unrelated distractors ($B = -3.15$, $SE = 5.58$, $t = -0.57$, $p = .57$).

3.2.4. ***Discussion***

In Experiment 4, Chinese-English bilinguals showed overall semantic interference, phonological facilitation, and phono-translation facilitation irrespective of SOA. Further analysis revealed that semantically related distractor words led to interference at -150 ms and 0 ms SOA, phonologically related distractor words led to facilitation at -150 ms, 0 ms, and +150 ms SOA, and phono-translation distractors led to facilitation at -150 ms SOA.

The phono-translation facilitation effect at SOA -150 ms accords with Costa et al. (2008), Deravi (2009), Goh and Chen (2017), and Hoshino et al. (2021) but not Boukadi et al. (2015), Costa et al. (2003), Hermans et al. (1998), Hoshino and Thierry (2011), and Klaus et al. (2018); see table 1. This facilitation suggests that while the picture's Chinese name was activated, it did not engage in lexical selection of the target name, which would have otherwise resulted in a phono-translation interference effect. The presence of the phono-translation facilitation and semantic interference at the same SOA further confirms that the phono-translation facilitation effect comes from the lexical selection process but not the lexeme retrieval process, and hence suggests that the picture's Chinese translation is activated at the lemma level but is not phonologically encoded.

We now turn to Experiment 5, which used the same experimental materials and procedures as Experiment 4, but involved participants who were L1 English speakers with no knowledge of Chinese. We conducted the experiment for three reasons. Most importantly, we have concluded that the phono-translation facilitation effect arises from the non-competitive activation of words in the non-target language. But it is possible that it is due to irrelevant characteristics of the distractors that differ from the characteristics of the distractors in the other conditions. In addition, we wished to investigate whether there is early phonological facilitation in monolinguals (considering the inconsistent previous findings such as those reported by Meyer and Schriefers (1991) and Schriefers et al. (1990). Finally, a comparison of the two experiments would allow us to determine whether Chinese-English bilinguals process within-language distractors similarly to L1 monolingual English speakers.

3.3. Experiment 5

In this experiment, L1 English speakers with no knowledge of Chinese took part in the same tasks as in Experiment 4, except that they did not complete the LexTALE English language proficiency test or the English learning questionnaire.

3.3.1.1. Participants

One hundred and twenty L1 English speakers (42 males, 78 females) aged 17-39 (*M* = 21.67 years, *SD* = 3.77) at the University of Edinburgh took part in this experiment. All of them were from English-speaking countries (the UK, the USA, Australia, Canada, or Ireland) and had no knowledge of Chinese. Each participant was paid £6. We excluded an additional 26 participants who missed out more than 15% of the trials.

3.3.2. ***Results***

Criteria for data exclusion and statistical analysis were the same as Experiment 4. Table 11 displays the mean naming latencies and naming accuracy for each condition among L1 English speakers.

Table 9

Experiment 5: Mean Naming Latencies (NL, in ms), Standard Deviations (SD, in ms), and Mean Accuracy (A, in %) for Each Distractor Type and Picture-Word Stimulus Onset Asynchrony (SOA) for L1 English Speakers

Distractor type	SOA							
	-150		0		+150		Mean	
	NL (SD)	A	NL (SD)	A	NL (SD)	A	NL (SD)	A
Phonological	897 (137)	87.3	927 (176)	91.4	779 (164)	88.0	868 (171)	88.9
Semantic	936 (131)	86.9	954 (173)	89.8	799 (177)	87.4	896 (175)	88.0
Phono-translation	900 (123)	86.9	947 (158)	90.8	791 (168)	86.0	879 (163)	87.9
Unrelated	904 (122)	87.2	946 (164)	88.2	790 (169)	87.6	880 (165)	87.7
Mean	909 (126)	87.1	943 (166)	90.1	790 (168)	87.3	881 (222)	88.3

3.3.2.1. Naming accuracy

The analysis of naming accuracy revealed a main effect of SOA ($\chi^2(2) = 8.82$, $p = .012$), but the main effect of distractor type ($\chi^2(3) = 3.85$, $p = .278$) was not significant, and there was no interaction between these two factors ($\chi^2(6) = 3.81$, $p = .702$). Further analysis showed that compared to 0 ms SOA, the naming accuracy at both -150 ms ($B = -0.37$, $SE = .14$, $z = -2.55$, $p = .011$) and +150 ms ($B = -0.36$, $SE = .14$, $z = 2.55$, $p = .011$) was lower.

3.3.2.2. Naming latency

The analysis of latencies revealed a main effect of SOA ($F(2, 117.01) = 10.82$, $p < .001$) and distractor type ($F(3, 48.60) = 8.23$, $p < .001$), and there was an interaction between these two factors ($F(6, 126.47) = 3.06$, $p = .008$). Further analysis showed that compared to 0 ms SOA, there was no difference in the naming latency between 0 ms and -150 ms SOAs ($B = -34.26$, $SE = 32.91$, $t = -1.04$, $p = .301$), but the naming latency at +150 ms was shorter ($B = -152.71$, $SE = 37.44$, $t = 4.08$, $p < .001$). Irrespective of SOA, we found that compared with unrelated distractors, semantically related distractors led to longer naming latencies ($B = 14.63$, $SE = 7.01$, $t = 2.09$, $p = .042$), and phonologically related distractors led to shorter naming latencies ($B = -14.82$, $SE = 6.64$, $t = -2.23$, $p = .030$). But there was no effect of phono-translation distractors compared to unrelated distractors ($B = -0.23$, $SE = 7.32$, $t = -0.03$, $p = .975$).

At -150 ms SOA, we found that compared with unrelated distractors, semantically related distractors resulted in longer naming latencies ($B = 31.61$, $SE = 10.35$, $t = 3.06$, $p = .004$). However, there was no difference in naming latency between phonologically related distractors and unrelated distractors ($B = -7.96$, $SE = 9.32$, $t = -0.85$, $p = .398$) or between phono-translation distractors and unrelated distractors ($B = -3.55$, $SE = 9.62$, $t = -0.37$, $p = .714$).

At 0 ms SOA, we found that compared with unrelated distractors, there was no difference in naming latency between semantically related distractors and unrelated distractors ($B = 7.41$, $SE = 9.10$, $t = 0.81$, $p = .420$). Phonologically related distractors led to shorter naming latencies ($B = -20.07$, $SE = 8.94$, $t = -2.24$, $p = .030$), but there was no difference between phono-translation distractors and unrelated distractors (*B* = 1.89, *SE* = 9.66, *t* = 0.20, *p* = .846).

At +150 ms SOA, we found that compared with unrelated distractors, there was no difference in naming latency between semantically related distractors and unrelated distractors (*B* = 7.31, *SE* = 6.22, *t* = 1.18, *p* = .246). Phonologically related distractors led to shorter naming latencies (*B* = -12.89, *SE* = 4.79, *t* = -2.69, *p* = .007), but there was no difference in naming latency between phono-translation distractors and unrelated distractors (*B* = 1.67, *SE* = 4.98, *t* = 0.34, *p* = .738).

3.3.3. ***Discussion***

For L1 English speakers, we observed overall effects of semantic interference and phonological facilitation irrespective of SOA. Specifically, we observed semantic interference at -150 ms SOA and phonological facilitation at 0 and +150 ms SOA. Most important, there was no effect of phono-translation distractors at any SOA.

3.3.3.1. Comparison of Experiment 4 and 5

To determine whether there were significant differences in the time course and magnitude of semantic interference, phonological facilitation, and phono-translation facilitation between bilinguals in Experiment 4 and L1 English speakers with no knowledge of Chinese in Experiment 5, we conducted additional analyses on the naming latencies across experiments. Since the phono-translation facilitation effect occurred only at SOA -150 ms in Experiment 4, we limited the comparison between Experiment 4 and 5 to the SOA -150 ms condition for this effect. For semantic interference and phonological facilitation, we compared naming latencies across all SOAs in both experiments.

For the semantic interference effect, there was no interaction with the experimental group (Experiment 4 and 5) ($F(1, 17621.2) = 0.47$, $p = .494$), and the three-way interaction among semantic interference, SOA, and experimental group was also not significant ($F(2, 17620.6) = 1.68$, $p = .187$). Similarly, for the phonological facilitation, there was no interaction with the experimental group ($F(1, 17835.0) = 1.57$, $p = .210$), and the three-way interaction among phonological facilitation, SOA, and experimental group was not significant ($F(1, 17831.9) = 0.25$, $p = .777$). Most importantly, there was an interaction between the phono-translation effect and the experimental group, although it was marginally significant ($B = -3.41$, $SE = 1.86$, $t = -1.83$, $p = .067$).

The comparison of Experiment 4 and Experiment 5 suggested that there was no difference in how Chinese-English bilinguals and L1 English speakers processed semantic and phonological distractors. However, there was suggestive evidence for a difference in how they processed phono-translation distractors.

3.4. General Discussion

We conducted two large-scale picture-word interference experiments by asking Chinese-English bilingual speakers (Experiment 4) and L1 English speakers (Experiment 5) to name pictures in English while ignoring auditorily presented English distractor words which were semantically related, phonologically related, or unrelated to the English picture name, or phonologically related to the Chinese translation of the English picture name.

As expected, we observed semantic interference effect at early SOAs in both experiments: at -150 ms and 0 ms SOA in Experiment 4, and at -150 ms SOA in Experiment 5. We also found phonological facilitation in both experiments: across all 3 SOAs in Experiment 4, and at 0 and +150 ms SOA in Experiment 5. But there was a notable difference between the two experiments with phono-translation distractors: There was an early facilitation effect for phono-translation distractors at -150 ms SOA for bilinguals in Experiment 4, but no effect for L1 English speakers in Experiment 5. These results indicated that the facilitation effect found in Experiment 4 was indeed due to cross-language interaction in bilingual language production among bilinguals.

Next, we will discuss the implications of our results for the activation of information related to the non-target language in a one-language experimental setting. We will begin by examining the language-specific and non-specific selection accounts, which posit on-line activation of the non-target language, hereafter referred to as the on-line activation account. Then we will propose an alternative explanation for the phono-translation facilitation effect in our study, in which the effect is the result of learning rather than on-line cross-language activation.

3.4.1. ***On-line activation account***

The similarity in semantic interference and phonological facilitation effects in Experiments 4 and 5 suggests that processing within a single language is similar across L1 and L2 speakers. But the unique phono-translation facilitation effect in Experiment 4 but not Experiment 5 suggests that L2 speakers also activate their L1. Specifically, the Chinese-English bilinguals activated representations associated with Chinese when naming pictures in English – and, importantly, when there was no use of Chinese in the experimental context at all.

The facilitation rather than interference of the phono-translation effect aligns with the logic of the cross-language identity effect. That is, the phono-translation distractor word activates the target word's translation, which in turn sends extra activation to the target word via the semantic representation relative to an unrelated word. Although the translation word also gets extra activation from the distractor word and is therefore highly activated, it is not considered for selection and therefore does not interfere with the word selection process. In contrast, the extra activation to the target word from the distractor word facilitates picture naming compared to an unrelated distractor word. On this account, the phono-translation facilitation effect in our study suggests that in a one-language context, the non-target language is activated but does not compete for lexical selection.

Our results are therefore consistent with the predictions of the language-specific selection accounts (Costa et al., 1999; Costa & Caramazza, 1999; Roelofs, 1998) which posit that bilinguals activate both languages but consider only target language words for selection, as opposed to language non-specific selection accounts (Abutalebi & Green, 2007; Colomé, 2001; Green, 1986, 1998) that suggest words from both languages compete for selection.

As noted above, previous studies have found facilitation, interference, and no effects for phono-translation distractors relative to unrelated distractors. Given that our study is the first well-powered study conducted in a one-language context, the facilitation effect has strong theoretical implications for bilingual lexical access in a purely L2 context. As expected, we observed phono-translation facilitation only when distractor words were presented just before the pictures but not when distractors were presented simultaneously with or just after the pictures. Our explanation for this is that it takes time for the phono-translation distractor to send additional activation to the target word: The phono-translator distractor first activates the picture's translation which then activates the target word through its semantic representation.

Consequently, when distractors were presented simultaneously with or after the pictures, the naming process had already progressed beyond the target word selection stage by the time it received additional activation from the phono-translation distractor. In other words, this additional activation was too late to facilitate naming. Summarizing, the phono-translation facilitation effect observed in our study indicates that a purely English context is already sufficient for highly proficient Chinese-English bilinguals to create a selective environment in which they disregard the non-target language and freely select words from the target language, despite the activation of the non-target language.

3.4.2. ***The learning account***

Up to now we have discussed the implications of our results for the online activation account. Clearly, the observed facilitation effect in our study in a one-language context is in line with the language specific selection account that argues that when bilinguals are speaking in the target language, words from the non-target language are still activated but are not considered for selection. However, the phono-translation facilitation effect observed in our study is also compatible with a learning-based account that does not assume online cross-language activation in a one-language context (Costa et al., 2017).

Costa et al. (2017) proposed an alternative explanation for the findings reported in Thierry and Wu (2007), who had Chinese-English bilingual speakers judge the semantic relatedness of English word pairs (e.g., *train – ham*). The Chinese translations of half of the word pairs were phonologically related (here, *huo che – huo tui*), and the other half were not. They recorded event-related potentials and found that the N400 amplitude was smaller when their translations were related than unrelated. They argued that when bilinguals processed words in their L2 English, they co-activated translation equivalents in L1 Chinese – that is, they "unconsciously translated" L2 words into their L1.

Costa et al.'s (2017) alternative explanation was based on learning and did not assume online co-activation. On this account, bilingual speakers carry over the lexical structure from their L1 to their L2 during learning. When Chinese learners of English encounter the word *train*, they initially activate its translation equivalent *huo che* and activation spreads to the form-related word *huo tui*, which in turn activates its translation *ham*. As a result, *train* and *ham*, which are unrelated in the monolingual English lexicon, end up being linked together in the L2 English lexicon via Hebbian learning ("units that fire together wire together") – a link that leads to the reduction in N400 amplitude. Thus, Costa et al. (2017) argued that Thierry and Wu's (2007) findings may reflect traces of the L1 lexical structure in the L2 lexical structure, rather than on-line "unconscious translation".

More generally, Costa et al. (2017) claimed that the L2 lexicon may simply be different from the L1 lexicon. Words such as *train* and *ham* may have no association in the L1 English lexicon. But they are linked in the L2 English lexicon of a Chinese-English bilingual. Thus, the pattern of online cross-language activation that would lead to "unconscious translation" may not occur in a one-language context. Instead, it may reflect the activation of information originating from L1 that has been incorporated into L2. As we noted in the introduction, the learning account can be extended beyond "unconscious translation": Costa et al. pointed out that cognate facilitation can also be explained by learning rather than on-line activation.

Let us now consider whether the phono-translation effect can also be explained by learning rather than on-line activation. We first consider the scenario where the English word *mouse* is learned before *hat* (Scenario 1). We posit that when Chinese speakers learn the English word *mouse*, they coactivate the Chinese word *mao zi* (meaning hat in English) because of their phonological similarity, and therefore forms a link between the representations of *mouse* and *mao zi*. Later, when they learn the English word *hat,* they activate its Chinese translation *mao zi* via their semantic relationship (i.e., of equivalence), which, in turn, spreads activation to the English word *mouse* via their phonological relationship. Thus, the English words *hat* and *mouse* are co-activated during learning, and this coactivation increases the connection between them via Hebbian learning. Therefore, during the learning process, *hat* and *mouse* develop an association in the L2 lexicon of Chinese-English bilinguals.

Now consider the scenario in which Chinese speakers learn the English word *mouse* after *hat* (Scenario 2). When they learn *mouse*, they activate not only its Chinese translation *lao shu* via their semantic relationship, but also the Chinese word *mao zi* via their phonological relationship. In turn, *mao zi* spreads some activation to its English translation *hat*. As a result, the English words *mouse* and *hat* are coactivated, and therefore a connection is developed between them via Hebbian learning, and so the English words *hat* and *mouse* again become associated. Thus, the association occurs regardless of which word is learned first. This association causes the word *mouse* to prime the naming of a hat in English, as our Experiment 4 revealed, without (on-line) activation of the L1. But English monolinguals with no knowledge of Chinese have no association between *hat* and *mouse*, and so there is no priming.

To assess the plausibility of this explanation for our experimental data, we developed a simplified computational model, based on the model developed by Costa et al. (2017). Our model contained six words: three L1 (Chinese) words (*mao zi*, *lao shu*, *ling dang*) and their corresponding L2 (English) translations (*hat*, *mouse*, *bell*), with each word's activity being simulated by a neuron pool. The three Chinese words were unrelated to each other in both meaning and form, and their English translations were also unrelated to each other. Crucially, however, the English word *mouse* is phonologically related to the Chinese word *mao zi*. The model was trained in the two scenarios: Scenario 1, where *mouse* is learned before *hat,* and Scenario 2, where *mouse* is learned after *hat*.

In Scenario 1, the connection between *mao zi* and *mouse* was initialized as *Cph* to reflect their phonological similarity, and all other connections were initialized at zero. During training, for each presentation of a L2 word, the target node received an input of V_H and the corresponding translation node received an input of V_{H2}, while all other nodes received a background input of V_{VL}. To introduce variability in activation levels, each input was modified by adding random noise, ranging from 0 to Δv. The model used Hebbian learning rules outlined by Costa et al. (2017) and Oppenheim et al. (2018): During each trial, the initial activation of each node on the presentation of an L2 English word was its noisy net input—the sum of external input and the random noise. Thereafter, the initial activation of each node was calculated as the sum of the activations from all the other nodes at the previous timestep, multiplied by their connection weight to that node. This activation process continued until the network stabilized. Once stabilized, connection weights into each node were modified if the node's activation exceeded a specified threshold (Θ_L). Additionally, changes in weight (the learning speed) were scaled according to a sigmoidal function of the activation of the sending node, and over time the rate of connection weight change between nodes decelerated. All parameter values used in our model are detailed in Table 12.

Table 10

Values of All Parameters Used in Our Model

Trial number	30,000
Ω	6,000
V_H	40 a.u.
V_{H2}	15 a.u.
V_{H3}	14 a.u.
V_{VL}	4 a.u.
Δv	2 a.u.
Cph	0.15
α_L	0.001
Θ_L	20
β_L	6 a.u.

As in Oppenheim et al. (2018),we trained the model over 30,000 trials. For each trial, a L2 word was randomly selected as the target, and therefore each L2 word was presented about 10,000 times. In Scenario 1, after training, we expected that the activity of the target's translation *mao zi* should be relatively high when the target word *hat* was presented, and the activity of the word *mouse* should be relatively high too. But the activity of the other words (*lao shu*, *ling dang*, *bell*) should be relatively low.

In Scenario 2, where *hat* is learned before *mouse*, all connections were initialized to zero. For the presentation of the L2 word *mouse*, the target node *mouse*, the corresponding translation node *lao shu*, and the phonologically similar L1 word *mao zi* received inputs of V_H, V_{H2}, and V_{H3} respectively while all other nodes received a background input of V_{VL}. For the presentation of the other two L2 words (*hat* and *bell*), the target node received an input of V_H, and the corresponding translation node received an input of V_{H2}, while all other nodes received a background input of V_{VL}. We used the same learning rules from Scenario 1 and again trained the model 30,000 times. After training, we expected that the activity of *lao shu* (the translation of the target word *mouse*) would be high when *mouse* was presented. Additionally, the activity of *mao zi*, being phonologically similar to *mouse*, was expected to be high, and the activity for its English translation *hat* was expected to have an intermediate value. But the activity of words unrelated in both meaning and form to the target word and its translation (*bell*, *ling dang*) should be relatively low.

3.4.2.1. Simulation

As in Costa et al. (2017), we simulated our study in three different situations: "before learning" (panel B), "after learning with L1 co-activation" (panel C), and "after learning with only L2 activation" (panel D). The post-learning model with L1 co-activation corresponds to bilinguals in a two-language context where both languages are activated. The crucial test for our alternative learning-based hypothesis occurs in the final state, where the influence of L1 is entirely removed, corresponding to a situation where only L2 is active. To achieve this, we set all connections between L1 and L2 words to 0, as in Oppenheim et al. (2018). This setup allows us to isolate and examine the effects of learned associations within the L2 lexicon, without any influence from L1.

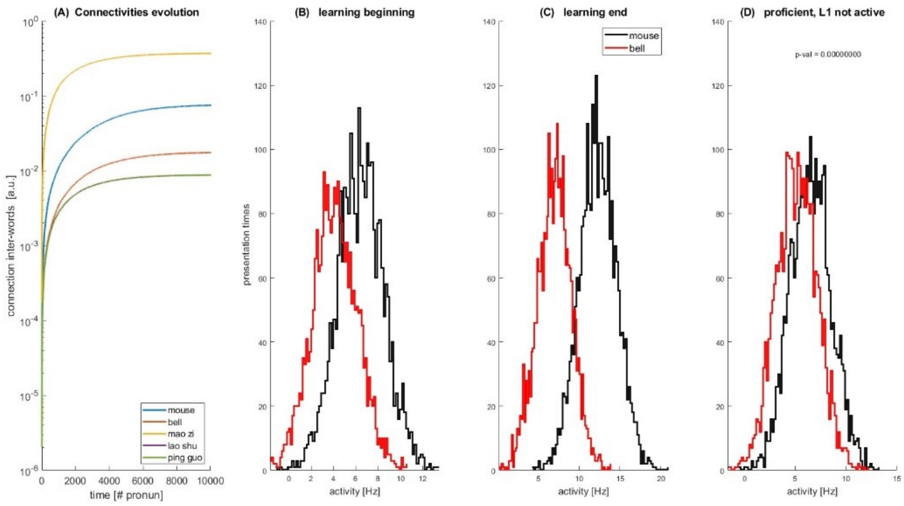
During the simulations, the target L2 word (*hat* in Scenario 1 and *mouse* in Scenario 2) was activated 8,000 times (as in Oppenheim et al., 2018), and the rules for input activation was the same as applied during the training, but without further updates to connection weights. Figure 4 shows the developmental trajectory of connections and word activations in Scenario 1 where *mouse* is learned before *hat*, and Figure 5 shows the learning process in Scenario 2 where *mouse* is learned after *hat*.

Simulation results for Scenario 1

In Scenario 1, Figure 4A shows the evolution of connection strength to *hat* from the other five words during the learning period. Initially, significant growth was observed mainly in the connection between translation pairs (*hat* and *mao zi*). Figures 4B and 4C show the activation distribution of *mouse* and *bell* before and after learning, respectively. Since there was already an established link between the representations of *mouse* and *mao zi*, learning *hat* could immediately activate *mouse* more than *bell* (*hat → mao zi→mouse*), even during the learning phase (Fig. 4B). By the end of learning, the connection strength became greater between *hat* and *mouse* than between *hat* and *bell* (Fig. 4A), and the L2 word *hat* activated the unrelated word *mouse* significantly more than the L2 word *bell* (Fig. 4C). This indicates that learning *hat* led to an association between the unrelated L2 words *hat* and *mouse*. Figure 4D shows the mean activation distribution of *mouse* (6.44) and *bell* (5.05) after all between-language connections were severed following presentation of the word *hat*. Here, a strong association between *hat* and *mouse* persisted even in an L2-only context (Cohen's d = 0.70). This suggests that the phono-translation facilitation effect in our study does not have to be explained in terms of the on-line activation of the L1. Instead, it can be explained in terms of the learned L2 association.

Figure 4

Simulation Results for Scenario 1 in Three Different Situations

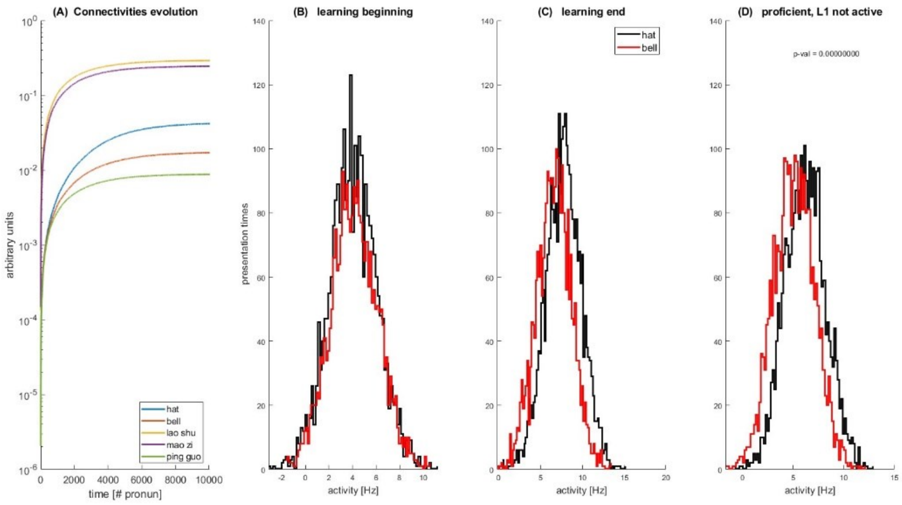


Simulation results for Scenario 2

In Scenario 2, Figure 5A shows the change in connection strength to the word *mouse* from the other five words during the learning period. Figures 5B and 5C show the activation distribution for the L2 words *hat* and *bell* before and after learning the word *mouse*, respectively. Initially, the most significant increase in connection strength was observed between the translation word pairs (*mouse* and *lao shu*), with the activation of *mouse* not yet linked to that of *hat* (Fig. 5B). However, by the end of the learning process, the connection strength between *mouse* and *hat* surpassed the connection strength between *mouse* and *bell* (Fig. 5A). This indicates that learning *mouse* led it to activating the unrelated word *hat* more than *bell* when prompted by *mouse* (Fig. 5C). These results suggest that learning the L2 word *mouse* led to an association between the otherwise unrelated L2 words *hat* and *mouse*.

Figure 5

Simulation Results for Scenario 2 in Three Different Situations



Figures 5D presents the mean activation of the L2 words *hat* (6.09) and *bell* (4.97) after severing both L1 to L2 and L2 to L1 connections. Notably, even with solely L2 words activated, a strong association between the activations of *hat* and *mouse* persisted on the presentation of *mouse* (Cohen's d = 0.56). This observation, consistent across both Scenario 1 and Scenario 2, reveals an association between *hat* and *mouse* regardless of the order in which they were learned. Importantly, this association is not attributable to simultaneous L1 activation, proving the feasibility of a learning-based account of our experimental findings.

In summary, we constructed a simplified model that simulated a learning process in which both languages are activated, followed by a post-learning process where activation is restricted to only one language. As noted above, regardless of the learning order of *mouse* and *hat*, activating *mouse* leads to increased activation of the seemingly unrelated *hat* relative to *bell* after learning and removing all L1 representations. Based on these model results, we conclude that the phono-translation facilitation effect in our study does not require the assumption of on-line activation of the non-target language; instead, it can be explained by assuming the initial activation of information that originates in the non-target language but has been transferred into the target language.

3.5. Conclusion

We conducted two large-scale picture-word interference experiments with phono-translation distractors among Chinese-English bilinguals and L1 English speakers with no knowledge of Chinese in a one-language context. We found that picture naming in bilinguals was facilitated when they were presented with a phono-translation distractor in comparison to an unrelated distractor. No such effect occurred for monolingual participants. This finding is compatible with an explanation in which lexical candidates in the non-target language are activated, but they do not engage in the target word lexical selection process. In other words, when highly proficient bilinguals are in a one-language context, lexical selection is language-specific, considering only words from the language currently in use. However, we have shown that our findings are also consistent with a learning-based explanation in which both languages are initially co-activated but where L1 is not co-activated when learning is complete. But whether the on-line or learning-based account is correct, our experiments demonstrate found that bilinguals use information associated with L1 in a purely L2 context.

4. Study 3 Experiments 6-7: Predicting Words Across Languages Depends on Language Context: Evidence from Visual World Eye-Tracking

Chapter 4 of this thesis is based on a manuscript that was submitted to a peer-reviewed journal:

Yin, H., & Pickering, M. J. (under review). Predicting words across languages depends on language context: evidence from visual world eye-tracking. *Journal of Memory and Language*. Authorship details: Yin designed the study, ran the participants, analyzed the data, and wrote the original manuscript. Pickering acted as supervisor, gave feedback on each of these steps, and contributed to the revision of the manuscript.

Note: The reference list is not included in this chapter but is brought together with other references in this thesis.

4.1. Introduction

Language comprehension is not merely a bottom-up passive process of waiting for words, but also involves actively generating top-down predictions about what is likely to occur (Huettig, 2015; Kuperberg & Jaeger, 2016; Pickering & Gambi, 2018). For bilinguals, this prediction process is made more complicated because they can conduct bottom-up and top-down processing in two languages. Researchers have extensively studied whether bilingual word recognition makes reference to both languages or not (e.g., Dijkstra et al., 1998; Thierry & Wu, 2007), but little is known about whether prediction does so or not. We therefore asked whether bilinguals predict words in just the *target* language that is currently in use (*selective prediction*) or whether they predict in both the target and the non-target languages (*non-selective prediction*). Moreover, we asked whether selectivity depends on whether they have recently encountered both languages (in a *two-language context*) or just the target language (in a *one-language context*). To address these questions, we examined whether highly proficient bilingual speakers pre-activate the phonological representations of predictable words in their native language (L1) while comprehending in their second language (L2). We conducted two experiments in which mandarin Chinese-English bilinguals (i.e., L1 Chinese) listened to English sentences while looking at pictures and we monitored their eye movements to determine what they were predicting.

This introduction has three parts: First, it reviews research on bilingual lexical access in bottom-up word recognition, suggesting that bilinguals often activate words from both languages, though this activation might vary with language context. This review supports the possibility of L1 co-activation during L2 prediction. Second, it examines predictive processing in L1 and L2 and presents evidence of L1 co-activation affecting the extent to which L2 prediction occurs during L2 comprehension. Finally, it introduces the current study, which investigates whether bilinguals predict words across languages in different language contexts.

4.1.1. ***Bilingual lexical access in bottom-up word recognition***

Decades of research has argued that words from both languages can be activated in parallel in word recognition. Much evidence comes from studies on cognates and interlingual homographs/homophones. Cognates, which are words that have both the same meaning and same or similar form across languages (e.g., *taxi* in English and Spanish), are processed faster than non-cognate controls in tasks such as lexical decision (Dijkstra et al., 1998; Duyck et al., 2007; Van Hell & Dijkstra, 2002) and progressive demasking (Dijkstra et al., 1999; Lemhöfer et al., 2008). This facilitation is often attributed to the co-activation of the target word's cognate in the non-target language, with converging activation speeding comprehension. But note that cognates could be learned better than non-cognates (through early cross-language activation) (Winther et al., 2023), or their syllables may have higher frequencies than those of non-cognates (Gollan & Acenas, 2004), so facilitation might not be due to online cross-language activation at the time of the experiment.

Some studies showed that cognate facilitation is influenced by language context, though the findings remain somewhat inconsistent. In a high-constraint sentence, the target word is highly predictable based on the context (e.g., as assessed by a Cloze test), whereas in a low-constraint sentence, neither the target word nor any other word is predictable. Titone et al. (2011) found that English-French bilinguals showed cognate facilitation for low- but not high-constraint L1 English sentences. But when the experiment included L2 French sentences, facilitation appeared for both low- and high-constraint L1 sentences, suggesting that a two-language context enhances cross-language activation. In an L2 English lexical decision task, Dijkstra et al. (2015) found that Dutch-English bilinguals showed cognate facilitation regardless of whether the cognates were preceded by Dutch or English sentence contexts. In contrast, Vanlangendonck et al. (2020) reported that in an L2 lexical decision task, cognate facilitation turned into inhibition when L1 items were included in the stimulus list.

Interlingual homographs (words with the same orthography but different meanings across languages) provide additional evidence for cross-language activation. Bilinguals take longer to respond to interlingual homographs than non-homographs in L2 lexical decision tasks (Dijkstra et al., 1998, 1999; Dijkstra et al., 2000; Schulpen et al., 2003). This delay is often interpreted as evidence for the co-activation of both the form and meaning of homographs in the non-target language.

Like cognate facilitation, the interlingual homograph interference effect is influenced by language context. For example, in Dijkstra et al.'s (1998) English lexical decision task, there was no response time difference between interlingual homographs and control words when only English words or nonwords that were orthographically legal in English were used (one-language context). But when Dutch filler words were added (two-language context), response times for homographs were longer than for English control words (see also Dijkstra, Bruijn, et al., 2000; Poort & Rodd, 2017). Similarly, Elston-Güttler et al. (2005) presented German-English bilinguals with English sentences (e.g., *The woman gave her friend an expensive…*) ending with either an interlingual homograph (*gift*, meaning “poison” in German) or a control word (*item*),followed by target words corresponding to the homograph's L1 meaning (*poison*). Participants who watched a German movie before the experiment showed faster lexical decisions and N200/N400 modulations for homograph-related targets in the first block—an effect absent for those who watched an English movie, suggesting that cross-language activation is influenced by language context (see also Elston-Güttler & Gunter, 2009).

Thierry and Wu (2007) had Chinese-English bilinguals judge the semantic relatedness of English word pairs (e.g., *train – ham*) whose Chinese translations (e.g., *huo che – huo tui*) shared a character, and found reduced N400 amplitudes for these pairs in comparison to English pairs whose Chinese translations did not share a character. They interpreted these results in terms of unconscious activation of Chinese translations during English comprehension (see also Wu & Thierry, 2010; Zhang et al., 2011). In auditory word recognition, Wang et al. (2017) showed that Chinese-English bilinguals listening to English words (e.g., *rain, "*yu3*"* in Chinese) fixated more on a competitor object (e.g., *a feather*, *"*yu3*"* in Chinese) whose Chinese name was a homophone of the Chinese translation of the target word than an unrelated object, suggesting cross-language activation. However, Costa et al. (2017) argued that these findings might reflect remnants of L2 learning rather than online cross-language activation.

4.1.2. ***Cross-language activation and language context***

Further evidence for the impact of language context on cross-language activation comes from findings on language switch costs in language comprehension. Cheng and Howard (2008) presented Chinese-Taiwanese bilinguals with pairs of Chinese sentences that either both included Taiwanese words (two-language context) or were entirely in Chinese (one-language context) and had them judge if two sentences were semantically synonymous in Chinese. Participants showed a switch cost (i.e., slower to respond) for language-switching pairs only when they believed that only Chinese would be used in the experiment, but such switch cost disappeared when they expected that both Chinese and Taiwanese would be involved in the experiment (Olson, 2017).

In an eye-tracking study, Olson (2017) had Spanish-English bilinguals read a target word in English following a context that was entirely in English, entirely in Spanish, or consisted of some English words followed by some Spanish words. Relative to the English-only context, participants had more difficulty with a context entirely in Spanish but did not have difficulty with the mixed language context, suggesting that the non-target language is activated to a larger extent in a two-language context than in a one-language context (see also Declerck & Grainger, 2017; Kheder & Kaan, 2019). Hoversten and Traxler (2020) had Spanish-English bilinguals read low-constraint English sentences (e.g., *We saw that his _ had a horrible scar*) containing a critical word in English (*hand*), Spanish (*mano*), or a pseudoword (*erva*). Eye movements revealed that overtly presented Spanish words (two-language context) caused early reading disruptions compared to English words, though less than pseudowords, suggesting that code-switched words were less accessible but not fully treated as pseudowords. However, when code-switched words were presented covertly using the gaze-contingent boundary paradigm (one-language context), they were processed like pseudowords (see also Hoversten & Martin, 2023), thus in a one-language context Spanish had the same status as nonwords – it was not activated.

In summary, much evidence suggests that comprehenders activate both languages when they encounter words – that is, non-selective lexical access. However, most of this evidence comes from experiments conducted in two-language contexts, and findings of cross-language activation in one-language contexts can alternatively be explained by the learning account. Thus, it remains unclear whether parallel activation depends on language context or not.

4.1.3. ***Within-language prediction in bilinguals***

We first note that L1 comprehenders can predict many aspects of upcoming words (see Pickering & Gambi, 2018), such as meaning (Altmann & Kamide, 1999; Dijkgraaf et al., 2019; Grisoni et al., 2017), syntax (Van Berkum et al., 2005; Wicha et al., 2004), and form (Ito et al., 2018; Kukona, 2020; Li et al., 2022; Martin et al., 2013; Xu et al., 2022). For example, Altmann and Kamide (1999) found that after hearing *the boy will eat the…*, participants were more likely to look at an edible object (a cake) than inedible objects (a ball, a toy train, and a toy car) before the word *cake* was spoken, suggesting that participants pre-activated a component of the meaning of the upcoming word (here, that it is edible). With regard to form, Li et al. (2022) had L1 Mandarin Chinese speakers listen to Chinese sentences containing a highly predictable word (e.g., *放学了, 我把铅笔盒和本子装进了书包里准备回家* "After school, I put my pencil case and notebooks into my <u>schoolbag</u> and get ready to go home") while viewing a scene containing a critical object whose Chinese name (e.g., *shu*1*zi*5, meaning comb) shares the same pronunciation and tone (homophone) with the predictable word (*shu*1*bao*1, meaning schoolbag). Participants fixated more on the Chinese homophone competitor than an unrelated object before the target word onset, demonstrating pre-activation of the phonological information of the predictable word (see also Ito et al., 2018; Li et al., 2022; Shen et al., 2021; Xu et al., 2024; Zhao et al., 2024).

The results for L2 comprehenders are much less clear. Some studies have found prediction in L2 comprehenders (Chun & Kaan, 2019; Dijkgraaf et al., 2017; Lew-Williams & Fernald, 2010; Momenian et al., 2024), while others have not (Hopp, 2015), or have reported reduced prediction effects compared to L1 comprehenders (Ito et al., 2018; Martin et al., 2013; Mitsugi & Macwhinney, 2016). Overall, there is good evidence that L2 comprehenders can predict, but do so less than L1 comprehenders (for a review, see Schlenter, 2023).

The clearest difference between L1 and L2 prediction appears to relate to form, as no study has found form prediction in L2 comprehension. For example, in an ERP study, Martin et al. (2013) had Spanish-English bilinguals and L1 English speakers read English sentences with a predictable or unpredictable final noun, which was preceded by an article either congruent or incongruent with the noun (as in DeLong et al., 2005). L1 speakers, but not L2 speakers, showed an increased N400 amplitude effect for articles incongruent with the predictable nouns, suggesting that L2 speakers did not pre-activate the phonological representation of predictable words. Similarly, Ito et al. (2017b) had Spanish-English bilinguals read highly constraining L2 English sentences that continued with a predictable word, a phonologically related word, a semantically related word, or an unrelated word. Both phonologically and semantically related words elicited increased N400 effects similar to those for non-predictable words but greater than for predictable words, suggesting that L2 speakers did not pre-activate the semantic or form representations of the predictable words (see also Ito et al., 2018).

4.1.4. ***Suggestive evidence for L1 co-activation in L2 prediction***

One possible reason for the difference between L1 and L2 predictive processing is that L1 co-activation affects L2 prediction (Hopp & Lemmerth, 2018; Kaan, 2014; Schlenter, 2023). Indeed, some studies are compatible with interference, and as far as we are aware, all experiments concerning prediction have been conducted in a one-language context. Using the visual-world paradigm, van Bergen and Flecken (2017) examined L2 prediction in L2 Dutch speakers with different L1s, which vary in whether placement verbs specify the position of the patient. German and Dutch placement verbs specify its position (i.e., they distinguish "put into a standing position" from "put into a lying position"), while French and English verbs do not (i.e., they just have "put"). When listening to Dutch sentences with placement verbs, L1 German speakers made predictive eye movements toward objects whose position was compatible with the verb, but L1 English and French speakers did not. This may suggest that L1 English and French speakers co-activated their L1 verbs, leading them to predict objects without considering their position. However, it could also be that the L1 English and French learners had not fully learned the correct meaning of Dutch placement verbs, unlike the L1 German learners, rather than solely being affected by L1 activation.

Similarly, Ito et al. (2024) had heritage speakers of Vietnamese in Germany listen to Vietnamese sentences (e.g., *Mai mặc một chiếc áo* "Mai wears a shirt") for which verb constraints differ between German and Vietnamese (here, German *tragen* allows clothing and accessories as its objects, while Vietnamese *mặc* only allows clothing). Participants fixated more on objects compatible with German verb constraints (e.g., earrings) rather than Vietnamese ones (e.g., shirt). Again this suggests that participants could have activated L1 verb information, or they could have failed to learn Vietnamese verbs well.

Other studies have shown that L1 activation interferes with L2 syntactic prediction. Russian and German both have genders, but Russian marks gender on nouns and adjectives as suffixes and lacks articles, whereas German marks gender on adjectives and determiners. Using the visual-world paradigm, Hopp and Lemmerth (2018) presented advanced and high-intermediate Russian-German bilinguals with German sentences ending with gender-marked adjective-noun or article-noun phrases. Advanced learners showed predictive gender processing for both adjectives and articles, while high-intermediate learners showed gender prediction for adjectives, but only did so for articles when noun genders in Russian and German were congruent. This suggests that high-intermediate learners co-activate L1 lexical gender, with incongruent genders interfering with L2 syntactic prediction, modulated by L2 proficiency (see also Dussias et al., 2013). But of course, this could also be because high-intermediate learners had not fully learned German articles.

In an ERP study, Alemán Bañón and Martin (2021) had Swedish-English and Spanish-English bilinguals read English stories featuring two characters (e.g., Julia's niece and Albert's sister) that biased participants to expect *his sister* (referring to Albert's sister) rather than *her niece* (referring to Julia's niece) as the upcoming possessive construction. In both Swedish and English, the possessive pronoun indicates the possessor noun’s natural gender, but in Spanish, it agrees with the possessed noun. Swedish learners of English elicited increased N400 amplitudes for unexpected prenominal possessives compared with expected ones, whereas Spanish learners did not. This suggests that Spanish-English bilinguals activated L1 information of possessive pronouns, interfering with L2 syntactic prediction (or that they had not fully learned L2 usage).

Note that L1 activation does not necessarily interfere with L2 prediction. Ito et al. (2024) had Spanish-English bilinguals listen to English sentences containing either cognate or non-cognate verbs that predicted target objects while viewing a scene. Participants showed faster and greater predictive fixations towards target objects when the verb was a cognate than a non-cognate. This suggests that L1 activation of cognate verbs facilitated L2 prediction, though the effects can also be explained in terms of learning (see *Bilingual lexical access in bottom-up word recognition*).

There is, however, no evidence that L1 form representations of predictable words are activated during L2 prediction. In an ERP study, FitzPatrick and Indefrey (2010) had Dutch-English bilinguals listen to high-constraining English sentences ending with semantically incongruent words, predictable words, or words phonologically related to the Dutch translations of predictable words (e.g., *My Christmas present came in a bright-orange doughnut*"; *doughnut* had initial overlap with *doos*, meaning "box"). There was no difference in the N400 peak or onset latency between phonologically related words and incongruent words (though incongruent words did differ from predictable words), suggesting that the L1 phonological representations of the predictable words were not activated during L2 prediction.

In addition, Ito et al. (2018) had Japanese-English bilinguals listen to sentences containing a highly predictable word (e.g., *The tourists expected rain when the sun went behind the cloud*) while viewing a display of four objects. They found no difference in predictive fixations between an object whose Japanese name was phonologically related to the Japanese translation of the predictable word (*bear*; kuma) and an unrelated object (*globe*; tikyuugi), nor between an English phonological competitor (*clown*) and an unrelated object. Thus, there was no evidence that L2 speakers pre-activated phonological representations of either predictable words or their L1 translations. Using the same design, Amos et al. (2022) found similar results for French-English translators or interpreters who listened to English sentences and translated them into French.

Although these studies did not find evidence of L1 phonological pre-activation, we cannot be certain that L1 phonological representations of predictable words are not activated during L2 comprehension. Even in L1 comprehension, phonological prediction effects are small (see Ito, 2024). In Ito et al. (2018), Japanese competitors and Japanese translations of predictable words shared only 2.6 out of 4.9 phonemes (53%), which may be insufficient to trigger activation of phonologically related words, and the study had low power (96 observations per condition in Ito et al., 2018), as did Amos et al. (2022) (192 per condition).

4.1.5. ***The present study***

Our study investigated whether bilinguals comprehending sentences in their L2 make predictions in their L1. To do so, we conducted two visual-world eye-tracking experiments. We examined whether Chinese-English bilinguals listening to English predict in both Chinese and English or whether they restrict predictions to English. Also, we explored whether such predictions occur when they heard only English (one-language context, Experiment 6) or both Chinese and English (two-language context, Experiment 7).

Our experiments were related to Ito et al. (2018), but there were two important differences. First, to enhance the likelihood of detecting L1 phonological activation, we used (intralingual) homophones in Chinese as L1 phonological competitors. Chinese has an abundance of homophones—words with identical pronunciations but different meanings and spellings. Compared to the L1 phonological competitors used by Ito et al. (2018), our use of homophones greatly increased the phonological overlap with the Chinese translations of predictable words. We assumed that this would maximize the likelihood of detecting cross-language L1 phonological activation, provided that L1 Chinese translations of predictable words are indeed activated during L2 English comprehension.

The second difference from Ito et al. (2018) was an increased sample size. Since Ito et al. (2018) and Amos et al. (2022) did not detect cross-language L1 phonological activation, we based our sample size on studies that used Chinese homophones and have detected phonological prediction in L1 comprehension (Li et al., 2022; Xu et al., 2024). Xu et al. (2024) had 288 observations per condition and Li et al. (2022) had 450. We therefore decided to have 360 observations per condition. The third difference from Ito et al. (2018) was that we included only three conditions, excluding the English phonologically related condition. We made this decision because previous studies consistently showed no form prediction among L2 speakers and our primary aim was to investigate whether L2 speakers pre-activate L1 form representations of predictable words during L2 comprehension.

Our participants heard English sentences containing a highly predictable word (e.g., *rain* in *You should take an umbrella with you, because there will be heavy rain at three o'clock this afternoon*) while viewing a display which contained three distractors and a critical object (see Figure 1). The critical object corresponded to the target word (e.g., *rain* [Chinese: *yu*3]), a Chinese homophone competitor whose Chinese name was a homophone (e.g., *feather* [Chinese: *yu*3]) of the Chinese translation of the predictable word, or a word (e.g., *comb* [Chinese: *shu*1]) that was unrelated to the predictable word.

We assume that participants predict components of the meaning of highly predictable words in L2 sentences, and therefore hypothesize that they will fixate the target objects more than unrelated objects before the target word onset. The critical question is whether they pre-activate L1 representations of predictable words in L2 sentences. If they do, they should fixate more on Chinese homophone objects than on unrelated objects before the target word onset. Experiment 6 investigated these issues using a one-language context (where filler sentences were in English), and Experiment 7 did so using a two-language context (where filler sentences were in Chinese).

4.2. Experiment 6

In Experiment 6, the whole experimental session was conducted in English. The only use of Chinese was in a familiarization session (see below).

Data availability

The code and data associated with this paper are available from https://osf.io/4w6hy/.

4.2.1. ***Method***

4.2.1.1. Participants

Thirty Chinese students at the University of Edinburgh (5 males and 25 females), aged between 21 and 28 years (M = 23.37, SD = 1.61) participated in this experiment. All participants were native Mandarin Chinese speakers with English as their L2. They had all lived in the UK for at least 5 months and were currently studying in the UK at the time of the experiment. Each participant received a payment of £9 for their participation. After the main experiment, participants were asked to indicate their scores on International English Language Testing System, the age at which they began learning English, the daily duration of their English use, and their immersion length in an English-speaking country. Additionally, they were asked to self-rate their English proficiency in reading, writing, speaking, and listening separately on a scale from 1 (not good at all) to 7 (very good); see Table 11.

Table 11

The Language History and Proficiency of the Chinese-English Participants in Experiment 6 and 7

Measure	One-language context (Experiment 6)	One-language context (Experiment 7)
	Mean (*SD*)	Mean (*SD*)
English self-rating reading (7-point scale)	5.45 (1.09)	5.93 (0.74)
English self-rating listening (7-point scale)	5.26 (1.24)	5.53 (1.00)
English self-rating speaking (7-point scale)	4.71 (1.22)	4.77 (1.25)

English self-rating writing (7-point scale)	4.68 (0.98)	5.07 (0.94)
English proficiency test (IELTS score)	7.03 (0.44)	7.19 (0.42)
Daily English usage (hours)	6.50 (4.67)	5.17 (4.35)
Age of English acquisition (years)	7.71 (2.67)	6.95 (2.66)
Length of immersion (months)	13.87 (13.11)	10.57 (11.02)

4.2.1.2. Stimuli

We created 36 pairs of English sentences (see Appendix) involving a highly predictable target noun (underlined), for example *You should take an umbrella with you because there will be heavy rain at three o'clock this afternoon* and *Many birds, like parrots and peacocks, have beautiful and colorful feathers that make them very exotic and eye-catching*. The Chinese translation of the predictable word from one member of the pair (here, *rain*, with translation *yu3*) was homophonous with the Chinese translation of the predictable word from the other member of the pair (here, *feathers*, also with translation *yu3*). The experimental sentences had a mean length of 23.9 words (*SD* = 3.1, range = 17–31 words), and the predictable word appeared at different positions in each sentence (range = 10th-25th word, *M* = 16.6, *SD* = 3.0) but never sentence-finally.

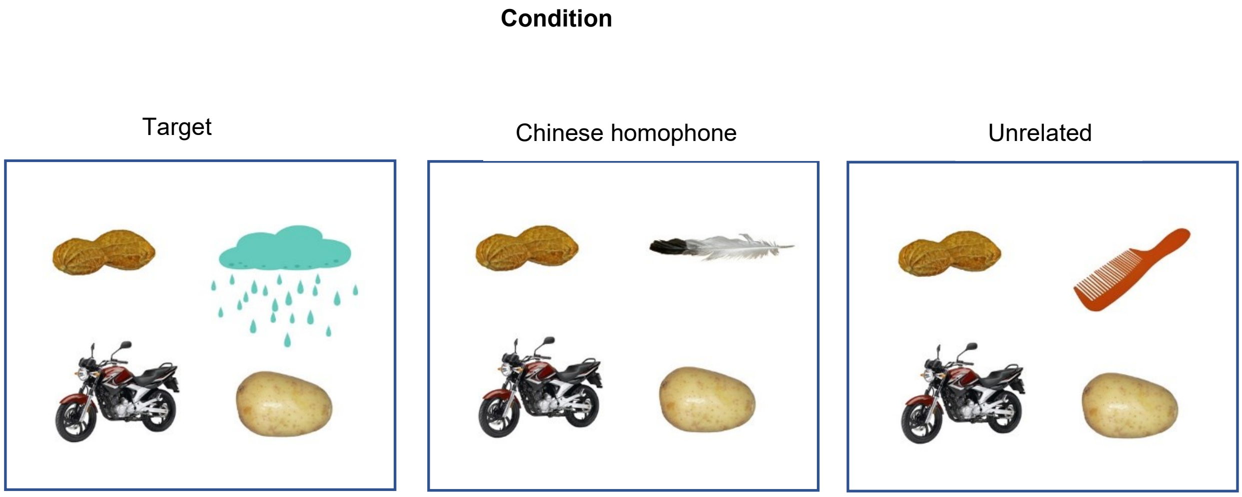
Target-word predictability was assessed using a cloze-probability test. Fourteen further Chinese-English bilinguals who were studying in the UK were presented with sentence fragments which were truncated immediately before the target word, and were asked to complete each sentence with the first word that came to mind. The cloze probability of a word was defined as the percentage of participants who used the exact word to complete the sentence. The mean cloze probability of the target word was 88.08 % (*SD* = 12.54, range = 61.54 %–100 %). There were an additional 36 English filler sentences (e.g., *When my brother and I were playing in the street, we lost 200 pounds, and we don't want our mum to know that*) with a similar length to the experimental sentences (*M* = 24.0, *SD* = 3.5, range = 20–34 words) but were not designed to have a highly predictable word.

The sentences were generated using Murf AI voice generator, a text to speech software which can produce human-like and natural-sounding voice. These sentences were generated with the synthesized voice which was set as "English-UK-Edward (M), middle-aged, general tone, pitch (0%), speed (-50%)" (https://murf.ai/studio/project/2/P017026364560496CY?workspaceId=WORKSPACEID017026364543209BE&) at 48 kHz with a format of 32-bit float and a bit rate of 1,536 kbps, and was downloaded in high-quality WAV format. This configuration was chosen because it produced audio that closely resembled a native British English speaker, including natural speaking speed, as confirmed by three further Chinese-English bilinguals from the University of Edinburgh.

Each of the sentences was paired with a scene containing four objects: a critical object and three distractors. In the target condition, the critical object corresponded to the target word (e.g., *rain* [Chinese: *yu*3]). In the Chinese homophone condition, the Chinese name of the critical object was a homophone of the Chinese translation of the target word (e.g., *feather* [Chinese: *yu*3]). English and Chinese names of the Chinese homophone objects were both unrelated to any of the English names of the target and unrelated objects. In the unrelated condition, the name of the critical object was neither phonologically nor semantically related to the predictable word (e.g., *comb* [Chinese: *shu*1*zi*0]). The unrelated condition served as a baseline. English and Chinese names of each critical object had no phonemes in common. An example item with four conditions is shown in Fig.6.

Figure 6

Example Visual Scene in the Three Conditions for the Experimental Sentence ''You should take an umbrella with you, because there will be heavy rain at three o'clock this afternoon"



Note. The object depicted at the top right corner is the critical object for this item. The visual stimuli were also paired with the filler sentence ''When my brother and I were playing in the street, we lost 200 pounds, and we don't want our mum to know that".

For the two versions of sentence contexts in each homophone pair, the target object in the target condition for one sentence context was used as the Chinese homophone object for the other sentence context in the Chinese homophone condition, and vice versa. In the unrelated condition, these two sentence contexts were paired with two different unrelated objects, which were also used as a target or homophone object in other trials. This design ensured counterbalancing, and allowing each critical object to alternate between roles across conditions for a more controlled comparison.

A further 28 Chinese-English bilinguals from the University of Edinburgh participated in a name agreement test for the critical objects: Of these, 14 provided the first Chinese name that came to their mind for each picture, and the other 14 provided the English name. In the English naming pre-test, the instructions were in English throughout the test. In the Chinese naming pre-test, the instructions were in Chinese throughout the test. The Chinese and English naming agreement for the retained critical objects was 86.71% (*SD* = 15.90, range = 50%–100%) and 88.89% (*SD* = 14.48, range = 50%–100%) respectively.

All the visual stimuli were shown twice, once in an experimental trial and once in a filler trial. The matched visual stimuli for an experimental and filler recording contained the same four objects, but the quadrant in which each of the four objects appeared was varied. Each experimental list comprised 72 sentences: 36 experimental sentences and 36 filler sentences. Each list was divided into two half lists, each containing 36 visual arrays paired with 18 experimental and 18 filler sentences. Visual arrays that were paired with experimental items in one half-list were paired with fillers in the other half-list, and vice versa. Experimental pictures were counterbalanced across the full lists, resulting in three different sets of items and a total of 12 experimental lists (six lists for each version of sentence context in a homophone pair). The order of the sentences within each block was randomized for each participant and the whole experiment took approximately 35 minutes, with participants having four breaks during the session.

Critical objects appeared in each quadrant equally frequently. Filler sentences mentioned one of the three distractor objects in the visual display 2/3 of the time. Thus, in total 50% of sentences mentioned an object in the visual display.

4.2.1.3. Procedure

Participants were tested in a laboratory at the University of Edinburgh, and the whole session had three parts: the picture-familiarization task, the eye-tracking experiment, and the language-background questionnaire.

In the picture-familiarization task, participants were shown 180 objects (72 critical objects and 108 distractor objects) one by one on a screen, each accompanied by its English and Chinese names displayed horizontally below. The name order was counterbalanced: For half the pictures, English names appeared on the left and Chinese names on the right, and vice versa for the other half. Participants were told to memorize both the Chinese and English names for each object. Once they indicated that they had remembered all the names, the pictures were shown again without the names, and participants were asked to name each object in both Chinese and English using the previously given names. To balance positional effects, participants first articulated the Chinese names for pictures with English names on the left, followed by the English names, and vice versa for pictures with Chinese names on the left. The mean picture naming accuracy on the first presentation was 92.41%. The high accuracy suggests that the pictures were familiar to our participants and were relatively easy to associate with the intended names. If they did not respond correctly with both the English and Chinese names for a picture, that picture was presented again in another picture-familiarization session (until all pictures were named correctly).

The experimenter used solely English for all communication, including greetings and instructions, and participants were also told to respond only in English. In addition, all instructions displayed on the screen and filler sentences were also in English. Thus, the experiment provided an entirely one-language context, except for the familiarization session.

In the eye-tracking experiment, participants were seated in front of a computer screen, at a distance of about 60 cm. Participants' right eye movements were recorded using an SR Research EyeLink® 1000 mount eye-tracker with a sample rate of 500 Hz. Participants were instructed to listen carefully to each sentence and judge whether it mentioned any of the objects on the screen after the sentences ended. Before the experiment, participants put their chin on a chin rest, and the eye-tracker was calibrated using a nine-point calibration grid. The experiment began with two practice trials, followed by a break in which participants could ask questions. The pictures were displayed on a screen with a resolution of 1024 ×768 pixels. Each trial started with a drift correction, followed by a 500 ms blank screen. On experimental trials, the visual scene was presented 1000 ms before the onset of predictable words in experimental trials. In filler trials, the scene appeared 1000 ms before the onset of a word referring to a distractor object or at an arbitrary mid-sentence position if the sentence did not mention any of the objects. The picture remained on the screen for 750 ms after sentence offset, at which point it was replaced with the question "Did the sentence mention any of the pictures?". Participants indicated their answers by pressing the left button for "No" and the right button for "Yes", using a button box, and the next trial began immediately after the response. No feedback was given during the experiment. The session took about 40 minutes.

4.2.2. ***Data analysis***

One item was excluded from the eye-tracking analyses in Experiment 6, because the target object for this item attracted significantly more looks than the unrelated objects within 1000 ms after the picture onset when the pictures were presented with a neutral sentence that was unrelated to the target objects in filler trials (see the analysis for filler trials in the section below). This left 35 items for the analyses. We began by analyzing the fixation on the critical objects for the filler sentences (without having analyzed the experimental sentences) and one item showed many more looks to the target object than the unrelated object. Indeed, the analysis of all the filler items showed that participants looked at the target object more than the unrelated object. When we removed the item, the analysis now showed no difference in fixations toward the target objects and the unrelated objects.

In both Experiment 6 and 7, we first analyzed the eye-tracking data using generalized linear mixed-effects models (Baayen et al., 2008) with the lme4 package (Bates et al., 2015) in R (R Core Team, 2020). The fixations on critical objects (target, Chinese homophone, and unrelated objects) were coded binomially (fixated = 1, not fixated = 0) in each 50 ms bin from 1000 ms before to 1000 ms after the target word onset. If fixations fell in the area of 300 × 300 pixels around a picture, they were regarded as falling on it. Blinks and fixations outside the interest areas were coded as 0 and were included in the data. The model used binomially coded fixation as the dependent variable, predicted by condition. The condition variable was dummy-coded, with the unrelated condition set as the reference level. Thus, we could test effects of each critical condition relative to the unrelated (baseline) condition (target vs. unrelated, Chinese homophone vs. unrelated). The model included random intercepts by participants and by items (Baayen et al., 2008). Random slopes were not included because the models with them did not converge for several of the time bins. As in Ito et al. (2018), we determined whether a critical condition significantly differed from the baseline condition by assessing if there was a period with at least three consecutive bins showing significant differences.

But this approach has two limitations. First, fixations in adjacent time bins are highly correlated, because the eye-tracker records a fixation at every millisecond, but fixations usually last for a few hundreds of milliseconds (Ito & Knoeferle, 2023; Rayner, 1998). Second, the binned analysis was conducted in many time bins and therefore involved multiple comparisons, and so it increases the chance of Type 1 error (Hochberg, 1987). To address these issues, we additionally conducted a cluster-based permutation analysis for the time period from -1000 ms before until 1000 ms after target word onset, which controls for autocorrelation of eye-movement across neighboring time bins and overcomes the multiple comparisons issue.

4.2.3. ***Results***

4.2.3.1. Comprehension question accuracy

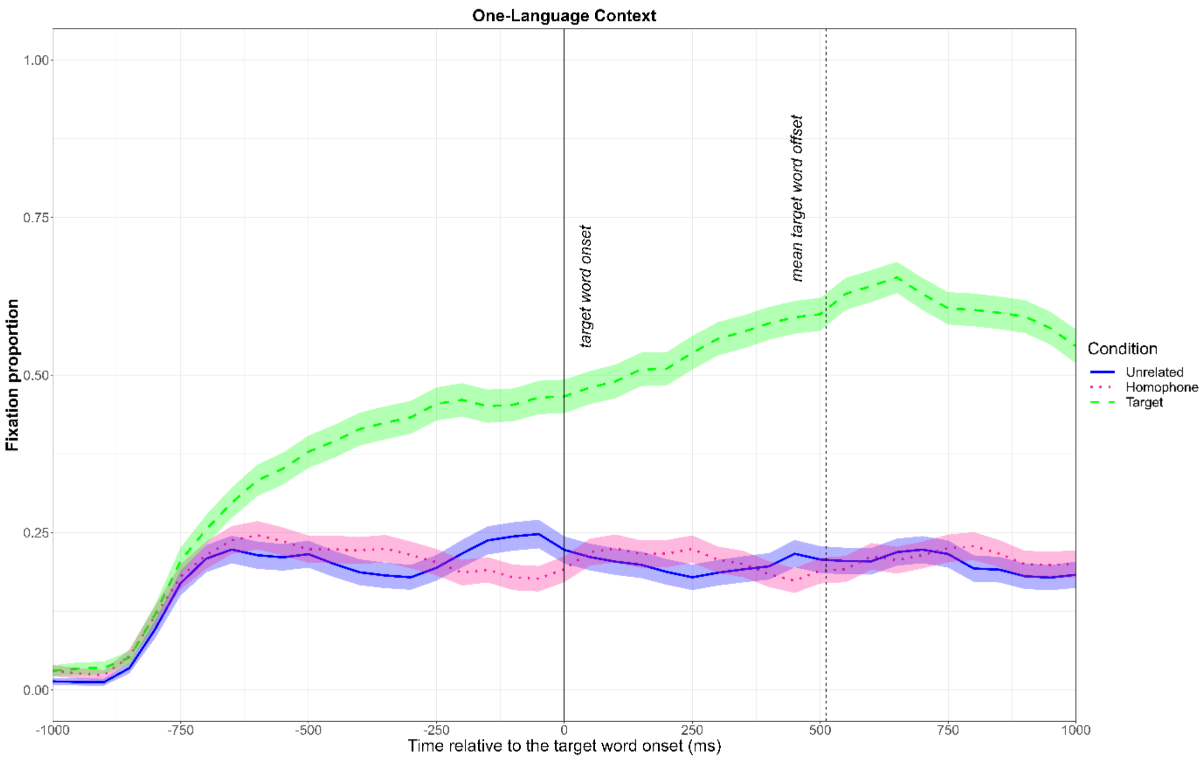
The mean accuracy for the comprehension questions in the experimental trials was 98.19% (*SD* = 13.33%). Incorrectly answered trials were excluded from the eye-tracking analyses.

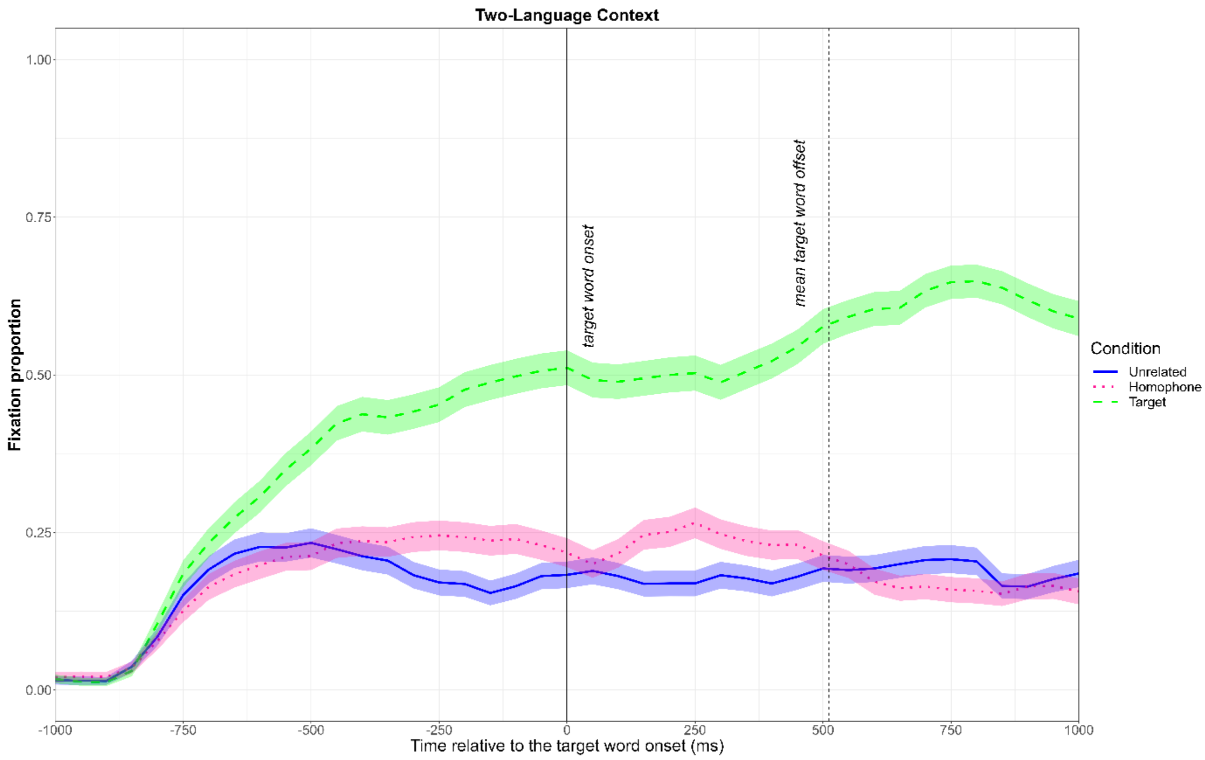
4.2.3.2. Eye-tracking data

Fig. 7 shows the mean fixation proportions on the target objects, the Chinese homophone objects, and unrelated objects in the time window from -1000 ms before to 1000 ms after target word onset. Time was synchronized to target word onset.

Figure 7

Mean Fixation Proportions on Critical Objects





Note. Eye-tracking results for the one-language context in Experiment 6 (top) and two-language context in Experiment 7 (bottom). Time-course graphs show the mean fixation proportions on target, Chinese homophone, and unrelated objects. Time 0 ms shows target word onset. The dashed vertical line (y = 512 ms) indicates the mean target word offset. Transparent thick lines are error bars representing standard errors.

The binned generalized mixed-effects models showed that bilinguals were more likely to fixate on target objects than on unrelated objects from -650 ms before they heard the target word until (at least) 1000 ms after the target word onset. However, from -1000 ms before to at least 1000 ms after the target word onset, there was no fixation bias toward Chinese homophone objects compared to unrelated objects. In fact, participants fixated more on unrelated objects than on homophone objects during two time bins: -100 ms to -50 ms and -50 ms to 0 ms.

The cluster-based permutation analysis showed that target objects attracted more fixations than unrelated objects in the time window from -750 ms before to

1000 ms[11] after the target word onset (cluster-mass = 6787, $p < 0.001$). Chinese homophone objects received more fixations than unrelated objects from -900 ms to -800 ms before the target word onset (cluster-mass = 22.9, $p < 0.001$), which, based on the visual plot (see Fig. 2) and the fact that it occurred very soon after picture presentation and before the target-object effect began, was interpreted as fixation noise.

We also analyzed the filler trials in order to examine whether there was any visual bias towards critical objects irrespective of the predictive contexts. As reported above, one item was removed. Both the generalized mixed-effects model analysis and the cluster-based permutation analysis showed no significant fixation bias toward target objects or Chinese homophone objects than unrelated objects.

4.2.4. ***Discussion***

Experiment 6 investigated whether bilinguals pre-activate L1 phonological representations of predictable words during L2 comprehension when only L2 was needed throughout the experiment except for the familiarization session. Chinese-English participants fixated on target objects more than unrelated objects before hearing target words, but they did not fixate on Chinese homophone objects more than unrelated objects either before or after the target word onset. These findings suggest that participants predicted the target words or their meanings but did not pre-activate L1 representations of predictable words in a one-language context when only L2 was used.

[11] Note that the cluster-based results do not reveal the onset, offset, or duration of these effects (Matuschek et al., 2017). Rather they indicate a significant effect somewhere within these time windows (Ito & Knoeferle, 2023).

4.3. Experiment 7

In Experiment 7, we tested whether Chinese-English bilinguals pre-activate Chinese phonological representations of predictable words during English comprehension in a two-language context where both Chinese and English were used.

4.3.1. *Method*

4.3.1.1. Participants

Thirty further participants from the same population as Experiment 6 (3 males and 29 females) aged 21-28 (M = 23.37 years, SD = 1.47) took part in this experiment. After the main experiment, participants were also asked to indicate their language history and English proficiency; see Table 1.

4.3.1.2. Stimuli and procedure

To ensure a two-language context, the experimenter greeted participants and talked to them only in Chinese throughout the whole experiment; the instructions for the experiment were in Chinese; we translated 2/3 of the filler sentences from Experiment 6 into Chinese, with half of them containing a "YES" answer and the other half containing a "NO" answer. The remaining 1/3 filler sentences from Experiment 6 were still in English, with all of them containing a "YES" answer. Overall, filler sentences mentioned one of the three distractor objects in the visual display 2/3 of the time, so together with the experimental sentences (which mentioned one of the four objects 1/3 of the time), 50% of sentences mentioned an object in the visual scene. The experimental materials and other procedures remained the same as Experiment 6. The mean picture naming accuracy on the first presentation was 94.32%.

4.3.2. ***Results***

4.3.2.1. Comprehension question accuracy and eye-tracking data

The mean accuracy for the comprehension questions in the experimental trials was 97.93% (*SD* = 14.22%). The bottom part of Fig. 2 shows bilinguals' proportions of fixations on target objects, Chinese homophone objects, and unrelated objects in a two-language context. The eye-tracking data were analyzed using the same procedures as in Experiment 6. Two items were excluded from the eye-tracking analyses in Experiment 7, because the target objects and Chinese homophone objects in these items attracted significantly more looks than the unrelated objects within 1000 ms after the picture onset when the pictures were presented with a neutral sentence that was unrelated to the target and Chinese homophone objects in filler trials (see the analysis for filler trials in the section below). This left 34 items for the analyses. We analyzed fixations on the critical objects for the filler sentences using the same procedure as in Experiment 6. After we removed two items, the analysis showed no difference in fixations toward the target objects, homophone objects, and the unrelated objects.

The binned generalized mixed-effects model showed that participants fixated target objects more than unrelated objects from -600 ms before they heard the target word until at least 1000 ms after the target word onset. Critically, participants also fixated more on Chinese homophone objects than on unrelated objects from -250 ms before to -100 ms (three consecutive time bins) before the target word onset and from 150 ms to 300 ms (three consecutive time bins) after the target word onset.

The cluster-based permutation analysis showed that target objects attracted more fixations than unrelated objects in the time window from -750 ms before to

1000 ms after the target word onset (cluster-mass = 6577, $p < 0.001$). Importantly, Chinese homophone objects received more fixations than unrelated objects in the time window from -300 ms to -50 ms before the target word (cluster-mass = 61.3, $p < 0.001$), and also in the time window from 150 ms to 450 ms after the target word onset (cluster-mass = 51.5, $p < 0.001$).

Two items were excluded from the analysis in Experiment 7 after an initial analysis of the filler items. In the remaining 34 items, both the generalized mixed-effects model analysis and the cluster-based permutation analysis revealed no significant fixation differences between conditions within the time window from -1000 ms before to 1000 ms after the target word onset.

4.3.3. ***Discussion***

Experiment 7 investigated whether bilinguals pre-activate L1 phonological representations of predictable words during L2 comprehension when both their L1 and L2 were used. We found that Chinese-English participants fixated more on target objects than unrelated objects before hearing the target words. Critically, they were more likely to fixate on Chinese homophone objects than unrelated objects, both before and after the target word onset. These findings suggest that in a two-language context, participants not only pre-activated the highly predictable target words (or their meaning), but also pre-activated the L1 translations of predictable words during L2 comprehension.

4.3.3.1. Comparison of Experiment 6 and 7

Experiment 6 and Experiment 7 tested whether bilingual speakers pre-activated L1 representations of predictable words during L2 comprehension in a one-language and two-language contexts, respectively. Participants showed a cross-language L1 prediction effect in Experiment 7 but not in Experiment 6, suggesting an effect of language context on cross-language prediction. To verify the role of language context, we combined data from both experiments and conducted a cluster-based permutation analysis from 1000 ms before to 1000 ms after the target word onset, with the effect of language context sum-coded and the condition dummy-coded, using the unrelated condition as the reference level.

The analysis showed that participants fixated more on the target objects than the unrelated objects in the time window from -750 ms before to at least 950 ms after the target word onset, in both Experiment 6 and 7. They also fixated more on the Chinese homophone object than the unrelated object in the time windows from -950 to -850 ms, -400 to -200 ms, and from 150 to 300 ms. Critically, participants fixated more on the Chinese homophone objects than the unrelated objects in the time window from -200 ms to -50 ms before the target word onset in Experiment 7 than Experiment 6. The combined analysis suggests that bilinguals in a two-language context pre-activated L1 translation of predictable words to a larger extent than those in a one-language context.

4.4. General Discussion

We investigated whether L1 phonological representation of predictable words are pre-activated during L2 comprehension in a one-language context (Experiment 6) where only L2 English was used except for the familiarization session and a two-language context (Experiment 7) where both English and Chinese were used. In both experiments, participants fixated more on target objects than on unrelated objects before the target word onset. In the two-language context, participants also fixated more on objects whose Chinese names were homophones of the Chinese translations of predictable words than unrelated objects, both before and after the target word onset. However, this effect was not observed in a one language context.

4.4.1. ***Evidence for cross-language prediction during L2 comprehension***

In the two-language context, participants made predictive fixations toward Chinese homophone objects before the target word onset. This suggests that bilingual speakers preactivated L1 translation equivalents of predictable words during L2 comprehension.

Our findings differ from Amos et al. (2022) and Ito et al. (2018), who reported that L2 speakers did not make predictive eye movements toward L1 phonological competitors before the target word onset. One explanation is that we used homophones with complete phonological overlap with L1 picture names, making it easier to detect the cross-language prediction effect. In contrast, Ito et al. (2018) used competitors with only partial overlap with L1 picture names, which may have been too weak to activate L1 phonological competitors or influence eye movements. Another difference lies in the picture familiarization task. We presented participants with both L1 Chinese and L2 English names for each picture, potentially boosting L1 phonology activation, whereas Ito et al. (2018) presented participants only with the L2 English names. However, this alone cannot explain the difference, as cross-language L1 prediction was observed only in Experiment 7, where additional L1 elements (i.e., the instructions, greetings, chatting, and two-thirds of the fillers) were included. Thus, the language context and the use of homophones as L1 phonological competitors are likely the key factors behind the differing results.

However, the reasons for the different results between our study and Amos et al. (2022) are somewhere different. As in our study, Amos et al. (2022) presented bilingual participants with both L1 and L2 picture names in the picture familiarization task. More importantly, participants were also placed in a two-language context by constantly interpreting or translating from L2 to L1. Yet, they found no evidence for the pre-activation of L1 translation equivalents of predictable words. This discrepancy may be due to the cognitive load experienced by participants in their study. The interpreting task might have taxed participants so much that no resources were left for L1 form prediction, considering that cognitive resources are crucial for prediction (Pickering & Gambi, 2018). Alternatively, the overlap between the L1 French phonological competitors and L1 French translations of predictable words in their study may have been too small to affect participants' eye movements, even if there is pre-activation of L1 translations of predictable words.

Our finding that L2 speakers pre-activate L1 phonological representation of predictable word fits with the possibility that the absence of L2 form prediction may result from L1 interference. But our finding that L1 co-activation occurred only in a two-language context but not in a one-language context could not explain the lack of L2 form prediction in studies conducted in a one-language context (e.g., Ito et al., 2018). Thus, the lack of L2 form prediction could also be because pre-activating L2 form representations is too cognitively demanding for L2 speakers, as prediction is resource-intensive, and reduced automaticity in L2 comprehension and production may leave fewer cognitive resources available for prediction (Ito & Pickering, 2021).

4.4.2. ***Cross-language pre-activation and language context***

Our findings suggest that bilinguals can make predictions across languages during L2 comprehension, but only in a two-language context. How does this cross-language L1 prediction occur, and why is it influenced by language context? A possible explanation comes from production-based prediction accounts (e.g., Pickering & Gambi, 2018; Pickering & Garrod, 2013; see also Dell & Chang, 2014). These accounts propose that comprehenders use their production system to predict by deriving the speaker's intention and then pre-activating representations of the predictable word in the order of meaning, syntax, and phonology—similar to production processes but without articulation. In a one-language context, comprehenders may pre-activate representations only in the target language. But in a two-language context, they may pre-activate representations in both languages. This context sensitivity may explain why cross-language L1 pre-activation occurred in a two-language context but not in a one-language context.

In a two-language context, where L1 filler sentences were included, participants encountered L1 and L2 sentences apparently randomly, creating uncertainty about the language of upcoming words. This led to non-selective predictions, with participants activating L1 representations of predictable words while using their production system for prediction. In contrast, in a one-language context where only L2 sentences were included, participants were quite certain that they would only hear L2 sentences, leading them to expect that the upcoming predictable word would be in L2. This language-specific certainty led to selective predictions, with the prediction system activating only L2 representations, thus avoiding co-activation of L1 representations.

Note that although we found evidence that bilinguals pre-activate L1 representations of predictable words during L2 comprehension, it remains unclear whether they directly pre-activated L1 lexical representations of predictable words, or they first pre-activated L2 lexical representations, which then activated their L1 translation equivalents.

4.5. Conclusion

We reported two visual-world eye-tracking experiments that investigated whether highly proficient L2 speakers pre-activate L1 translation equivalents of predictable words during L2 comprehension. We found that bilingual speakers pre-activated L1 phonological representations of predictable words during L2 comprehension, but such cross-language lexical predictions only occurred in a two-language context where both L1 and L2 were relevant for the task, but not in a one-language context where only L2 was needed for the task. These findings suggest that whether lexical predictions are language-selective depends on language context.

5. General Discussion

Numerous studies have shown that that L1 speakers predict upcoming words at many different linguistic levels, whereas L2 speakers predict more slowly and less effectively than L1 speakers. However, it remains unclear whether these differences arise from fewer cognitive resources available for predictions for L2 speakers or from L1 co-activation. To answer this question, this thesis examined (i) whether prediction requires cognitive resources, (ii) whether there is cross-language activation during language production in a one-language context (on the assumption that prediction makes use of the production system), (iii) whether comprehenders predict across languages.

This chapter first provides an overview of the findings from the three studies presented in Chapters 2, 3, and 4 (Section 5.1) before interpreting these findings in relation to theories of prediction mechanism and bilingual language comprehension and production in more detail (Section 5.2).

5.1. Summary of empirical findings

5.1.1. ***The effect of speech rate on prediction speed***

In the first set of Experiments (Study 1; Experiments 1-3), we manipulated both speech rate (i.e., whether the speech was presented at a fast or slow rate) and the contextual predictability (i.e., whether the contexts were highly predictive, moderately predictive, or unpredictive of the final word). Specifically, we used a letter-judgment task to first determine the impact of fast speech rates on prediction in highly predictable contexts (Experiment 1), a picture naming task to determine whether the observed fast speech rate effect was due to impaired prediction or changes in other aspects of comprehension process (Experiment 2), and a word naming task to investigate how speech rate effects on prediction vary across contexts of different predictabilities (Experiment 3). We found that listeners' response latency was longer in both the letter-judgment task (Experiment 1) and the word naming task (Experiment 3) at a faster speech rate. Moreover, the effect of fast speech rates was greater for more than less predictable contexts in Experiment 3. In Experiment 2, we confirmed that this longer response latency at a faster speech rate was due to impaired prediction rather than changes in other aspects of the comprehension process.

Consistent with previous research on the cognitive load effect on prediction (Ito et al., 2018; Schuckart et al., 2024), these experiments demonstrate that prediction is a cognitively demanding process. Increased cognitive load impairs comprehenders' prediction, with greater impairment in more predictable contexts than less predictable ones, as the former engage prediction mechanisms to a larger extent. In addition, we found that participants' word response durations were shorter when contexts were presented at a fast speech rate than a slow rate in Experiments 2 and 3. This finding is consistent with previous research (Cohen Priva et al., 2017; Dilley & Pitt, 2010; Jungers & Hupp, 2009; Schultz et al., 2016), suggesting that listeners entrain to the speakers' speech rates.

5.1.2. ***L1 activation in L2 production in a one-language context***

Experiment 4 and 5 (Study 2) examined cross-language activation and competition in bilingual language production within a one-language context using a picture-word-interference paradigm. In Experiment 4, highly proficient Chinese-English bilinguals, and in Experiment 5, L1 English speakers named pictures in English while ignoring English auditory distractors presented either before, at, or after picture onset. The distractors were either phonologically related, semantically related, or unrelated to the English name of the picture, or phonologically related to the Chinese name of the picture (phono-translation distractors). We found that both bilinguals and L1 English speakers named pictures more slowly with semantic distractors and more quickly with phonological distractors. Crucially, bilinguals showed facilitated picture naming when presented with a phono-translation distractor compared to an unrelated distractor, whereas no such effect was observed for L1 participants.

These findings suggest that the Chinese-English bilinguals activated representations associated with Chinese when naming pictures in English – and, importantly, when there was no use of Chinese in the experimental context at all. In addition, the facilitated picture naming is consistent with research (e.g., Costa et al., 1999) demonstrating that lexical candidates in the non-target language are activated but they do not engage in the target word lexical selection process.

5.1.3. *L1 activation during L2 prediction*

Experiments 6-7 (Study 3) looked at whether bilinguals predict in both languages, or restrict predictions to the one they are currently hearing. To do so, we had Chinese-English bilingual speakers hear L2 English sentences containing a highly predictable word (e.g., *You should take an umbrella with you, because there will be heavy rain at three o'clock this afternoon*) while viewing a display with three distractors and a critical object corresponding either to the target word (e.g., *rain* [Chinese: *yu3*]), a competitor whose Chinese name was a homophone of the Chinese translation of the predictable word (e.g., *feather* [Chinese: *yu3*]), or an unrelated object.

We found that participants fixated more on the target objects than on unrelated objects before the target word onset regardless of the language context. More importantly, they fixated more on Chinese homophone objects than on unrelated objects before the target word onset in a two-language context (Experiment 7, where both L1 and L2 were used) but not in a one-language context (Experiment 6, where only L2 was used). These findings suggest that bilinguals pre-activate L1 translations of predictable words during L2 comprehension when both languages are contextually relevant but not otherwise.

5.2. General implications and future directions

5.2.1. *Implications for models of prediction mechanism*

In Study 1 (Experiment 1-3), we investigated whether comprehenders' prediction is constrained by cognitive resources by presenting L1 speakers with speech manipulated at varying rates and contextual predictability. We found that participants responded more slowly at a faster speech rate across three experiments, with greater effects in more than less predictable sentence contexts. Crucially, we demonstrated these effects were attributed specifically to the prediction process rather than other aspects of comprehension.

These findings challenge a family of prediction models that claim prediction is automatic and resource free (e.g., Kuperberg & Jaeger, 2016; Levy, 2008). Instead, they support the idea that prediction is cognitively demanding (Chang et al., 2006; Dell & Chang, 2014; Federmeier, 2007; Huettig & Mani, 2016; Pickering & Gambi, 2018; Pickering & Garrod, 2013), and that greater engagement of the prediction mechanism in more predictable contexts requires more cognitive resources compared to less predictable contexts. Specifically, our results support Pickering and Gambi's

(2018) production-based prediction account, which posits that comprehenders first covertly imitate speakers to derive their intention underlying the utterance, and then run this intention through their production system to produce the representations of the predictable word in the order of meaning, syntax, and form. This process is resource-intensive and optional, meaning that when cognitive resources are taxed, such as under faster speech rates, fewer resources can be allocated to prediction, resulting in slower predictive processing.

While our findings showed that speeded speech slows down comprehenders' prediction speed, they are not informative about which sub-processes of prediction are affected. For instance, it is conceivable that increased speech rates might specifically hinder the pre-activation of the semantic aspects of a predictable word, while leaving the pre-activation of the word's syntactic or form aspects unaffected. Alternatively, fast speech rates might potentially influence all stages of the prediction process. To gain more clarity, future research could investigate whether speech rate affects all sub-processes of prediction uniformly or selectively disrupts certain aspects, providing a more detailed understanding of how prediction operates under cognitive load.

5.2.2. *Implications for models of bilingual language production*

In Study 2 (Experiment 4-5), we investigated whether bilinguals' L1 is activated and competes for selection when producing words in L2 by having bilingual participants name pictures in L2 while ignoring L2 distractors that were phonologically related to the L1 translations of the picture names. We found naming facilitation for phono-translation distractors compared to unrelated distractors, suggesting that lexical candidates in the non-target language are activated but do not engage in the lexical selection process for the target word.

Our findings suggest that bilingual lexical selection is at least language-specific in some circumstances (i.e., in a one-language context). This challenges bilingual production models (Abutalebi & Green, 2007; Colomé, 2001; Green, 1986, 1998) that assume that words from both languages are always activated and compete for selection. In other words, for highly proficient bilinguals, a purely L2 context appears sufficient to create a selective environment for Chinese-English bilinguals to ignore the non-target language and freely select words from the target language, despite the online activation of the non-target language.

However, the observed phono-translation facilitation in a one-language L2 context is also compatible with a learning-based account that does not require online L1 activation (Costa et al., 2017). According to this view, the facilitation effect may arise from residual L1 traces in the L2 lexicon due to learning processes, rather than on-line cross-language activation during production. Future research should further investigate whether phono-translation facilitation reflects language-specific selection or is better explained by the influence of L1 on L2 through learning. Disentangling these accounts will provide valuable insights into the mechanisms underlying bilingual lexical access and production.

5.2.3. ***Implications for models of bilingual prediction***

In Study 3 (Experiment 6 and 7), we investigated whether L2 speakers pre-activate L1 translations of predictable words during L2 comprehension in both one-language (Experiment 6) and two-language contexts (Experiment 7). We found that bilinguals pre-activated L1 phonological representations of predictable words in the two-language context (where both L1 and L2 were used), but not in the one-language context (where only L2 was needed for the task). These findings suggest that lexical access in bilingual prediction is language non-selective when both languages are contextually relevant but not otherwise.

While these findings demonstrate that bilinguals pre-activate L1 representations of predictable words during L2 comprehension, the precise mechanism of cross-language prediction remains unclear. One possibility is that bilinguals directly pre-activate L1 lexical representations of predictable words. Alternatively, they may first pre-activate L2 lexical representations, which then activate their L1 translation equivalents. Future research should further investigate how exactly bilinguals predict across languages. Moreover, since this is the first study to provide evidence of cross-language pre-activation during L2 comprehension, additional research is needed to confirm its reliability. Further studies should employ other established paradigms, such as switch costs, that have been used to investigate cross-language activation, to further explore cross-language prediction.

5.2.4. *Implications for the differences between L1 and L2 prediction*

In Study 1 (Experiments 1-3), we found evidence that prediction is constrained by cognitive resources, with greater cognitive load impairing prediction. In Study 3 (Experiments 6-7), we found that L2 speakers pre-activate L1 translations of predictable words during L2 comprehension. Together, these findings suggest that the reduced effectiveness of L2 prediction compared to L1 prediction stems from two factors: increased cognitive load during L2 prediction and interference from L1 co-activation. Specifically, the heightened cognitive demands of L2 comprehension—

stemming from reduced automaticity and greater processing effort—combined with interference from activated L1 representations that differ in syntax or phonology, likely contribute to the slower and diminished prediction in L2. This dual influence of cognitive resource limitations and cross-language L1 activation highlights the complexity of predictive processing in L2.

Future research should explore how these two factors interact with each other. For instance, studies can investigate whether there is still cross-language prediction under conditions of reduced cognitive resources. Such research would offer insights into whether cross-language L1 pre-activation occurs automatically without effort or also requires cognitive resources.

5.3. Conclusion

Numerous studies have shown that L2 speakers predict less effectively than L1 speakers during comprehension. This thesis investigated the mechanisms of language processing in monolinguals and bilinguals, focusing on two possible reasons for the difference between L1 and L2 speakers. We found that in L1 comprehension, a faster speech rate slows down prediction speed, with greater effects in more than less predictable sentence contexts. This suggests that prediction is a cognitively demanding process, and less available cognitive resources can impair prediction, even for L1 speakers. We also found that bilinguals speakers co-activate words from their non-target L1 when producing words in their L2, even when L1 is irrelevant to the task. However, these L1 words do not compete for lexical selection, suggesting that lexical selection can be language-specific. In L2 comprehension, we found that bilingual speakers pre-activated L1 representations of predictable words. Importantly, this cross-language prediction occurred only in a two-language context where both L1 and L2 were relevant, but not in a one-language context where only L2 was used. These findings suggest that lexical access in bilingual prediction is language non-specific when both languages are contextually relevant but not otherwise. Taken together, these findings suggest that the less effective prediction observed in L2 speakers compared to L1 speakers is likely due to the combined influence of two factors: (1) L2 speakers have fewer available cognitive resources, likely due to the higher processing demands of L2 comprehension and production, and (2) co-activation of the non-target L1 introduces interference during L2 prediction.

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7. Appendix A: Experimental materials used in Experiments 1-7

7.1. Experimental materials used in Study 1

7.1.1. *Stimuli for Experiment 1*

All 120 sentences from the experiment are listed below with the predictable character and its Pinyin and English translations. The mean cloze value of the target word is shown at the end of each sentence. Below each sentence are the letter judgement questions used in positive trials and negative trials respectively.

1. 今天是母亲节，我要去花店给母亲买（花 hua）。(81%)

   Today is Mother's Day. I am going to the flower shop to buy my mom flowers

   您所预测的字的拼音中是否包含字母 "a"？

   您所预测的字的拼音中是否包含字母 "g"？

   Does the pinyin of your predicted word contain the letter "a"?

   Does the pinyin of your predicted word contain the letter "g"?

2. 今天的天空特别蓝，上边还飘着几朵白（云 yun）。(95%)

   The sky is particularly blue today, with a few white clouds

   您所预测的字的拼音中是否包含字母 "n"？

   您所预测的字的拼音中是否包含字母 "a"？

   Does the pinyin of your predicted word contain the letter "n"?

   Does the pinyin of your predicted word contain the letter "a"?

3. 在大街上要注意文明，不要随地吐（痰 tan）。(92%)

   Be civilized on the street and don't spit

   您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "e"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "e"?

4. 夏天到了，女孩子们都喜欢穿上漂亮的裙子去逛（街 jie）。(89%)

   Summer is here, and girls like to wear beautiful skirts and go shopping in the street

   您所预测的字的拼音中是否包含字母 "e"？

   您所预测的字的拼音中是否包含字母 "o"？

   Does the pinyin of your predicted word contain the letter "e"?

   Does the pinyin of your predicted word contain the letter "o"?

5. 吃鱼的时候要特别小心，因为里面有很多（刺 ci）。(86%)

   Be especially careful when eating fish because there are many thorns

   您所预测的字的拼音中是否包含字母 "i"？

   您所预测的字的拼音中是否包含字母 "a"？

   Does the pinyin of your predicted word contain the letter "i"?

   Does the pinyin of your predicted word contain the letter "a"?

6. 因为我有糖尿病，所以我很少吃 (糖 tang) 。(83%)

   Because I have diabetes, I rarely eat sugar.

   您所预测的字的拼音中是否包含字母 "g"？

   您所预测的字的拼音中是否包含字母 "i"？

   Does the pinyin of your predicted word contain the letter "g"?

   Does the pinyin of your predicted word contain the letter "i"?

7. 不是我不想买这件衣服，而是因为口袋里没有（钱 qian）。(95%)

It's not that I don't want to buy this dress, but because I don't have (money)

您所预测的字的拼音中是否包含字母 "n" ?

您所预测的字的拼音中是否包含字母 "o" ?

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "o"?

8. 杰克写给安娜的情书很真诚，字里行间都充满了对她的（爱 ai）。（84%）

Jack's love letter to Anna is very sincere, and the lines are full of love

您所预测的字的拼音中是否包含字母 "i" ?

您所预测的字的拼音中是否包含字母 "e" ?

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "e"?

9. 你要多吃饭多运动，不然会很容易生（病 bing）。（89% ）

You have to eat more and exercise more, otherwise you will easily get sick

您所预测的字的拼音中是否包含字母 "g" ?

您所预测的字的拼音中是否包含字母 "u" ?

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "u"?

10. 这条河上没有桥，要去河对面必须要坐（船 chuan）。（89% ）

To go to the other side of the river, you have to take a boat because there is no bridge on this river.

您所预测的字的拼音中是否包含字母 "n" ?

您所预测的字的拼音中是否包含字母 "i"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "i"?

11. 李明是个素食主义者，他从来不吃（肉 rou）。（92% ）

Li Ming is a vegetarian, he never eats (meat)

您所预测的字的拼音中是否包含字母 "u"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "a"?

12. 小王打完篮球回来出了一身汗，所以第一件事就是去洗（澡 zao）。（92% ）

Xiao Wang was sweating after playing basketball, so the first thing he did was to take a bath

您所预测的字的拼音中是否包含字母 "o"？

您所预测的字的拼音中是否包含字母 "u"？

Does the pinyin of your predicted word contain the letter "o"?

Does the pinyin of your predicted word contain the letter "u"?

13. 艾米莉今年拿到了驾照，打算明年给自己买一台(车 che)。（92%）

Emily got her driver's license this year and next year plans to buy herself a car

您所预测的字的拼音中是否包含字母 "e"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "e"?

Does the pinyin of your predicted word contain the letter "g"?

14. 夏天天气变化非常快，我们出门最好带一把(伞 san)。（97% ）

The weather changes very quickly in summer, so when we go out we'd better bring an umbrella

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "o"?

15. 今天是中秋节，大家吃完饭后一起坐在院子里赏(月 yue)。（95% ）

Today is the Mid-Autumn Festival. After eating, everyone sits in the yard to see the moon

您所预测的字的拼音中是否包含字母 "e"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "e"?

Does the pinyin of your predicted word contain the letter "g"?

16. 丽丽每天晚上都睡得很晚，因为他喜欢熬(夜 ye)。（92% ）

Lili goes to bed very late every night because she likes to stay up late

您所预测的字的拼音中是否包含字母 "e"？

您所预测的字的拼音中是否包含字母 "i"？

Does the pinyin of your predicted word contain the letter "e"?

Does the pinyin of your predicted word contain the letter "i"?

17. 我姥姥生病了，我要去医院给她买(药 yao)。（95% ）

My grandma is sick, and I'm going to the hospital to buy her medicine

您所预测的字的拼音中是否包含字母 "o" ?

您所预测的字的拼音中是否包含字母 "g" ?

Does the pinyin of your predicted word contain the letter "o"?

Does the pinyin of your predicted word contain the letter "g"?

18. 妈妈早上刚拖完地，进门请换(鞋 xie)。（92%）

Mom just finished mopping the floor in the morning, so when entering the door please change your shoes.

您所预测的字的拼音中是否包含字母 "e" ?

您所预测的字的拼音中是否包含字母 "o" ?

Does the pinyin of your predicted word contain the letter "e"?

Does the pinyin of your predicted word contain the letter "o"?

19. 以前通信技术不发达，人们之间联系主要靠写(信 xin)。（89% ）

A long time ago, the communication technology was underdeveloped, and the communication between people mainly depended on writing letters

您所预测的字的拼音中是否包含字母 "n" ?

您所预测的字的拼音中是否包含字母 "u" ?

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "u"?

20. 铃声响了，老师走进教室给同学们上(课 ke)。（89% ）

The bell rang, and the teacher walked into the classroom to teach (lesson)

您所预测的字的拼音中是否包含字母 "e"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "e"?

Does the pinyin of your predicted word contain the letter "a"?

21. 早上吃的饭太咸了，现在我特别渴,想喝(水 shui)。（92%）

The meal I ate in the morning was too salty. Now I am very thirsty and want to drink (water)

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "g"?

22. 植树节到了，学校组织我们去山上种(树 shu)。（92%）

Arbor Day is here, and the school organizes us to plant trees.

您所预测的字的拼音中是否包含字母 "u"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "o"?

23. 小红是个懂事的孩子，吃完饭总是抢着帮妈妈洗(碗 wan)。（92%）

Xiaohong is a sensible child, always rushing to help her mother wash dishes.

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "i"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "i"?

24. 现在的女孩子都特别注重自己的形象，出门前都要化(妆 zhuang)。（89%）

Girls nowadays pay special attention to their own image, and before going out they have to put on makeup.

您所预测的字的拼音中是否包含字母 "g"？

您所预测的字的拼音中是否包含字母 "i"？

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "i"?

25. 家里的窗户被打碎了，门锁也被撬了，肯定进了(贼 zei)。（84% ）

The windows at home were broken and the door lock was picked, so there must be a thief

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "o"?

26. 他实在太胖了，真的需要赶紧减(肥 fei)。（92% ）

He is too fat and really needs to lose weight

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "a"?

27. 为了锻炼身体，我每天吃完晚饭后都去操场跑(步 bu)。（92% ）

In order to exercise, every day on the playground after dinner I go for a run.

您所预测的字的拼音中是否包含字母 "u" ?

您所预测的字的拼音中是否包含字母 "n" ?

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "n"?

28. 最近天气太热了，真期待能下一场大(雨 yu)。（92% ）

The weather has been too hot recently. I really look forward to a heavy rain

您所预测的字的拼音中是否包含字母 "y" ?

您所预测的字的拼音中是否包含字母 "n" ?

Does the pinyin of your predicted word contain the letter "y"?

Does the pinyin of your predicted word contain the letter "n"?

29. 春节快要到了，我期待学校赶紧放寒(假 jia)。（95% ）

The Spring Festival is coming soon, and I am looking forward to the winter vacation

您所预测的字的拼音中是否包含字母 "a" ?

您所预测的字的拼音中是否包含字母 "e" ?

Does the pinyin of your predicted word contain the letter "a"?

Does the pinyin of your predicted word contain the letter "e"?

30. 这个大钻戒看起来好漂亮，在灯光下闪闪发(光 guang)。（100% ）

This big diamond ring looks so beautiful, and under the light it is sparkling

您所预测的字的拼音中是否包含字母 "g" ?

您所预测的字的拼音中是否包含字母 "e"？

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "e"?

31. 刚接的开水不要立马就去喝，不然会烫(嘴 zui)。（76% ）

Don’t drink the boiled water you just received, otherwise it will burn your mouth

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "g"?

32. 王刚考了班级倒数第一名，他现在很伤(心 xin)。（92% ）

Wang just took the exam and ranked last in the class. He is very sad now

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "o"?

33. 爷爷退休之后很清闲，每天都去河边钓(鱼 yu)。（92% ）

Grandpa has a lot of leisure time after retirement. He goes to the river to going fishing

您所预测的字的拼音中是否包含字母 "y"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "y"?

Does the pinyin of your predicted word contain the letter "a"?

34. 今天是开学第一天，老师会给我们发新(书 shu)。（86% ）

Today is the first day of school, the teacher will send us a new book

您所预测的字的拼音中是否包含字母 "u" ?

您所预测的字的拼音中是否包含字母 "g" ?

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "g"?

35. 爸爸给我买的这双鞋太小了，穿起来磨(脚 jiao)。（95% ）

The pair of shoes my father bought for me are too small, and they wear out their feet.

您所预测的字的拼音中是否包含字母 "o" ?

您所预测的字的拼音中是否包含字母 "n" ?

Does the pinyin of your predicted word contain the letter "o"?

Does the pinyin of your predicted word contain the letter "n"?

36. 我想把这个西瓜切开，请去厨房给我拿一把(刀 dao)。（95% ）

I want to cut this watermelon, please go to the kitchen and get me a (knife)

您所预测的字的拼音中是否包含字母 "o" ?

您所预测的字的拼音中是否包含字母 "i" ?

Does the pinyin of your predicted word contain the letter "o"?

Does the pinyin of your predicted word contain the letter "i"?

37. 我们要节约用电，白天光线充足的时候不要开(灯 deng)。（89% ）

We must save electricity, and when there is sufficient light during the day, please do not turn on (lights)

您所预测的字的拼音中是否包含字母 "g" ?

您所预测的字的拼音中是否包含字母 "u" ?

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "u"?

38. 我们要讲文明守秩序，在食堂打饭的时候不要插(队 dui)。(92%)

We must talk about civility and order, and when eating in the cafeteria don't intervene queuing

您所预测的字的拼音中是否包含字母 "i" ?

您所预测的字的拼音中是否包含字母 "n" ?

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "n"?

39. 他刚做过手术，医生嘱咐他不要抽烟喝(酒 jiu)。(92%)

He just had an operation, and the doctor told him not to smoke or drink wine

您所预测的字的拼音中是否包含字母 "u" ?

您所预测的字的拼音中是否包含字母 "a" ?

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "a"?

40. 兰兰和她的男朋友已经相恋 8 年了，打算明年结(婚 hun)。(92%)

Lanlan and her boyfriend have been in love for 8 years and next year plan to get married

您所预测的字的拼音中是否包含字母 "n" ?

您所预测的字的拼音中是否包含字母 "e"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "e"?

41. 结婚后夫妻双方要对彼此忠诚，千万不要出(轨 gui)。（92%）

After marriage, the husband and wife should be loyal to each other and never cheat on each other.

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "o"?

42. 她和男朋友的感情非常地好，从来不吵(架 jia)。（86%）

She has a very good relationship with her boyfriend and they never quarrel

您所预测的字的拼音中是否包含字母 "a"？

您所预测的字的拼音中是否包含字母 "e"？

Does the pinyin of your predicted word contain the letter "a"?

Does the pinyin of your predicted word contain the letter "e"?

43. 这个世界上没有无缘无故的爱，也没有无缘无故的(恨 hen)。（89%）

There is no love without reason in this world, and likewise there is no hatred

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "o"?

44. 我喜欢喝甜的，请在咖啡里帮我多放点(糖 tang)。（92%）

I like to drink sweet food. Please put more sugar in my coffee

您所预测的字的拼音中是否包含字母 "g"？

您所预测的字的拼音中是否包含字母 "u"？

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "u"?

45. 我刚下飞机，就看到姑姑在不远处向我招(手 shou)。（95%）

As soon as I got off the plane, I saw my aunt waving hands.

您所预测的字的拼音中是否包含字母 "u"？

您所预测的字的拼音中是否包含字母 "i"？

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "i"?

46. 我已经闷在家里好几天了，打算待会儿出去透透(气 qi)。（92%）

I have been bored at home for several days, and I plan to go out later to get some air

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "a"?

47. 小丽天生有一副好嗓门，我们都喜欢听他唱(歌 ge)。（89%）

Xiaoli is born with a good voice. We all like to listen to him sing songs

您所预测的字的拼音中是否包含字母 "e"？

您所预测的字的拼音中是否包含字母 "i"？

Does the pinyin of your predicted word contain the letter "e"?

Does the pinyin of your predicted word contain the letter "i"?

48. 这个女孩身材比例特别好，拥有一双让人羡慕的大长(腿 tui)。（92%）

This girl has a particularly good figure and has a pair of enviable long legs

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "o"?

49. 为了保持口腔健康，最好每天刷两次(牙 ya)。（92%）

In order to maintain oral health, it is best to brush your teeth

您所预测的字的拼音中是否包含字母 "a"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "a"?

Does the pinyin of your predicted word contain the letter "o"?

50. 疫情期间我们要少出门，多通风，勤洗(手 shou)。（89%）

During the epidemic, we should go out less, ventilate more, and wash hands

您所预测的字的拼音中是否包含字母 "u"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "g"?

51. 站在一望无际的大草原上，我想去骑(马 ma) 。（89%)

Standing on the endless prairie, I want to ride a horse

您所预测的字的拼音中是否包含字母 "a" ?

您所预测的字的拼音中是否包含字母 "u" ?

Does the pinyin of your predicted word contain the letter "a"?

Does the pinyin of your predicted word contain the letter "u"?

52. 他不能参加比赛了，因为他的腰部受了重(伤 shang) 。（92%)

He can't take part in the competition because he hurt his waist

您所预测的字的拼音中是否包含字母 "g" ?

您所预测的字的拼音中是否包含字母 "o" ?

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "o"?

53. 这个小女孩多才多艺，不仅会唱歌还会跳(舞 wu) 。（89%）

This little girl is versatile. She can not only sing but also dance

您所预测的字的拼音中是否包含字母 "u" ?

您所预测的字的拼音中是否包含字母 "a" ?

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "a"?

54. 这位德高望重的科学家刚进会场，观众就立马起立鼓(掌 zhang) 。（92%)

As soon as this respected scientist entered the venue, the audience immediately stood up and applauded

您所预测的字的拼音中是否包含字母 "g"？

您所预测的字的拼音中是否包含字母 "i"？

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "i"?

55. 最近小偷很多，你走的时候千万不要忘了锁(门 men)。（92%)

There have been a lot of thieves recently, so when you leave don't forget to lock the door

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "o"?

56. 虽然我脸上的伤好了，但是却留下了一道(疤 ba)。（89%）

Although the wound on my face healed, there was a (scar)

您所预测的字的拼音中是否包含字母 "a"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "a"?

Does the pinyin of your predicted word contain the letter "g"?

57. 五一期间出行人流量大，高速路上很容易堵(车 che)。(95%)

During the May 1st period, there is a large flow of people, and it is easy to be blocked on the expressway

您所预测的字的拼音中是否包含字母 "e"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "e"?

Does the pinyin of your predicted word contain the letter "a"?

58. 他是一名户外运动爱好者，每到周末都要去爬(山 shan)。(92%)

He is an outdoor sports enthusiast, and every weekend he has to climb (mountain)

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "i"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "i"?

59. 每个周一早上，我们学校都要组织同学们去广场上升国(旗 qi)。(95%)

Every Monday morning, our school organizes students to go to the square to raise the national flag

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "g"?

60. 这个星期我要去美术馆，因为里面展览了很多幅达芬奇的(画 hua)。(95%)

I'm going to the art museum this week, because there are many Leonardo da Vinci's painting

您所预测的字的拼音中是否包含字母 "a"？

您所预测的字的拼音中是否包含字母 "n"？

Does the pinyin of your predicted word contain the letter "a"?

Does the pinyin of your predicted word contain the letter "n"?

61. 雪莉是个性格内向的女孩，不喜欢和同学说(话 hua) 。 (92%)

Shirley is an introverted girl who doesn't like talking

您所预测的字的拼音中是否包含字母 "a" ?

您所预测的字的拼音中是否包含字母 "i" ?

Does the pinyin of your predicted word contain the letter "a"?

Does the pinyin of your predicted word contain the letter "i"?

62. 马上就要交卷了，我还有两道题没做出来，急得直挠(头 tou) 。(84%)

I'm about to hand in the paper, and I still have two questions to answer, so I'm in such a hurry and scratching my head

您所预测的字的拼音中是否包含字母 "u" ?

您所预测的字的拼音中是否包含字母 "a" ?

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "a"?

63. 赵丽颖是个十足的工作狂，忙起来总是顾不上吃(饭 fan) 。 (89%)

Zhao Liying is a complete workaholic, and she always does not have time for food

您所预测的字的拼音中是否包含字母 "n" ?

您所预测的字的拼音中是否包含字母 "i" ?

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "i"?

64. 范冰冰是个劣迹艺人，因为她曾涉嫌偷(税 shui) 。 (81%)

Fan Bingbing is a bad artist because she was once suspected of stealing taxes

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "a"?

65. 现在的很多明星和网红都在抖音上做直播带(货 huo)。(92%)

Many celebrities and Internet celebrities now make live broadcasts on Tiktok to sell goods.

您所预测的字的拼音中是否包含字母 "o"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "o"?

Does the pinyin of your predicted word contain the letter "g"?

66. 赶紧去楼顶把衣服收了，因为天要刮大(风 feng)。(84%)

Go to the roof of the building quickly to collect your clothes, because there will be wind.

您所预测的字的拼音中是否包含字母 "g"？

您所预测的字的拼音中是否包含字母 "u"？

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "u"?

67. 他的度量实在太小了，因为一件小事就跟我翻(脸 lian)。(81%)

His tolerance is too small, and he would fall out with me over a trivial matter.

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "o"?

68. 如果你不按规则随便乱停车，就会被罚(款 kuan)。(76%)

If you park randomly without following the rules, you will be fined

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "o"?

69. 李白是一个很有才华的人，他的一生作了很多首(诗 shi)。(92%)

Li Bai was a very talented man and in his life wrote many poems

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "g"?

70. 春天来了，花丛中有很多蜜蜂在勤劳地采(蜜 mi)。(86%)

Spring is coming, and there are many bees in the flowers working hard to collect honey

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "n"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "n"?

71. 老婆觉得这个衣服卖的太贵了，她正在和老板砍(价 jia)。 (86%)

My wife thinks this dress is too expensive, and she is negotiating with the boss about the price

您所预测的字的拼音中是否包含字母 "a"？

您所预测的字的拼音中是否包含字母 "n"？

Does the pinyin of your predicted word contain the letter "a"?

Does the pinyin of your predicted word contain the letter "n"?

72. 等车的时候要注意保持安全距离，不要越过黄(线 xian)。 (95%)

When waiting for the bus, be sure to keep a safe distance and do not cross the yellow (line)

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "u"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "u"?

73. 他是个数学天才，每次数学考试都能拿满(分 fen)。 (92%)

He is a math genius and on every math test he gets full marks

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "a"?

74. 昨天我过生日，妈妈给我做了满满的一桌(菜 cai)。 (89%)

It was my birthday yesterday, and my mother cooked a table of dishes

您所预测的字的拼音中是否包含字母 "i" ?

您所预测的字的拼音中是否包含字母 "g" ?

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "g"?

75. 美国已经有 3000 万人感染了新冠病毒，今天又有两千人被确(诊 zhen) 。(95%)

Thirty million people in the United States have been infected with the new coronavirus, and today 2,000 more people have been diagnosed

您所预测的字的拼音中是否包含字母 "n" ?

您所预测的字的拼音中是否包含字母 "o" ?

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "o"?

76. 弟弟参加了学校运动会的跑步项目，并且获得了一等(奖 jiang) 。 (92%)

My younger brother participated in the running event of the school sports meeting and won the first prize

您所预测的字的拼音中是否包含字母 "g" ?

您所预测的字的拼音中是否包含字母 "u" ?

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "u"?

77. 脚踩在雪地上发出咯吱咯吱的声音，身后留下一串清晰的脚(印 yin) 。(89%)

You need to prepare a lot of materials for the final exam. The dean said you can go to his office to make copies

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "a"?

78. 给患者做手术前，医生都会先对伤口进行消(毒 du)。 (89%)

Before operating on a patient, the doctor will disinfect the wound

您所预测的字的拼音中是否包含字母 "u"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "g"?

79. 放学后，校长召集所有的老师们去会议室开(会 hui)。(86%)

After school, the principal called all the teachers to the conference room for a (meeting)

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "o"?

80. 大家都说这场比赛的结果不公平，一定有黑(幕 mu)。 (84%)

Everyone said that the result of this game was unfair and that there must be some evil behind it

您所预测的字的拼音中是否包含字母 "u"？

您所预测的字的拼音中是否包含字母 "e"？

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "e"?

81. 哥哥今年炒股赚了很多钱，所以又买了一套(房 fang)。 (89%)

Brother made a lot of money from stock trading this year, so he bought another house

您所预测的字的拼音中是否包含字母 "g"？

您所预测的字的拼音中是否包含字母 "e"？

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "e"?

82. 你这篇作文文采不错，但是里面有很多错别(字 zi)。 (95%)

Your essay is of good literary quality, but there are many mistaken words.

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "a"?

83. 哥哥抢走了妹妹的布娃娃，妹妹哭着去找妈妈告(状 zhuang)。 (81%)

The brother took away the sister's doll. The sister cried and went to her mother to complain

您所预测的字的拼音中是否包含字母 "g"？

您所预测的字的拼音中是否包含字母 "e"？

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "e"?

84. 最近公司很忙，老板逼着我们天天加(班 ban) 。 (92%)

The company is very busy recently, and every day the boss forces us to work overtime

您所预测的字的拼音中是否包含字母 "n" ?

您所预测的字的拼音中是否包含字母 "u" ?

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "u"?

85. 这份文件非常重要，你要再三检查千万不能出任何差(错 cuo) 。(92%)

This document is very important. You should check it again and again to make sure there are no mistakes

您所预测的字的拼音中是否包含字母 "o" ?

您所预测的字的拼音中是否包含字母 "e" ?

Does the pinyin of your predicted word contain the letter "o"?

Does the pinyin of your predicted word contain the letter "e"?

86. 今天上学你要多穿些衣服，因为天气要降(温 wen) 。（84%)

You have to wear more clothes when you go to school today, because the weather is going to drop (temperature)

您所预测的字的拼音中是否包含字母 "n" ?

您所预测的字的拼音中是否包含字母 "o" ?

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "o"?

87. 公司今年的效益不好，所以老板决定裁(员 yuan) 。（89%)

The company's performance this year is not good, so the boss decided to lay off employees

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "e"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "e"?

88. 对于男人而言，他们都喜欢在手腕上带一只表(表 biao) 。（89%）

For men, they all like to wear a watch on their wrist

您所预测的字的拼音中是否包含字母 "o"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "o"?

Does the pinyin of your predicted word contain the letter "g"?

89. 我的表姐已经 30 岁了还没有男朋友，舅舅让她明天去相(亲 qin) 。（95%)

My cousin is 30 years old and has no boyfriend yet. Tomorrow my uncle asked her to go on a blind date

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "a"?

90. 由于通货膨胀的缘故，人民币在不断地贬(值 zhi)。（92%）

Due to inflation, the renminbi is constantly depreciating

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "u"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "u"?

91. 这个女孩子心眼儿特别小，动不动就生(气 qi)。（89%)

This girl is very petty and gets angry easily.

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "a"?

92. 他第一次一个人来到这个陌生的城市，晚上特别想爸妈想回(家 jia)。（89%)

It was the first time he came to this strange city alone, and at night he especially missed his parents and wanted to go home

您所预测的字的拼音中是否包含字母 "a"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "a"?

Does the pinyin of your predicted word contain the letter "o"?

93. 他没有本事但是又死要面子，所以总在朋友面前吹(牛 niu)。（86%)

He has no skills but wants to save face, so he always brags (niu) in front of his friends.

您所预测的字的拼音中是否包含字母 "u"？

您所预测的字的拼音中是否包含字母 "e"？

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "e"?

94. 如果你没有钱全款买房子也没关系，可以先付个首(付 fu)。（89%）

If you don’t have the money to buy a house in full, it doesn’t matter. You can pay a down payment

您所预测的字的拼音中是否包含字母 "u"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "g"?

95. 这个小女孩从小被父母娇生惯养，从来没有吃过(苦 ku)。(78%)

This little girl was spoiled and spoiled by her parents since she was a child, and she has never experienced hardships.

您所预测的字的拼音中是否包含字母 "u"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "o"?

96. 这个好消息来得太突然，感觉就像做了一场(梦 meng)。(95%)

This good news came so suddenly, it felt like a dream

您所预测的字的拼音中是否包含字母 "g" ?

您所预测的字的拼音中是否包含字母 "u" ?

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "u"?

97. 我最近心情很不好，连着好几天晚上都失(眠 mian) 。（95%）

I have been in a bad mood recently and have been unable to sleep for several days in a row

您所预测的字的拼音中是否包含字母 "n" ?

您所预测的字的拼音中是否包含字母 "g" ?

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "g"?

98. 她嫁给了一个离过婚带孩子的男人，所以年纪轻轻就当了后(妈 ma) 。（86%）

She married a divorced man with children, so she became a mother at a young age.

您所预测的字的拼音中是否包含字母 "a" ?

您所预测的字的拼音中是否包含字母 "i" ?

Does the pinyin of your predicted word contain the letter "a"?

Does the pinyin of your predicted word contain the letter "i"?

99. 弟弟吃饭的时候太调皮，一不小心就打碎了一只(碗 wan) 。（81%）

My younger brother was too naughty when eating and accidentally broke a bowl

您所预测的字的拼音中是否包含字母 "n" ?

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "o"?

100.我们做事情要脚踏实地勤勤恳恳，因为成功没有捷(径 jing)。（86%）

We must be down-to-earth and diligent in doing things, because there is no shortcut

您所预测的字的拼音中是否包含字母 "g"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "a"?

101.儿子的脚长大了，我要带他去买双新(鞋 xie)。（92%）

My son’s feet have grown up. I want to take him to buy a new pair of shoes

您所预测的字的拼音中是否包含字母 "e"？

您所预测的字的拼音中是否包含字母 "u"？

Does the pinyin of your predicted word contain the letter "e"?

Does the pinyin of your predicted word contain the letter "u"?

102.小刚新交了一个女朋友，他们俩这周末要去公园约(会 hui)。（92%）

Xiaogang has a new girlfriend. They are going to the park for a date

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "e"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "e"?

103.袁华是一名高三的学生，再有两个多月就要参加高(考 kao)。（95%）

Yuan Hua is a senior high school student and will take the high school entrance exam in more than two months.

您所预测的字的拼音中是否包含字母 "o"？

您所预测的字的拼音中是否包含字母 "u"？

Does the pinyin of your predicted word contain the letter "o"?

Does the pinyin of your predicted word contain the letter "u"?

104.为了降低新冠病毒传播风险，国家提倡我们要尽快打疫(苗 miao)。（97%）

In order to reduce the risk of the spread of the new coronavirus, the state advocates that we should vaccinate (miao) as soon as possible

您所预测的字的拼音中是否包含字母 "o"？

您所预测的字的拼音中是否包含字母 "e"？

Does the pinyin of your predicted word contain the letter "o"?

Does the pinyin of your predicted word contain the letter "e"?

105.苹果手机像素非常高，我非常喜欢用它来拍(照 zhao)。（95%）

Apple mobile phones have very high pixels and I like to use them to take photos

您所预测的字的拼音中是否包含字母 "o"？

您所预测的字的拼音中是否包含字母 "n"？

Does the pinyin of your predicted word contain the letter "o"?

Does the pinyin of your predicted word contain the letter "n"?

106.明星吴越不喜欢化妆，她每次出席活动都是素(颜 yan)。（95%）

Wu Yue doesn't like makeup, she always wears plain (Yan yan) every time she attends an event

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "u"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "u"?

107.沈腾曾经又瘦又年轻，但是最终还是难逃中年发(福 fu)。（76%）

Shen Teng was once thin and young, but in the end he couldn’t escape the fate of becoming fat.

您所预测的字的拼音中是否包含字母 "u"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "a"?

108.中国好声音在开始正式比赛之前，需要在全国范围内进行海(选 xuan)。（95%）

Before starting the official competition, The Voice of China needs to carry out the first-round of competitions across the country

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "o"?

109.很多学生毕业之后没有找工作，而是选择了自主创(业 ye)。（92%）

Many students did not find a job after graduation, but chose to start their own business

您所预测的字的拼音中是否包含字母 "e"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "e"?

Does the pinyin of your predicted word contain the letter "a"?

110.玲玲非常喜欢宠物，家里边养了很多猫和(狗 gou)。（95%）

Lingling likes pets very much. There are many cats and gou in the house

您所预测的字的拼音中是否包含字母 "u"？

您所预测的字的拼音中是否包含字母 "i"？

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "i"?

111.现在互联网行业竞争激烈，如果你不好好干会立马失(业 ye)。（92%）

The competition in the Internet industry is fierce now, if you don’t work hard, you will lose your job

您所预测的字的拼音中是否包含字母 "e"？

您所预测的字的拼音中是否包含字母 "o"？

Does the pinyin of your predicted word contain the letter "e"?

Does the pinyin of your predicted word contain the letter "o"?

112.我的儿子什么都喜欢吃，吃饭从来不挑(食 shi)。（89%）

My son likes to eat everything, and he is never picky about food

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "a"?

113.作为一名职场上的打工人，我们最渴望的就是升职加(薪 xin)。(86%)

As a worker in the workplace, what we desire most is a promotion and a salary increase

您所预测的字的拼音中是否包含字母 "n"

您所预测的字的拼音中是否包含字母 "e"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "e"?

114.山西煤矿发生瓦斯爆炸事故，8 名伤者正在医院被抢(救 jiu)。 (86%)

A gas explosion accident occurred in a coal mine in Shanxi, and in the hospital eight injured people were rescued

您所预测的字的拼音中是否包含字母 "u"？

您所预测的字的拼音中是否包含字母 "a"？

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "a"?

115.这个女人插足了别人的婚姻，成为了一名人人唾骂的小(三 san)。(89%)

This woman meddled in other people’s marriages and became a mistress.

您所预测的字的拼音中是否包含字母 "n"？

您所预测的字的拼音中是否包含字母 "i"？

Does the pinyin of your predicted word contain the letter "n"?

Does the pinyin of your predicted word contain the letter "i"?

116.他现在的妻子是二婚，并不是他的原(配 pei) 。（84%）

His current wife is a second marriage, not his first wife.

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "g"?

117.现在医美技术越来越发达，很多想要变美的女生选择去整(容 rong) 。（89%）

Nowadays, medical and aesthetic technology is more and more developed, and many girls who want to look beautiful choose to have plastic surgery

您所预测的字的拼音中是否包含字母 "g"？

您所预测的字的拼音中是否包含字母 "u"？

Does the pinyin of your predicted word contain the letter "g"?

Does the pinyin of your predicted word contain the letter "u"?

118.章泽天嫁给了京东总裁刘强东，成为了一名豪门阔(太 tai)。（81%）

Zhang Zetian married Liu Qiangdong, the president of Jingdong, and became a rich married woman.

您所预测的字的拼音中是否包含字母 "i"？

您所预测的字的拼音中是否包含字母 "g"？

Does the pinyin of your predicted word contain the letter "i"?

Does the pinyin of your predicted word contain the letter "g"?

119.每天放学后，王刚都要去操场找同学们踢足(球 qiu) 。(95%)

Every day after school, Wang Gang goes to the playground to play football with his classmates

您所预测的字的拼音中是否包含字母 "u" ?

您所预测的字的拼音中是否包含字母 "o" ?

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "o"?

120.按照新的法律规定，男性需要工作到 65 岁才能退(休 xiu) 。(89%)

According to the new law, men need to work until they are 65 years old before they can retire

您所预测的字的拼音中是否包含字母 "u" ?

您所预测的字的拼音中是否包含字母 "e" ?

Does the pinyin of your predicted word contain the letter "u"?

Does the pinyin of your predicted word contain the letter "e"?

7.1.2. ***Stimuli for Experiment 2***

All 96 pairs of sentence contexts from Experiment 1 are listed below with the first one in each pair being more predictable and the second one being less predictable (cloze value indicated in brackets). The picture number corresponding to the target word in each pair is shown at the end of each sentence.

1. 小明拨打了 120，没过多久就驶来了一辆(救护车 jiu hu che) 。 (96.88%)

   Xiao Ming dialed 120, and not long after, arrived an ambulance.

   今天不知道发生了什么事，这里停了很多辆(救护车 jiu hu che) 。 (2.94%)

   I don't know what happened here today, because there are many ambulances.

2. 在中国古代，商人做生意算帐都是用（算盘 suan pan)。（88.24%）

   To perform mathematical function, businessmen in ancient China usually use abacus.

   如果这些算术题不好算，你可以使用(算盘 suan pan) 。（0%）

   If these arithmetic problems are difficult to solve, you can use an abacus.

3. 在上海浦东机场，平均每天起飞 1000 多架(飞机 fei ji)。（93.75%）

   At Shanghai Pudong Airport, on average every day there are more than 1,000 airplanes.

   这些恐怖分子胆子太大了，竟然试图劫持(飞机 fei ji) 。（2.94%）

   These terrorists are very daring; they attempted to hijack an airplane.

4. 小姑娘的脸红扑扑的，看起来像一个熟透了的(苹果 ping guo) 。（91.12%）

   The little girl's face was rosy, looking like a ripe apple.

   昨天我和妈妈去姑姑家做客，给他们带了一箱(苹果 ping guo) 。（9.09%）

   Yesterday, my mom and I visited my aunt's house and brought a box of apples.

5. 陈雨菲是一名羽毛球运动员，每天都会练习打（羽毛球 yu mao qiu ）。（88.24%）

Chen Yufei is a badminton player and every day she practices playing badminton.

这家公司研发出了一批专供运动员比赛使用的(羽毛球 yu mao qiu)。 (0.00%)

To make athletes, this company has developed a batch of badminton.

6. 求婚现场，这个男生精心布置了许多只五颜六色的 （气球 qi qiu）。（90.91%）

At the marriage proposal scene, this young man carefully arranged many colorful balloons.

元旦放假期间，大街上很热闹，有一个老爷爷在卖（气球 qi qiu）。（4.55%）

During the New Year's holiday, the streets were lively, and an old man was selling balloons.

7. 外婆年纪大了，苹果咬不动，所以我给她剥了一根（香蕉 xiang jiao）。（91.18%）

Grandma is elderly and can't bite into apples, so I peeled her a banana.

我去医院看望姥姥，给她买了许多她最爱吃的(香蕉 xiang jiao) 。（0%）

I went to the hospital to visit my grandmother and bought her many bananas.

8. 和姚明一样，他最擅长的运动也是打（篮球 lan qiu ）。（100%）

Like Yao Ming, his favorite sport is playing basketball.

今天在商场里，爸爸给弟弟买了一个（篮球 lan qiu）。（4.55%）

Today, at the mall, Dad bought my little brother a basketball.

9. 这间卧室太小了只够一个人住，所以只放了一张单人（床 chuang）。（100.00%）

This bedroom is too small for more than one person, so there's only a single bed.

刚才我下楼倒垃圾，看到小区的垃圾堆旁边放了一张（床 chuang）。（13.64%）

When I went downstairs to take out the trash, next to the garbage pile I saw a bed.

10. 如果你想更清楚地看远处的东西，就需要使用（望远镜 wang yuan jing）。（90.63%）

If you want to see distant things more clearly, you need to use binoculars.

他沉默地望着天空，时不时地举起手中的（望远镜 wang yuan jing）。（0.00%）

He silently gazed at the sky, occasionally raising the binoculars.

11. 请你不要再没事找事了，你这完全就是鸡蛋里挑（骨头 gu tou）。（93.75%）

Please stop looking for trouble when there's none, it is like you're picking bones out of an egg.

老人惊奇地发现，山上的破庙里面居然有几根（骨头 gu tou）。（0.00%）

The elderly person was surprised to find that in the temple on the mountain there were a few bones.

12. 图书馆新进了一批书但是没地方摆放，所以需要买一些（书架 shu jia）。（90.24%）

The library has received a new batch of books, but there's no place to put them, so they need to buy some bookshelves.

刚拖过的地非常滑，所以走路的时候要小心，不要撞倒旁边的(书架 shu jia) 。（0%）

The recently cleaned floor is very slippery, so you need to be careful while walking not to bump into the bookshelves.

13. 小红是个懂事的孩子，吃完饭总是抢着帮妈妈洗（碗 wan）。（90.63%）

Xiao Hong is a sensible child; after every meal, she always eagerly helps her mom wash the dishes.

我和妹妹在客厅跑着玩，不小心打碎了桌子上的（碗 wan）。（0.00%）

When my sister and I were running and playing in the living room, we accidentally broke the dishes.

14. 这个人非常地讲义气，对朋友总是两肋插(刀 dao) 。（97.56%）

This person is very loyal and always stands by his friends.

列车安检员告诉我们，火车上不允许带(刀 dao) 。（6.25%）

The train security officer told us that knives are not allowed on the train.

15. 春天百花盛开，花丛中飞舞着许多美丽的（蝴蝶 hu die）。（100%）

In spring, flowers bloom abundantly, and above the flowers there are many flying butterflies.

她的手非常灵巧，能够绣出各种图案，比如（蝴蝶 hu die）。（0.00%）

Her hands are very skillful and can embroider various patterns, like butterflies.

16. 今天是妈妈的生日，我去蛋糕店给她买了一个生日（蛋糕 dan gao）。（100.00%）

Today is my mom's birthday, so I went to the cake shop to buy her a birthday cake.

妹妹每次从这家小店路过，都会趴在橱窗上看里面的（蛋糕 dan gao）。（4.55%）

Every time my sister passes by this small shop, she leans against the window to look at the cakes.

17. 我不知道今天是什么日子，因为我忘了看（日历 ri li）。（93.75%）

I don't know what day it is today because I forgot to check the calendar.

我的办公桌上摆放了很多物品，其中一个是（日历 ri li）。（0.00%）

There are many items on my office desk, and one of them is a calendar.

18. 新疆有许多我喜欢的动物，尤其是被称为“沙漠之舟”的（骆驼 luo tuo）。（94.12%）

Xinjiang has many animals I like, especially the camels.

这个小宝宝咯咯咯地笑起来，因为他看到不远处有一只健壮的(骆驼 luo tuo)（0.00%）

The little baby giggled because he saw a big camel.

19. 人们经常把老师比喻成为燃烧自己照亮别人的（蜡烛 la zhu）。（90.63%）

People often compare teachers to candles.

警察调查后发现这场大火的罪魁祸首竟然是一支（蜡烛 la zhu）。（9.09%）

After investigation, the police found that the culprit of the fire turned out to be a candle.

20. 他很怕老师，每次见到老师就像老鼠见到（猫 mao）。(96.88%)

He is very afraid of the teacher. Every time he sees the teacher, he is like a mouse seeing a cat.

幼儿园老师正在认真地教小朋友画一只（猫 mao）。(4.55%)

The kindergarten teacher is seriously teaching the children to draw a cat.

21. 他不是什么盖世英雄，而是一个滑稽可笑的跳梁(小丑 xiao chou ）。

(80.49%)

He is not a hero of the world, but a ridiculous jumping beam clown.

为了逗全家人开心，爸爸把自己乔装打扮成了一个(小丑 xiao chou) 。(25%)

To amuse the whole family, dad disguised himself as a clown.

22. 我今天早上起床后没有梳头发，因为我找不到(梳子 shu zi) 。(93.75%)

I didn’t comb my hair after getting up this morning because I couldn’t find comb.

淘气的妹妹偷偷溜进了我的房间，拿走了我的(梳子 shu zi) 。(0.00%)

My naughty sister sneaked into my room and took my comb.

23. 为了辨别方向，轮船在海上航行的时候需要用到（指南针 zhi nan zhen）。(81.25%)

In order to identify the direction at sea, the ship needs to use compass.

我的爸爸是个海员，所以他很喜欢摆弄桌子上的（指南针 zhi nan zhen）。(6.25%)

My dad is a sailor so he likes to fiddle with the compass.

24. 他在互联网公司上班，每个人的桌子上都放着一台（电脑 dian nao）。(93.75%)

He works in an Internet company, and on each table there is a computer.

妈妈叫他去吃饭，可他却像没听见一样继续玩（电脑 dian nao）。(4.55%)

His mother asked him to go to dinner, but he continued to play computer.

25. 星期天，我和爸爸去玉米地里帮奶奶掰（玉米 yu mi）。(85.29%)

On Sunday, my father and I went to the cornfield to help grandma break corn.

我去奶奶家玩，看到她的屋檐下挂了许多（玉米 yu mi）。(4.55%)

I went to my grandma’s house to play and under her roof I saw a lot of corn.

26. 他的办公室有一套专门用来招待客人坐的软软的（沙发 sha fa）。(90.63%)

To make guests more comfortable, in his office there is a soft sofa.

下个月我家要搬进新房，打算重新添置一套（沙发 sha fa）。(11.76%)

My family is moving into a new house next month and plans to buy a new set sofa.

27. 他勤勤恳恳，老老实实工作，就像一头甘愿奉献的老黄（牛 niu）。(95.45%)

He works diligently and honestly, just like a willing and dedicated cow.

她虽然看起来很成熟，但是实际上只比我小一岁，她的属相是（牛 niu）。(3.13%)

Although she looks very mature, she is actually only one year younger than me. Her zodiac sign is Ox.

28. 女孩子在家要注意保护隐私，一到晚上就要拉上房间的（窗帘 chuang lian）。(93.75%)

Girls should pay attention to protecting privacy at home, and at night should close the curtains.

我奶奶是一个裁缝，她把我给她买的一块布改成了一个（窗帘 chuang lian）(2.94%)

My grandma is a seamstress and she turned a piece of cloth I bought her into a curtain.

29. 男朋友送了她一枚戒指，上面镶嵌着一颗闪闪发光的（钻石 zuan shi）。(94.12%)

Her boyfriend gave her a ring with a sparkling diamond.

小偷趁主人不在家入室盗窃，偷走了放在保险柜里的（钻石 zuan shi）。(0%)

The thief broke into the house while the owner was not at home and stole the diamond.

30. 在两亿年前的侏罗纪时代，地球上的统治者是（恐龙 kong long）。(100.00%)

During the Jurassic period 200 million years ago, the rulers of the earth were dinosaurs.

让我惊讶的是，这部电影的主角竟然是一只（恐龙 kong long）。(0.00%)

To my surprise, the protagonist of this movie turned out to be a dinosaur.

31. 他从医学院毕业之后进入医院成为了一名外科（医生 yi sheng）。(94.12%)

After graduating from medical school, he entered the hospital and became a surgeon doctor.

他看起来其貌不扬，谁也没想到居然是一名（医生 yi sheng）。(0%)

He looked unattractive, no one expected that he was actually a doctor.

32. 玲玲非常喜欢宠物，家里边养了很多猫和（狗 gou）。(93.75%)

Lingling likes pets very much, and in her house she has many cats and dogs.

这个车主因为车速过快，撞倒了邻居家的（狗 gou）。(8.82%)

Because the driver was driving too fast, he knocked down his neighbor's dog.

33. 妈妈告诉我进别人房间之前，一定要记得先敲（门 men）。(100.00%)

My mother told me that before entering someone else’s room, I must remember to knock door.

我的爷爷是一个木匠，他现在正在帮客户打造(门 men) 。(0%)

My grandfather is a carpenter, and he is now helping customers build doors.

34. 宿舍里实在太吵了，他只能用耳塞塞住（耳朵 er duo）。(100%)

It was so noisy in the dormitory that he could only plug (his ears) with earplugs.

爷爷是一名抗战老兵，在战场上被炸伤了一只（耳朵 er duo）。(0.00%)

Grandpa is a veteran of the Anti-Japanese War and during the war there was a blast injury of his ears.

35. 双方力量悬殊过大，就好像蚂蚁和（大象 da xiang）。(91.18%)

The disparity in power between the two sides is too great, just like an ant and an elephant.

我和弟弟每次去动物园，都要去看（大象 da xiang）。(4.55%)

Every time my brother and I go to the zoo, we have to go see elephant.

36. 小凯考试考砸了，没精打采的，蔫的就像一个霜打的（茄子 qie zi）。(90.63%)

Xiao Kai failed in the exam, listless, and limp like a beaten eggplant eggplant.

今天菜市场有很多人，原来是新上市了一批新鲜的（茄子 qie zi）。(0%)

There are many people in the vegetable market today. It turns out that there is a new batch of fresh eggplant.

37. 爷爷写完信后， 把它小心折叠放入（信封 xin feng）。(88.24%)

After grandpa finished writing the letter, he carefully folded it and put it into the envelope.

在幼儿园里老师教小朋友用纸制作（信封 xin feng）。(0%)

In kindergarten, the teacher teaches children how to use paper to make envelope.

38. 她有一张鹅蛋脸和一双水汪汪的大（眼睛 yan jing）。(100%)

She has an oval face and a pair of watery big eyes.

我不得不承认，这是我见过的最漂亮的一双（眼睛 yan jing）。(13.64%)

I have to admit, this is the most beautiful pair of eyes.

39. 孔雀开屏的时候之所以美丽，是因为它有一身五颜六色的（羽毛 yu mao）。(93.75%)

The reason why the peacock is beautiful when it opens its tail is because it has colorful feathers.

对于名人来说，一定不要做违反道德的事情，要爱惜自己的（羽毛 yu mao）。(11.76%)

For celebrities, they must not do anything that violates morality and cherish their own feathers.

40. 爷爷退休之后很清闲，每天都去河边钓（鱼 yu）。(97.06%)

Grandpa has a lot of leisure time after retirement. He goes to the river to catch fish.

厨房里传出阵阵香味，原来是妈妈在做红烧（鱼 yu）。(3.13%)

The smell came from the kitchen. It turned out to be my mother cooking braised fish.

41. 这个老板欺人太甚，工人们愤怒地握紧了（拳头 quan tou）。(96.88%)

The boss bullied people so much that the workers clenched their fists in anger.

我快速闪到一边，终于躲过了朝我打过来的(拳头 quan tou) 。(5.88%)

I quickly moved aside and finally dodged the fist.

42. 这种做法非常愚蠢，完全是搬起石头砸自己的(脚 jiao) 。(100%)

This approach is very stupid. It is completely shooting oneself in the foot.

今天他骑摩托车摔倒了，擦破了自己的(脚 jiao) 。(0%)

Today he fell while riding a motorcycle and scratched his foot.

43. 地球上现存的最高、脖子最长的动物就是（长颈鹿 chang jing lu）。(100%)

The tallest and longest-necked animal on earth is giraffe.

南京红山动物园今年从非洲引进了几只（长颈鹿 chang jing lu）。(2.94%)

This year from Africa, Nanjing Hongshan Zoo introduced several giraffes.

44. 现在很多学生都是高度近视，每天都要带（眼镜 yan jing）。(94.12%)

Many students nowadays are highly myopic and have to wear glasses.

出门时候因为太匆忙，我忘了带自己的（眼镜 yan jing）。(0%)

I was in such a hurry when I went out that I forgot to bring my own glasses.

45. 我们人类现在居住的星球叫（地球 di qiu）。(100.00%)

The planet we humans live on now is called Earth.

我们要像善待自己一样去善待（地球 di qiu）。(0.00%)

We need to be try to be kind to the Earth.

46. 今天下雪了，他的手冻得通红，因为他没有戴（手套 shou tao）。(100.00%)

It snowed today and his hands were red from the cold because he didn’t wear gloves.

我实在是拗不过妈妈，所以只好硬着头皮戴上（手套 shou tao）。(0.00%)

I really couldn't resist my mother, so I had to bite the bullet and put on gloves.

47. 我们都知道，葡萄酒的原材料是（葡萄 pu tao）。(95.45%)

We all know that the raw material of wine is grapes.

和哥哥一样，我们俩最讨厌的水果都是（葡萄 pu tao）。(0.00%)

Like my brother, the fruit we both hate the most is grapes.

48. 这对小夫妻很恩爱，每次出门老公都会牵着老婆的(手 shou) 。(94.12%)

This young couple is very loving, and every time they go outside, the husband will hold his wife’s hand.

她尴尬地笑了笑，一言不发地盯着母亲的(手 shou) 。(13.64%)

She smiled awkwardly and without saying anything, she just stared at her mother's hand.

49. 在图书馆要保持安静，想听歌曲必须要戴上（耳机 er ji）。(100%)

Keep quiet in the library and if you want to listen to songs, please wear headphones.

男友生日的时候，我送了他一副价格昂贵的（耳机 er ji）。(0.00%)

On my boyfriend’s birthday, I gave him an expensive pair of headphones.

50. 你已经铸成大错，千万不可一错再错，请赶紧悬崖勒（马 ma）。(100%)

You have already made a big mistake. You must not make the same mistake again and again. Please step back from the cliff horse.

这是我第一次来到大草原，以前从来没见过这么多的（马 ma）。(12.50%)

This is my first time coming to the prairie. I have never seen so many horses.

51. 具有很强跳跃能力并且刚出生会呆在母亲胸前口袋里的动物是（袋鼠 dai shu）。(100.00%)

The animal that has strong jumping ability and stays in the mother’s breast pocket when it is born is kangaroo.

在自然界有很多四肢敏捷、跳跃能力很强的动物，比如（袋鼠 dai shu）。(18.75%)

In nature, there are many animals with agile limbs and strong jumping abilities, such as kangaroos.

52. 小亮到家了却进不去家门，因为他忘了带（钥匙 yao shi）。（100%）

Xiao Liang got home but couldn’t get in because he forgot to bring key.

女生的包包真是万能的，能放各种东西比如（钥匙 yao shi）。（2.94%）

Girls’ bags are really versatile, they can hold all kinds of things such as keys.

53. 我姐姐说自己既能上得了厅堂，也能下得了（厨房 chu fang）。(97.06%)

My sister said that she can both go to the hall and go to the kitchen.

刚一进门，叔叔就热情地领我去看他们家的（厨房 chu fang）。(0%)

As soon as I walked in, my uncle enthusiastically showed me their kitchen.

54. 今天外面的风很大，非常适合去公园放（风筝 feng zheng）。(100%)

The wind outside is very strong today, which is very suitable for flying kite.

妹妹今天在公园里捡到了一个没人要的（风筝 feng zheng）。(2.94%)

My sister picked up an unwanted kite in the park.

55. 草原上飞奔过来一群被称作"草原之王"、正在愤怒咆哮的（狮子 shi zi）。(81%)

Over the grassland, came over a group of roaring lions.

邻居家爷爷擅长剪纸，不一会儿他就剪了一只栩栩如生的（狮子 shi zi）。(0.00%)

The neighbor's grandfather is good at paper-cutting, and soon he cut a lifelike lion.

56. 为了防止在山上迷路，你们一定要带一张（地图 di tu）。(100%)

In order to prevent getting lost on the mountain, you must bring a map.

爸爸是一名工程师，他在工作中经常需要用到（地图 di tu）。(0%)

Dad is an engineer, so in his work he often needs to use map.

57. 夏季最能消暑解渴的水果就是又大又圆的无籽(西瓜 xi gua) 。(96.88%)

The fruit that best relieves summer heat and quenches thirst is the big, round seedless watermelon.

弟弟放学一回到家，就迫不及待啃起了桌子上的（西瓜 xi gua）。(2.94%)

As soon as my younger brother came home from school, he couldn't wait to eat the watermelon.

58. 传说中上半身是美女，下半身是鱼尾的生物叫（美人鱼 mei ren yu）。(88%)

According to legend, the creature whose upper body is a beautiful woman and whose lower body is a fish tail is called mermaid.

小时候，我最大的梦想就是变成海里的一条（美人鱼 mei ren yu）。（3.13%）

When I was a child, my biggest dream was to become a mermaid.

59. 湖面上没有一丝风，水面非常平静，像一面（镜子 jing zi）。(100%)

There is no wind on the lake, and the water is very calm, like a mirror.

家里的小猫咪太调皮了，打碎了桌子上的（镜子 jing zi）。(2.94%)

The kitten at home was too naughty and broke the mirror on the table.

60. 这个男明星晚年时看破红尘，出家当了（和尚 he shang）。(97.06%)

In his later years, this male star saw through the world of mortals and became a monk.

今天和妈妈逛街的时候我居然看到了两名（和尚 he shang）。（0.00%）

Today when I was shopping with my mother, I actually saw two monks.

61. 在西游记中，花果山上一共有四万多只调皮可爱的小（猴子 hou zi）。（100%）

In Journey to the West, on Huaguo Mountain there are more than 40,000 naughty and cute little monkeys.

这个男孩总是喜欢乱翻别人的东西，就像一只讨人嫌的（猴子 hou zi）。（4.55%）

This boy always likes to rummage through other people's things, like an annoying monkey.

62. 过去农村养猫不是为了当宠物，而是为了让猫来捉（老鼠 lao shu）。（97.01%）

In the past, cats were kept in rural areas not for pets, but for cats to catch mouse.

我们正在吃火锅，突然锅里面掉进去一只(老鼠 lao shu) 。（0.00%）

We were eating hot pot, suddenly in the pot there came a mouse.

63. 我们操作电脑一般都是通过键盘和（鼠标 shu biao)。（100%）

We usually operate computers through keyboard and mouse.

他想打开电脑工作，却怎么也找不到（鼠标 shu biao)。（14.71%）

He wanted to open the computer to work, but he couldn't find the mouse.

64. 他嗅觉高度灵敏，因为他有一个非常灵敏的（鼻子 bi zi)。（95.45%）

He has a highly sensitive sense of smell because he has a very sensitive nose.

赛场上，穿蓝色短裤的拳击运动员猛击对手的（鼻子 bi zi）。（0.00%）

In the ring, a boxer in blue shorts punches his opponent in the nose.

65. 在医院里面，有着很多穿着白大褂的医生和（护士 hu shi)。（93.75%）

In the hospital, there are many doctors and nurses.

这个女孩子说，自己长大后想要成为一名 （护士 hu shi)。（5.88%）

This girl said when she grew up she wanted to be a nurse.

66. 我们现代人写字用钢笔或者铅笔，而古代人写字用（毛笔 mao bi)。（91.18%）

We modern people use pens or pencils to write, while ancient people used brushes.

今天晚上我偶然发现，爷爷的书房里珍藏了很多（毛笔 mao bi）。（4.55%）

Tonight I accidentally discovered that my grandfather has a lot of brushes.

67. 大家都知道，我们国家的国宝动物是大（熊猫 xiong mao）。（100%）

As we all know, the national treasure animal of our country is the giant panda.

我长这么大从来没去过动物园，也没见过（熊猫 xiong mao）。（13.64%）

I have never been to a zoo or seen a panda.

68. 他们两个兴趣相投，形影不离，关系好到可以穿一条 (裤子 ku zi) 。（97.06%）

The two of them have similar interests and are inseparable. Their relationship is so good that they can wear a pair of pants.

上个月姐姐从国外出差回来，送了我一条昂贵的(裤子 ku zi) 。（0.00%）

Last month, my sister came back from a business trip abroad and gave me an expensive pair of pants.

69. “麻屋子，红帐子，里面住着个白胖子”这个谜语描述的是（花生 hua sheng）。（90.63%）

The riddle "A hemp house with a red tent and a fat white man living inside" describes peanut.

河南是个农作物大省，种植了很多可以用来榨油的农作物，比如（花生 hua sheng）。（14.71%）

Henan is a major agricultural province and has grown many crops that can be used for oil extraction, such as peanuts.

70. 在地球的南极地区生活着很多胖乎乎的、呆萌可爱的（企鹅 qi e）。（94.12%）

In the Antarctic region of the earth, there are many chubby, cute and cute penguins).

她穿着厚厚的衣服裹得严严实实的，看起来就像一只（企鹅 qi e）。（16.00%）

She was wrapped up in thick clothes and looked like a penguin.

71. 在这次音乐会上，我终于亲眼见到了朗朗在弹（钢琴 gang qin）。（100.00%）

At this concert, I finally saw Lang Lang playing piano.

空荡荡的房间里只剩下一台落满灰尘的(钢琴 gang qin) 。（4.00%）

In the empty room there is only a dusty piano.

72. 他每天吃吃睡睡，什么都不干，简直就像一头（猪 zhu）。（97.06%）

He eats and sleeps every day and does nothing. He is just like a pig.

让我感到意外的是，他居然在自己的别墅里养了一头（猪 zhu）。（9.09%）

What surprised me was that in his villa he actually raised a pig.

73. 他肯定不是一个人住，因为他的床上放了两个（枕头 zhen tou）。（96.88%）

He must not live alone because on his bed there are two pillows.

我不喜欢在奶奶的房间睡，因为她的床上没有（枕头 zhen tou ）。（11.76%）

I don't like sleeping in grandma's room because on her bed there is no pillow.

74. 商场里有两名小偷，请赶快拨打 110 求助(警察 jing cha) 。（88.00%）

There are two thieves in the mall. Please call 110 for help from police.

妈妈告诉我如果被坏孩子欺负了，就立即告诉(警察 jing cha) 。（4.55%）

My mother told me that if I am bullied by a bad boy, I should tell the police.

75. 万圣节到了，为了雕刻南瓜灯笼，我买了一个又大又圆的（南瓜 nan gua）。（95.45%）

Halloween is here. In order to carve a pumpkin lantern, I bought a big, round pumpkin.

家里没有蔬菜了，我和奶奶准备去菜园里摘几个（南瓜 nan gua）。（0%）

There are no vegetables at home. My grandma and I are going to the vegetable garden to pick some pumpkins.

76. 去埃及旅游，我们最想看的就是世界八大奇迹之一的（金字塔 jin zi ta）。（88.24%）

When traveling to Egypt, what we most want to see is one of the eight wonders of the world: the Pyramids.

这个小男孩在沙滩上堆了一个沙堆，看起来就像一座（金字塔 jin zi ta）。（6.25%）

The little boy made a pile of sand on the beach that looked like a pyramid.

77. 乌龟虽然跑得很慢，但是因为坚持努力，最终跑赢了(兔子 tu zi) 。（92.00%）

Although the tortoise ran very slowly, because of his persistence he finally defeated the rabbit.

今天和妹妹去森林公园玩，发现在草地里有一只(兔子 tu zi) 。（12.20%）

I went to the forest park to play with my sister today and in the grass found a rabbit.

78. 爸妈说饭菜吃不完也不用倒掉，可以把它们放进（冰箱 bing xiang）。（97.06%）

Parents say you don’t have to throw away the food if you can’t finish it. You can put it in the refrigerator.

去年过年的时候，我用自己的工资给爸妈买了一台（冰箱 bing xiang）。（0.00%）

During the Chinese New Year last year, I used my salary to buy my parents a refrigerator.

79. 有一句古诗是“不知细叶谁裁出，二月春风似(剪刀 jian dao)”。（100%）

There is an ancient poem "I don't know who will cut out the thin leaves, like the spring breeze in February scissors".

他今天打开家里的工具箱找东西时，发现丢了一把(剪刀 jian dao)。（24.00%）

When he opened the toolbox at home today to find something, he found that he had lost a pair of scissors.

80. 和其他爱美的女生一样，小丽喜欢夏天穿（裙子 qun zi）。（90.63%）

Like other girls who love beauty, in summer Xiaoli likes to wear skirts.

今天和姐姐一起逛街，她给我买了一件（裙子 qun zi）。（0.00%）

I went shopping with my sister today and she bought me a skirt.

81. 我要努力一步一步往上爬，就像背着一只重重的外壳的（蜗牛 wo niu）。(90.91%)

I will work hard to climb up step by step, like a snail.

一场大雨过后环境变得潮湿，路面上出现了很多只（蜗牛 wo niu）。(9.38%)

The environment became wet after a heavy rain, and on the road there are many snails.

82. 小时候我读过伊索寓言中一个故事，名字叫农夫与（蛇 she）。（100%）

When I was a child, I read a story from Aesop’s fables called The Farmer and the Snake.

我不敢一个人走这条路，因为这里有很多(蛇 she) 。（4.00%）

I dare not walk this road alone because there are many snakes.

83. 下雪天我们最喜欢的事情就是在雪地里堆（雪人 xue ren）。（94.12%）

Our favorite thing on snowy days is to build snowmen.

午夜十二点，小女孩蹑手蹑脚地起身去看(雪人 xue ren) 。（0%）

At twelve o'clock at midnight, the little girl got up quietly to watch Snowman.

84. 像贝克汉姆和 C 罗一样，我的两个弟弟也喜欢踢（足球 zu qiu）。（96.88%）

Like Beckham and Cristiano Ronaldo, my two younger brothers also like to play football.

个子矮小的她穿着一个不合身的外套，上面印着一个 (足球 zu qiu) 。（0%）

Short of stature, she wore an ill-fitting jacket emblazoned with a football.

85. 为了学地理，妈妈给我买了一个和地球真实形状一样的（地球仪 di qiu yi）。（97.06%）

In order to learn geography, my mother bought me a globe.

这个小男孩太厉害了，居然用乒乓球做了一个小小的(地球仪 di qiu yi) 。（13.64%）

This little boy is so awesome, as he used a table tennis ball to make a small globe.

86. 我的爸爸从年轻时候就喜欢收集信封上粘贴的（邮票 you piao）。（100%）

Since he was young, my dad has been collecting stamps.

让我感到诧异的是，姐姐的房间里到处都贴满了（邮票 you piao）。（0.00%）

What surprised me was that my sister’s room was covered with stamps.

87. 女朋友怕我上半身冷，就买毛线给我织了一件（毛衣 mao yi）。（84.85%）

My girlfriend was afraid that my upper body would get cold, so she bought wool and knitted me a sweater.

天气预报说今天要降温，妈妈让我多穿一件（毛衣 mao yi）。（0%）

The weather forecast says it will be cooler today, so my mother asked me to wear an extra sweater.

88. 这个狡猾商人终于按捺不住了，露出了狐狸（尾巴 wei ba）。（88.24%）

The cunning businessman finally couldn’t hold himself back anymore and revealed his fox tail.

姥姥给我买了一只小白兔，我特别喜欢它的（尾巴 wei ba）。（0.00%）

Grandma bought me a little white rabbit and I especially like its tail.

89. 校长办公室的桌子上有一台电脑和一部固定(电话 dian hua) 。（92.00%）

On the desk in the principal’s office, there is only one computer and a telephone.

这个乡村学校设施很落后，全校上下只有一部(电话 dian hua) 。（11.76%）

The facilities of this rural school are very backward, and in the whole school there is only one (telephone).

90. 今天我们要在野外露宿，所以需要带一个（帐篷 zhang peng）。（91.12%）

Today we are going to sleep in the wild, so we need to bring a tent.

这种布料耐磨又防水，所以适合用来制作（帐篷 zhang peng）。（0.00%）

This kind of fabric is wear-resistant and waterproof, so it is suitable for making tents.

91. 如果你想精确地测量室内的温度，就需要一支（温度计 wen du ji）。（95.45%）

If you want to accurately measure the indoor temperature, you need a thermometer.

为了严格记录化学实验发生的条件，实验人员需要用到（温度计 wen du ji）。（2.94%）

In order to strictly record the conditions under which chemical experiments occur, experimenters need to use thermometers.

92. 在重要的场合，男人应该穿西装打（领带 ling dai）。（94.12%）

On important occasions, men should wear a suit and tie.

儿子已经二十岁了，但是还是不会系(领带 ling dai) 。（3.13%）

My son is twenty years old, but he still can’t tie a tie.

93. 早上的时候我没有刷牙，因为我找不到自己的（牙刷 ya shua）。（100.00%）

I didn’t brush my teeth in the morning because I couldn’t find my toothbrush.

爸爸每次出差住酒店回来，都会带回来很多（牙刷 ya shua）。（9.09%）

Every time my father comes back from a business trip and stays in a hotel, he will bring back a lot of toothbrushes.

94. 不要在这条铁路上玩耍，因为这里即将驶来一列（火车 huo che）。（93.75%）

Don’t play on this railway line because there will be a train.

你能不能快一点？再慢的话我们就赶不上这趟 (火车 huo che) 。（11.76%）

Can you hurry up? If we go any slower, we won't be able to catch this train.

95. 现在人们洗衣服不需要手洗了，因为家里有（洗衣机 xi yi ji）。（94.18%）

Nowadays, people no longer need to wash clothes by hand because they have a washing machine.

奶奶家里的电器少得可怜，只有一台破旧的(洗衣机 xi yi ji) 。（0.00%）

There are very few electrical appliances in grandma's house, only a worn-out washing machine.

96. 为了彰显气质，男人们都喜欢在手腕上佩戴一块（手表 shou biao）。（96.88%）

In order to show their temperament, on their wrist men like to wear a watch.

这个女生是个富二代，家里面有很多国际名牌的（手表 shou biao）。（0.00%）

This girl is a rich second generation, and her family owns many international brands watches.

7.1.3. ***Stimuli for Experiment 3***

All 84 pairs of sentence contexts from Experiment 3 are listed below with the first one in each pair being more predictable and the second one being less predictable. The mean cloze value of the target word in each pair is shown at the end of each sentence.

1. 今天是母亲节，我要去花店给母亲买（花 hua）。(81%）

   Today is Mother's Day. I am going to the flower shop to buy my mom flowers.

   这幅画的背景真美，里面有许多漂亮的（花 hua）。（50%)

   The background of this painting is so beautiful, because in the painting there are many beautiful flowers.

2. 今天的天空特别蓝，上边还飘着几朵白（云 yun）。(95%）

   The sky is particularly blue today, with a few white clouds.

   小亮抬起头，看见天空中有很多的（云 yun）。(61.9%)

   Xiaoliang raised his head towards the sky and saw a lot of clouds.

3. 在大街上要注意文明，不要随地吐（痰 tan）。(92%）

   Be civilized on the street and don't spit.

   我进病房时，正好看到一个病人在吐（痰 tan）。(38.1%)

   When I entered the ward, I happened to see a patient spitting.

4. 夏天到了，女孩子们都喜欢穿上漂亮的裙子去逛（街 jie）。(89%）

   Summer is here, and girls like to wear beautiful skirts and go shopping in the street.

   妈妈每天下班后，都会开车经过这个热闹的（街 jie）。(65%)

   Every day after get off work, my mother drives by this busy street.

5. 吃鱼的时候要特别小心，因为里面有很多（刺 ci）。（86%）

Be especially careful when eating fish because there are many thorns.

经过医生检查才发现，这个婴儿的眼睛里扎进去一根（刺 ci）。（42.86%）

After a doctor's examination, it was discovered that the baby's eye had a thorn.

6. 因为我有糖尿病，所以我很少吃 (糖 tang) 。（83%）

Because I have diabetes, I rarely eat sugar.

和其他小孩子一样，我弟弟也喜欢吃(糖 tang) 。 （55%）

Like any other kid my brother likes sugar.

7. 不是我不想买这件衣服，而是因为口袋里没有（钱 qian）。（95%）

It's not that I don't want to buy this dress, but because I don't have money.

在卫生间的抽屉里，我找到了前几天丢失了的 (钱 qian）。（38.10%）

In the bathroom drawer, I found the lost money.

8. 杰克写给安娜的情书很真诚，字里行间都充满了对她的（爱 ai）。（84%）

Jack's love letter to Anna is very sincere, and the lines are full of love.

无论男女，每个人都渴望拥有很多的（爱 ai）。（61.90%）

Whether male or female, everyone desires to have a lot of love.

9. 你要多吃饭多运动，不然会很容易生（病 bing）。（89%）

You have to eat more and exercise more, otherwise you will easily get sick.

小明今天给老师请假了没有来上课，因为他有(病 bing）。（38.1%）

Xiao Ming asked the teacher for leave today and did not come to class because he was sick.

10. 李明是个素食主义者，他从来不吃（肉 rou）。（92% ）

Li Ming is a vegetarian, he never eats meat.

这个学生每顿饭都会吃很多的（肉 rou）。（40%）

At every meal, this student eats a lot of meat.

11. 小王打完篮球回来出了一身汗，所以第一件事就是去洗（澡 zao）。（92%）

Xiao Wang was sweating after playing basketball, so the first thing he did was to take a bath.

晚上老公刚从外面回到家，他的老婆就开始催促他去洗（澡 zao）。（52.38%）

As soon as my husband came home from outside at night, his wife started urging him to take a bath.

12. 艾米莉今年拿到了驾照，打算明年给自己买一台(车 che)。（92%）

Emily got her driver's license this year and next year plans to buy herself a car.

王刚今年运气特别好赚了不少钱，所以打算明年买(车 che) 。（60%）

Wang Gang is very lucky this year and made a lot of money, so he plans to buy a car.

13. 夏天天气变化非常快，我们出门最好带一把(伞 san)。（97%）

The weather changes very quickly in summer, so when we go out we'd better bring an umbrella.

无论春夏秋冬，我每次出门都会随身携带(伞 san) 。（47.62%）

Regardless of spring, summer, autumn and winter, when I go outside I always carry an umbrella.

14. 今天是中秋节，大家吃完饭后一起坐在院子里赏(月 yue)。（95%）

Today is the Mid-Autumn Festival. After eating, everyone sits in the yard to see the moon.

小时候我最喜欢的一件事就是和奶奶一起赏(月 yue) 。（45%)

One of my favorite things as a kid was watching the moon.

15. 我姥姥生病了，我要去医院给她买(药 yao)。（95%）

My grandma is sick, and I'm going to the hospital to buy her medicine.

我今天因为工作太忙就忘了给奶奶买(药 yao) 。（52.38%)

Because I was too busy at work today, I forgot to buy medicine for grandma.

16. 妈妈早上刚拖完地，进门请换(鞋 xie)。（92%）

Mom just finished mopping the floor in the morning, so when entering the door please change your shoes.

妈妈答应我，如果我这次考满分，就给我买新(鞋 xie) 。(52.38%)

My mother promised me that if I get a perfect score in this test, she will buy me new shoes.

17. 以前通信技术不发达，人们之间联系主要靠写(信 xin)。(89%)

A long time ago, the communication technology was underdeveloped, and the communication between people mainly depended on writing letters.

妈妈起床后发现了儿子昨天给她留在桌子上的(信 xin) 。 (47.62%)

Mom woke up and found the letter her son left on the table.

18. 铃声响了，老师走进教室给同学们上(课 ke)。(89%)

The bell rang, and the teacher walked into the classroom to teach lesson.

我明天不用早起，因为我明天上午不需要去上(课 ke) 。（50%)

I don't have to get up early tomorrow because I don't need to go to class.

19. 早上吃的饭太咸了，现在我特别渴,想喝(水 shui)。（92%）

The meal I ate in the morning was too salty. Now I am very thirsty and want to drink water.

晚饭的时候他几乎什么都没吃，只喝了一些 (水 shui)

At dinner he hardly ate anything but drank some water. （35%）

20. 植树节到了，学校组织我们去山上种(树 shu) 。（92%）

Arbor Day is here, and the school organizes us to plant trees.

我看到公园门口的街道旁边种了很多(树 shu) 。（55%）

Beside the street at the entrance of the park I saw a lot of trees.

21. 小红是个懂事的孩子，吃完饭总是抢着帮妈妈洗(碗 wan)。（92% ）

Xiaohong is a sensible child, always rushing to help her mother wash dishes.

家里的猫咪跳到客厅的桌子上，打碎了一只(碗 wan) 。（52.38%）

The family cat jumped on the living room table and broke a bowl.

22. 家里的窗户被打碎了，门锁也被撬了，肯定进了(贼 zei)。（84%）

The windows at home were broken and the door lock was picked, so there must be a thief.

我放学回到家的时候，正好看到家里进了一个(贼 zei) 。（47.62%）

When I came home from school, I happened to see a thief.

23. 他实在太胖了，真的需要赶紧减(肥 fei)。（92%）

He is too fat and really needs to lose weight.

我不想吃这块肉了，因为它太(肥 fei) 。（52.38%）

I don’t want to eat this piece of meat because it’s too fat.

24. 为了锻炼身体，我每天吃完晚饭后都去操场跑(步 bu)。（92%）

In order to exercise, every day on the playground after dinner I go for a run.

我也不知道她去哪里了，她只说要去一个人少的地方去散(步 bu) 。（60%)

I don’t know where she went, she just said she was going for a walk.

25. 最近天气太热了，真期待能下一场大(雨 yu)。(92%）

The weather has been too hot recently. I really look forward to a heavy rain.

最近天气太冷了，天气预报说将会有一场大(雨 yu) 。（55%)

The weather has been too cold recently. The weather forecast says there will be heavy rain.

26. 春节快要到了，我期待学校赶紧放寒(假 jia)。(95%）

The Spring Festival is coming soon, and I am looking forward to the winter vacation.

小刚接下来两星期都不用去上班，因为他要休(假 jia) 。（55%)

Xiaogang doesn’t have to go to work for the next two weeks because he has to take a vacation.

27. 王刚考了班级倒数第一名，他现在很伤(心 xin)。(92%)

Wang just took the exam and ranked last in the class. He is very sad now.

无论我怎么对他，他都不相信我是真(心 xin) 。（52.38%)

No matter how I treat him, he doesn’t believe that I am sincere.

28. 爷爷退休之后很清闲，每天都去河边钓(鱼 yu)。(92%)

Grandpa has a lot of leisure time after retirement. He goes to the river to going fishing.

夏天的时候，他最喜欢的事情就是去捉(鱼 yu) 。（57.14%)

In summer, his favorite thing is to catch fish.

29. 今天是开学第一天，老师会给我们发新(书 shu)。（86%）

Today is the first day of school, the teacher will send us a new book.

对于爷爷来说，他的唯一爱好就是看(书 shu) 。（50%)

For Grandpa, his only hobby is reading books.

30. 爸爸给我买的这双鞋太小了，穿起来磨(脚 jiao)。（95% ）

The pair of shoes my father bought for me are too small, and they wear out their feet.

他最近一个月都不能下床走路，因为他在篮球赛中伤到了(脚 jiao) 。（52.38%）

He couldn't get out of bed and walk for the last month because in a basketball game he hurt his feet.

31. 我想把这个西瓜切开，请去厨房给我拿一把(刀 dao)。（95%）

I want to cut this watermelon, please go to the kitchen and get me a knife.

路人趁这个醉汉不注意，一把抢过了他手里挥舞着的(刀 dao) 。（47.62%）

A passer-by took advantage of the drunk man's inattention and snatched the knife.

32. 我们要节约用电，白天光线充足的时候不要开(灯 deng)。（89%）

We must save electricity, and when there is sufficient light during the day, please do not turn on (lights)

他再次提醒我最后离开房间的时候要记得关(灯 deng) 。（60%）

When I finally leave the room he reminded me again to turn off the lights.

33. 我们要讲文明守秩序，在食堂打饭的时候不要插(队 dui)。（92%）

We must talk about civility and order, and when eating in the cafeteria don't intervene queuing.

小亮从教室窗户里看到三年级的同学正在操场上排(队 dui) 。（61.9%)

From the window of the classroom, Xiao Liang saw on the playground the third grade students queuing.

34. 他刚做过手术，医生嘱咐他不要抽烟喝(酒 jiu)。（92%)

He just had an operation, and the doctor told him not to smoke or drink wine.

舅舅来我家拜年时，给我们送了一箱(酒 jiu) 。（60%)

When my uncle came to my house to pay New Year's greetings, he gave us a case of wine.

35. 兰兰和她的男朋友已经相恋 8 年了，打算明年结(婚 hun)。（92%）

Lanlan and her boyfriend have been in love for 8 years and next year plan to get married.

这个男孩和女孩正在商量该如何处理这段短暂的感情，他们不知道是否应当结(婚 hun) 。57.14%

The boy and the girl are discussing how to deal with this short-term relationship, and they don't know whether they should get married.

36. 结婚后夫妻双方要对彼此忠诚，千万不要出(轨 gui)。（92%)

After marriage, the husband and wife should be loyal to each other and never cheat on each other.

晚上吃饭的时候，他给自己妻子说他不会出(轨 gui) 。（47.62%)

When having dinner at night, he told his wife that he would not cheat.

37. 这个世界上没有无缘无故的爱，也没有无缘无故的(恨 hen) 。（89% ）

There is no love without reason in this world, and likewise there is no hatred.

这个男人的一番话让在场的所有人都对他充满了(恨 hen) 。（38.1%）

This man’s words made everyone present hate.

38. 我刚下飞机，就看到姑姑在不远处向我招(手 shou) 。（95% ）

As soon as I got off the plane, I saw my aunt waving hands.

我很羡慕我的姐姐，因为她有一双纤细的(手 shou) 。（65%）

I envy my sister because she has a pair of slender hands.

39. 为了保持口腔健康，最好每天刷两次(牙 ya) 。（92%）

In order to maintain oral health, it is best to brush your teeth.

在医院里，医生正在用一个小镜子查看病人的(牙 ya) 。（61.9%）

In the hospital, the doctor is using a small mirror to look at the patient's teeth.

40. 站在一望无际的大草原上，我想去骑(马 ma) 。（89%）

Standing on the endless prairie, I want to ride a horse.

这个身材高大体格健壮的蒙古男人手里牵着(马 ma) 。（61.9%）

This tall and strong Mongolian man is holding a horse.

41. 他不能参加比赛了，因为他的腰部受了重(伤 shang) 。（92%）

He can't take part in the competition because he hurt his waist.

让人愤怒的是，这名怀着身孕的女子竟然被她老公打(伤 shang) 。（38.10%）

What makes people angry is that this pregnant woman was injured by her husband.

42. 这位德高望重的科学家刚进会场，观众就立马起立鼓(掌 zhang) 。（92%）

As soon as this respected scientist entered the venue, the audience immediately stood up and applauded.

无论今天儿子的表演水平到底怎么样，我们都要给他鼓(掌 zhang) 。（42.86%）

No matter what the performance level of our son is today, we will applaud.

43. 最近小偷很多，你走的时候千万不要忘了锁(门 men) 。（92%）

There have been a lot of thieves recently, so when you leave don't forget to lock the door.

他慢慢抬起身子，用眼神示意旁边的护士去关(门 men) 。（47.62%）

He slowly raised his body and signaled the nurse next to him to close the door with his eye.

44. 虽然我脸上的伤好了，但是却留下了一道(疤 ba) 。（89%）

Although the wound on my face healed, there was a scar.

如果你仔细看的话会发现她的脸上有很深的(疤 ba) 。（50%）

If you look closely, on her face there are deep scars.

45. 他是一名户外运动爱好者，每到周末都要去爬(山 shan) 。（92%）

He is an outdoor sports enthusiast, and every weekend he has to climb mountain.

我们都没有注意到，这里居然还有一座(山 shan) 。（57.14%）

None of us noticed that there is actually a mountain.

46. 这个星期我要去美术馆，因为里面展览了很多幅达芬奇的(画 hua) 。（95%）

I'm going to the art museum this week, because there are many Leonardo da Vinci's painting.

警察经过两周的调查发现，这名贪官的家里藏了很多名(画 hua)。(60%)

After two weeks of investigation, the police found that in the corrupt official's home there were many famous paintings.

47. 雪莉是个性格内向的女孩，不喜欢和同学说(话 hua) 。 (92%)

Shirley is an introverted girl who doesn't like talking.

我不是很了解这个女生，只知道她平时没有很多(话 hua) 。(52.38%)

I don’t know this girl very well, I only know that she doesn’t talk.

48. 马上就要交卷了，我还有两道题没做出来，急得直挠(头 tou) 。(84%)

I'm about to hand in the paper, and I still have two questions to answer, so I'm in such a hurry and scratching my head.

小亮今天爬山的时候不小心被一块落下来的石头砸伤了(头 tou) 。(45%)

Xiaoliang was accidentally hit by a falling stone while hiking today and injured his head.

49. 赵丽颖是个十足的工作狂，忙起来总是顾不上吃(饭 fan) 。 (89%)

Zhao Liying is a complete workaholic, and she always does not have time for food.

王亮告诉我说他待会儿要去公司给女朋友送(饭 fan) 。(50%)

Wang Liang told me that he would go to the company later to deliver his girlfriend food.

50. 范冰冰是个劣迹艺人，因为她曾涉嫌偷(税 shui) 。 (81%)

Fan Bingbing is a bad artist because she was once suspected of stealing taxes.

工作后爸爸妈妈一再叮嘱我，一定要按时交(税 shui) 。 (55%)

After working, my parents repeatedly told me that I must pay tax.

51. 现在的很多明星和网红都在抖音上做直播带(货 huo) 。(92%)

Many celebrities and Internet celebrities now make live broadcasts on Tiktok to sell goods.

因为疫情这个小区明天就要被封锁了，我们要赶紧去囤(货 huo) 。(61.90%)

Because of the epidemic, this community will be blocked tomorrow, so we have to stock up goods.

52. 赶紧去楼顶把衣服收了，因为天要刮大(风 feng) 。 (84%)

Go to the roof of the building quickly to collect your clothes, because there will be wind.

我特别讨厌这个地区的天气，因为经常有大(风 feng) 。(50%)

I particularly hate the weather in this area because there is often wind.

53. 他的度量实在太小了，因为一件小事就跟我翻(脸 lian) 。(81%)

His tolerance is too small, and he would fall out with me over a trivial matter.

昏暗的灯光下，小琴泪眼朦胧地看着他的(脸 lian) 。(60%)

Under the dim light, with tearful eyes Xiaoqin looked at his face.

54. 如果你不按规则随便乱停车，就会被罚(款 kuan) 。 (76%)

If you park randomly without following the rules, you will be fined.

刚刚收到一封邮件，看到发货方催促我们打(款 kuan) 。(57.14%)

I just received an email and saw that the shipper urged us to pay.

55. 李白是一个很有才华的人，他的一生作了很多首(诗 shi) 。 (92%)

Li Bai was a very talented man and in his life wrote many poems.

这个可爱的小男孩是我的外甥，我的姐姐正在教他背(诗 shi) 。(50%)

This cute little boy is my nephew and my sister is teaching him to recite poetry.

56. 春天来了，花丛中有很多蜜蜂在勤劳地采(蜜 mi)。(86%)

Spring is coming, and there are many bees in the flowers working hard to collect honey.

听到这话，他高兴地不得了，感觉就像吃了(蜜 mi)。(40%)

Hearing this, he was so happy that he felt like he had eaten honey.

57. 他是个数学天才，每次数学考试都能拿满(分 fen)。(92%)

He is a math genius and on every math test he gets full marks.

小明今天在医院附近乱停车，所以被交警扣了(分 fen)。(52.38%)

Xiao Ming parked randomly near the hospital today, so the traffic police deducted his points.

58. 昨天我过生日，妈妈给我做了满满的一桌(菜 cai)。(89%)

It was my birthday yesterday, and my mother cooked a table of dishes.

暑假在家吃饭时，妈妈不停地往我的碗里夹(菜 cai)。(50%)

When I was eating at home during the summer vacation, my mother kept adding vegetables.

59. 美国已经有 3000 万人感染了新冠病毒，今天又有两千人被确(诊 zhen)。(95%)

Thirty million people in the United States have been infected with the new coronavirus, and today 2,000 more people have been diagnosed.

正在吃饭的医生撂下筷子就走，因为护士告诉他医院有急(诊 zhen)。(61.9%)

The doctor who was eating put down his chopsticks and left because the nurse told him that the hospital had an emergency.

60. 脚踩在雪地上发出咯吱咯吱的声音，身后留下一串清晰的脚(印 yin) 。(89%)

Our feet made a creaking sound on the snow, leaving a series of clear footprints.

期末考试需要准备很多资料，院长说可以去他的办公室复(印 yin) 。(47.62%)

You need to prepare a lot of materials for the final exam. The dean said you can go to his office to make copies.

61. 给患者做手术前，医生都会先对伤口进行消(毒 du) 。 (89%)

Before operating on a patient, the doctor will disinfect the wound.

我不敢吃陌生人提供的饭菜，因为我担心里面被人下(毒 du) 。(52.38%)

I dare not eat food provided by strangers because I am worried that it will be poisoned.

62. 哥哥今年炒股赚了很多钱，所以又买了一套(房 fang) 。（89%）

Brother made a lot of money from stock trading this year, so he bought another house.

去年过年的时候，我在父母的资助下买了(房 fang) 。（47.62%）

During the Chinese New Year last year, with the support of my parents I bought a house.

63. 你这篇作文文采不错，但是里面有很多错别(字 zi) 。（95% ）

Your essay is of good literary quality, but there are many mistaken words.

上完课，弟弟跑过来对我说他不认识这个(字 zi) 。（65%）

After class, my younger brother came to me and said he didn’t know the word.

64. 哥哥抢走了妹妹的布娃娃，妹妹哭着去找妈妈告(状 zhuang) 。（81%）

The brother took away the sister's doll. The sister cried and went to her mother to complain.

哥哥在军队立了大功，国家颁发给他一个奖(状 zhuang) 。（40%）

My brother has made great contributions in the army, and the country gave him an award.

65. 最近公司很忙，老板逼着我们天天加(班 ban) 。（92%）

The company is very busy recently, and every day the boss forces us to work overtime.

张亮装病请了假，因为他今天太累不想去上(班 ban) 。（52.38%）

Zhang Liang pretended to be sick and asked for leave because he was too tired today and didn’t want to go to work.

66. 今天上学你要多穿些衣服，因为天气要降(温 wen) 。（84%）

You have to wear more clothes when you go to school today, because the weather is going to drop temperature.

天气预报说再过几天这个地区要降(温 wen) 。（38.10%）

The weather forecast says that the temperature in this area will drop by.

67. 我的表姐已经 30 岁了还没有男朋友，舅舅让她明天去相(亲 qin) 。（95%）

My cousin is 30 years old and has no boyfriend yet. Tomorrow my uncle asked her to go on a blind date.

今天是重要的日子，早上五点他就起床准备去迎(亲 qin) 。（50%）

Today is an important day, he wakes up at five o'clock in the morning and prepares to greet his relatives.

68. 由于通货膨胀的缘故，人民币在不断地贬(值 zhi) 。（92%）

Due to inflation, the renminbi is constantly depreciating.

她花 50 元买了三个苹果，却发现它们又酸又小，所以觉得这些苹果不(值 zhi) 。（47.62%）

She bought three apples for 50 yuan, but found that they were sour and small, so she felt that the apples were not worth the prize.

69. 他第一次一个人来到这个陌生的城市，晚上特别想爸妈想回(家 jia) 。（89%）

It was the first time he came to this strange city alone, and at night he especially missed his parents and wanted to go home.

晚上女儿独自一个人在学校，她难过地告诉好朋友说她想(家 jia) 。（42.86%）

The daughter was alone at school at night, and she sadly told her best friend that she was homesick.

70. 他没有本事但是又死要面子，所以总在朋友面前吹(牛 niu) 。（86%）

He has no skills but wants to save face, so he always brags (niu) in front of his friends.

他非常地倔强固执，就像一头(牛 niu) 。（60%）

He is very stubborn and stubborn, like a cow.

71. 这个好消息来得太突然，感觉就像做了一场(梦 meng) 。（95%）

This good news came so suddenly, it felt like a dream.

不知道是不是最近烦心事太多，他总是频繁做(梦 meng) 。（45%）

I don’t know if he has too many worries recently, but he always dreams.

72. 我最近心情很不好，连着好几天晚上都失(眠 mian) 。（95%）

I have been in a bad mood recently and have been unable to sleep for several days in a row.

他没有告诉别人他最近看起来精神不好是因为他失(眠 mian) 。（42.86%）

He didn’t tell others that he seemed to be in a bad mood recently because he had insomnia.

73. 她嫁给了一个离过婚带孩子的男人，所以年纪轻轻就当了后(妈 ma) 。（86%）

She married a divorced man with children, so she became a mother at a young age.

看到身后这个五十岁左右的女人，这名男子惊讶地叫了一声(妈 ma)。（60%）

Seeing the fifty-year-old woman behind him, the man called out "Mom" in surprise.

74. 袁华是一名高三的学生，再有两个多月就要参加高(考 kao) 。（95%）

Yuan Hua is a senior high school student and will take the high school entrance exam in more than two months.

老师说要从小学和初中就打牢基础，才能更好地迎接高(考 kao) 。（52.38%）

The teacher said that we need to lay a solid foundation from elementary school and junior high school in order to better prepare for the college entrance examination.

75. 为了降低新冠病毒传播风险，国家提倡我们要尽快打疫(苗 miao)。（97%）

In order to reduce the risk of the spread of the new coronavirus, the state advocates that we should vaccinate (miao) as soon as possible.

在当下时刻，这个科研团队最主要的任务就是研究疫(苗 miao)。（52.38%）

At the moment, the main task of this scientific research team is to study vaccines

76. 明星吴越不喜欢化妆，她每次出席活动都是素(颜 yan)。（95%）

Wu Yue doesn't like makeup, she always wears plain (Yan yan) every time she attends an event.

从这张照片中我们可以看出这个女明星的素(颜 yan)。（61.9%）

From this photo, we can see that the female star has no makeup.

77. 很多学生毕业之后没有找工作，而是选择了自主创(业 ye)。（92%）

Many students did not find a job after graduation, but chose to start their own business.

截止日期马上就要到了，系里催促我们尽快提交自己的作(业 ye)。（50%）

Deadlines are approaching and the department is urging us to submit our own assignments.

78. 玲玲非常喜欢宠物，家里边养了很多猫和(狗 gou)。（95%）

Lingling likes pets very much. There are many cats and gou in the house

和她妈妈一样，丽丽最喜欢的宠物也是(狗 gou)。（52.38%）

Like her mother, Lili's favorite pet is also a dog.

79. 作为一名职场上的打工人，我们最渴望的就是升职加(薪 xin) 。(86%)

As a worker in the workplace, what we desire most is a promotion and a salary increase.

早会上公司的老板突然告诉王刚，说公司决定给他降(薪 xin) 。(40%)

At the morning meeting, the boss of the company suddenly told Wang Gang that the company decided to cut his salary.

80. 山西煤矿发生瓦斯爆炸事故，8 名伤者正在医院被抢(救 jiu) 。 (86%)

A gas explosion accident occurred in a coal mine in Shanxi, and in the hospital eight injured people were rescued.

记者闻讯赶到医院时，两名歹徒正在医院进行抢(救 jiu) 。(40%)

When the reporter heard the news and rushed to the hospital, two gangsters were being rescued in the hospital.

81. 他现在的妻子是二婚，并不是他的原(配 pei) 。(84%)

His current wife is a second marriage, not his first wife.

队长和一群人正在讨论该如何对这些钱进行分(配 pei) 。(52.38%)

The captain and a group of people are discussing how to distribute the money.

82. 现在医美技术越来越发达，很多想要变美的女生选择去整(容 rong) 。(89%)

Nowadays, medical and aesthetic technology is more and more developed, and many girls who want to look beautiful choose to have plastic surgery.

现在的女孩子都特别爱美，她们一有空就会去做美(容 rong) 。(45%)

Girls nowadays are very fond of beauty, and 45% of them will go for beauty treatments whenever they have time.

83. 每天放学后，王刚都要去操场找同学们踢足(球 qiu) 。(95%)

Every day after school, Wang Gang goes to the playground to play football with his classmates.

儿子回家炫耀说，对方根本接不住他的(球 qiu) 。（47.62%)

My son came home and showed off that the opponent couldn't catch his ball.

84. 按照新的法律规定，男性需要工作到 65 岁才能退(休 xiu) 。（89%）

According to the new law, men need to work until they are 65 years old before they can retire.

刘伟给学校人事处打电话，说自己打算明年退(休 xiu) 。(60%)

Liu Wei called the school personnel office and said that next year he planned to retire.

7.2. Experimental materials used in Study 2 (Experiments 4 and 5)

Item	Target_name	Phono_ Chinese	Semantic distractor	Phonological distractor	Unrelated distractor
1	airplane	face	rocket	area	room
2	balloon	chicken	kite	ballistic	coffee
3	basketball	land	tennis	bathroom	police
4	bone	goose	muscle	boat	ladder
5	bowl	wonder	dish	ball	rain
6	butterfly	hoodie	mosquito	button	thigh
7	cake	dance	bread	cave	wind

8	camel	lottery	horse	camp	gift
9	candle	laugh	lighter	cancer	planet
10	pumpkin	Nancy	carrot	pump	niece
11	apple	pink	banana	application	cloud
12	bull	news	cow	bulb	diary
13	dog	girl	cat	dot	car
14	door	men	window	dormant	father
15	ear	air	eyes	year	bill
16	elephant	dark	dinosaur	element	mirror
17	pyramid	jeans	tower	picture	wrist
18	earth	deer	moon	urge	glue
19	grape	pudding	orange	grade	theatre
20	hand	show	arm	Hannah	school
21	headphone	airport	speaker	heaven	court
22	horse	mother	sheep	hormone	company
23	watermelon	sea	strawberry	walker	bank
24	monkey	hotel	tiger	monk	fetus
25	mouse	sugar	keyboard	mouth	teacher
26	nose	bee	mouth	note	egg
27	nurse	hook	dentist	nerve	eyelash
28	trousers	cook	shoes	trout	beef
29	penguin	cheese	dolphin	pencil	sword
30	ambulance	joke	bus	amber	zebra
31	rat	loudspeaker	squirrel	raft	shampoo

32	rabbit	tooth	cat	rap	cheek
33	fridge	beans	oven	fringe	chair
34	kangaroo	dice	fox	canvas	dust
35	snail	water	turtle	sale	book
36	snake	shirt	lizard	snack	video
37	stamp	yoga	postcard	stand	tire
38	jumper	mouse	coat	jump	ocean
39	tail	waiter	wing	tailor	magnet
40	tie	link	scarf	tide	wood
41	toothbrush	yard	razor	tool	pear
42	watch	shoulder	clock	wallet	onion
43	hat	mouth	gloves	ham	bell
44	piano	gang	drum	picnic	syrup

7.3. Experimental materials used in Study 3 (Experiments 6 and 7)

All 36 pairs of sentence contexts are listed below. In each pair, the underlined word in the first sentence is homophonous with the underlined word in the second sentence. The objects paired with each sentence in the target condition, Chinese homophone condition, and unrelated condition are provided in brackets.

1. My brother loves reading. He always goes to the library to borrow many books and finishes reading them in one day. (book, comb, paddle)

   My sister has long hair, and every morning she brushes it with a comb to make it smooth and manageable. (comb, book, chess)
2. Take an umbrella with you, because there will be heavy rain at about 3 o'clock in the afternoon. (rain, feathers, comb)

   Many birds like parrots and peacocks, have beautiful and colourful feathers that make them very exotic and eye-catching. (feathers, rain, bottle)
3. My parents are very proud of me because during the speech competition I won a prize, and we are going out to celebrate it. (prize, paddle, feather)

   In the boat competition, everyone was trying hard to move the boat forward with their paddles to finish the race in first place. (paddle, prize, sheep)
4. My younger sister injured her feet and could not walk, so I had to carry her on my back and walked all the way home. (back, shells, ant)

   When we went to the beach, my sister walked along the shore and found lots of beautiful shells which she showed to my mum and me. (shells, back, monkey)
5. She was scared to death when she looked at the ground, because there was a very big and long snake lying not far from her. (snake, tongue, jewellery)

My younger brother is very naughty, and he tries to lick my ice-cream with his tongue when I am not around him. (tongue, snake, pig)

6. Even though I grew up on a farm, I still don't know how to ride a horse, and that is not common for kids like me. (horse, ant, dumplings)

   The boy likes to observe insects and now he is staring at the ground and watching a group of tiny ants, and he could watch them for hours. (ants, horse, prize)

7. Be careful about your bananas and hats when you climb this mountain, because there are many naughty monkeys, and they may take them from you. (monkey, throat, drum)

   I had a cold yesterday and now I have a high fever and a sore throat, so I will get some rest today. (throat, monkey, horse)

8. In the spring, the flowers in the park attract lots of flying bees and butterflies, I love watching them going around. (butterflies, lake, tongue)

   In Hyde Park in London, there are many white ducks in the lake, and many tourists go there to feed them. (lake, butterflies, medicine)

9. I went to the library to print something, but it has run out of both ink and papers, so I will have to go somewhere else. (paper, nail, lake)

   Psychologists say that when people get nervous, they tend to bite their nails, and this is a quite common habit. (nail, paper, dragon)

10. Pork has high nutritional value and this meat comes from pigs, and I eat pork every day. (pig, jewellery, muscle)

    If you want to buy necklaces or earrings, you should go to a store that sells jewellery, and you will have lots of options there. (jewellery, pig, oil)

11. Girls usually carry their belongings such as cell phone and lipstick in their bags, because their clothes don't often have pockets. (bag, bud, cage)

    Spring is coming, and the flowers have not blossomed yet, but we can already see some buds growing on the branches of trees. (bud, bag, wine)

12. The war between the two armies was bloody and in the front line there were many injured soldiers, but nobody knows when the war will end. (soldier, ice, chip)

    It snowed last night and the street is very slippery this morning because there is ice on it, and you should be careful. (ice, soldier, clothes)

13. The flowers attract many bees, and these bees are working hard to produce honey, which is an important ingredient for food. (honey, maple, flag)

    From the national flag of Canada, we can know that its national symbol is the red maple leaf, which is used to represent Canadian identity. (maple, honey, paper)

14. The birds that represent the world peace are white pigeons, so we should love and protect them. (pigeon, arm, eyebrow)

    To catch the boy falling from the roof, his father quickly opened his arms and luckily, he managed to do it. (arm, pigeon, back)

15. He does not like this pair of shoes because they are too small for his big feet, so he will buy another pair next week. (feet, dumplings, onion)

    On the Spring Festival eve, the tradition for Chinese people is eating dumplings while watching fireworks with their loved ones. (dumplings, feet, sand)

16. I like to eat very spicy food, so I always buy lots of red chilli and put them in the food during cooking. (chilli, candle, stamp)

There was no electricity and the room was completely dark, so we had to light a <u>candle</u> so that we could see everything clearly. (candle, chilli, rose)

17. In ancient Chinese dynasties, the legend says that when an emperor is born, in the sky you will see a big <u>dragon</u> that symbolizes the new emperor. (dragon, cage, apple)

    You don't need to be scared when you see a tiger in the zoo, because the tiger is locked in a <u>cage</u>, and it will not be able to hurt you. (cage, dragon, butterfly)

18. The transportation in the countryside is very complex, because there are many crossing <u>roads</u>, and the driver does not know where to go. (road, deer, nail)

    On the night of Christmas Eve, Santa Claus delivers presents in a sleigh pulled by <u>deer</u>, visiting every well-behaved child in the world. (deer, road, solider)

19. It was Valentine 's Day yesterday, so my dad bought my mum a bouquet of red <u>roses</u> to make her feel happy and loved. (rose, eyebrow, throat)

    She has beautiful eyes, and above the eyes there is a pair of thick and dense <u>eyebrows</u> that many girls are jealous of. (eyebrow, rose, chicken)

20. After she finishes drinking the water, she throws away the empty <u>bottle</u>, and then keeps walking on the street. (bottle, apple, tattoo)

    In the fairy tale, the Evil Queen was jealous of Snow White's beauty and gave her a poisoned red <u>apple</u>, but luckily, she was saved by the prince. (apple, bottle, forehead)

21. In the desert, strong winds make it hard to open your eyes because there is lots of yellow <u>sand</u>, and you can't see very far ahead. (sand, shark, goose)

    You should never swim in the sea here, because there are big and dangerous <u>sharks</u> in this sea that have killed many people. (shark, sand, road)

22. I have a bad cold because of this horrible weather, so I need to take some <u>medicine</u> to recover as quickly as possible. (medicine, key, candle)

    I was standing in front of my door, but I couldn't get inside, because I forgot my <u>keys</u>, so I had to call my flatmate. (key, medicine, book)

23. My favourite meat is lamb, and we know lamb is the meat of <u>sheep</u>, and compared to other meat, lamb tastes better. (sheep, onion, arm)

    The purple vegetable that is often used in salad and makes us cry when we cut it up is called <u>onion</u>, and it is used in many other dishes. (onion, sheep, pigeon)

24. I fell off the stairs and the X rays shows that I had broken a <u>bone</u> in my leg and I need to do a surgery. (bone, drum, bud)

    My brother joined a musical band recently and now he is beating a <u>drum</u>, and it makes so much noise in the house. (drum, bone, rain)

25. I like to eat eggs, because eggs have lots of nutrition and they are produced by a female <u>chicken</u> which is also called a hen by us. (chicken, muscle, ice)

    My brother goes to the gym every day, and now on his arms there are very big and strong <u>muscles</u>, so his efforts finally paid off. (muscle, chicken, honey))

26. In the summer, I always wake up at night, because I get bitten by tiny and annoying <u>mosquitos</u> and I can hear them buzzing around. (mosquito, tattoo, maple)

    This guy looks really dangerous because his whole body is covered with lots of colourful and scary <u>tattoos</u>, so you better not mess with him. (tattoo, mosquito, bone)

27. After my grandpa retired, his only hobby is sitting in front of a table with my father and play <u>chess</u> and he quite enjoys this life. (chess, flag, deer)

Every morning in Tiananmen Square, the Chinese army raises the national flag, and lots of tourists come to watch this event. (flag, chess, mosquito)

28. If you want to deep-fry something such as chicken or chips, you need to put a lot of oil into the pan so that the food can be covered. (oil, stamp, doctor)

    My grandpa received a letter from his friend, and on the envelope, there was a colourful stamp which he added to his collection. (stamp, oil, feet)

29. I told my mum I may have a fever, so to check my body temperature, she put her hand on my forehead, and she said I had a fever. (forehead, goose, shell)

    There is a lake in the city park, and in the lake, there are many beautiful white swans, and I like to watch them in the mornings. (goose, forehead, glass)

30. It is cold outside, so my mom said that I should wear more warm clothes, because she doesn't want me to catch a cold. (clothes, doctor, shark)

    His daughter is seriously ill, so he needs to take her to see the doctor before he goes to work in the office. (doctor, clothes, snake)

31. Last night when I went out to a bar with my friends, I ordered red wine and my friends ordered pints of beer. (wine, chives, man)

    The green vegetable that looks like spring onion but is very thin and not common in the UK is called chives, and I like to eat it a lot. (chives, wine, pumpkin)

32. Chinese civilization emerged in two important parts, and one is the Yellow River, and the other is the Yangtze River. (river, box, pineapple)

    The young man is proposing to his girlfriend, so he opens a small box and takes out a big diamond ring. (box, river, chilli)

33. Halloween is coming and we want to carve lanterns, so we need to buy a few pumpkins from the supermarket this week. (pumpkin, men, box)

In this room, there are 100 people in total and specifically, there are 40 women and 60 men, but more people might come later. (men, pumpkin, bag)

34. The material of mirrors and windows is the same, and they are both made of glass that is widely used in different industries. (glass, pineapple, chives)

When it comes to what should be put on a pizza, Italian people always say that you should never put pineapple on it, and it's always a debated topic. (pineapple, glass, heart)

35. This three-month old baby cannot chew any food because in his mouth he hasn't grown teeth yet, but in a few months he will. (teeth, sprout, key)

Beans can be used to make Toufu and other food. If you put beans into water for a few days, you will get bean sprouts, and it is my favourite vegetable. (sprout, teeth, river)

36. To save the girl's life, the man is pressing down her chest to restore the beating of her heart, and she came back to life eventually. (heart, chip, sprout)

When we insert our bank card into a machine, we should insert the end that contains the chips, otherwise it will not function properly. (heart, chip, teeth)