From *No, she does* to *Yes, she does*: On the conceptual changes in the processing of negative yes-no questions by Chinese-English bilinguals

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Abstract

Negation in English and Mandarin Chinese exhibit a peculiar difference. In response to negative yes-no questions (e.g., *Doesn't she like cats?*), the typical English answers (->*Yes, she does/No, she doesn't*) substantially vary from those in Chinese (->*No, she does/Yes, she doesn't*). What are the processing consequences of these markedly different conventionalised linguistic responses to achieve the same communicative goals? Is this crosslinguistic variation associated with measurably different cognitive demands when English and Chinese speakers process negation in a nonverbal context? Does L1 linguistic patterns influence L2 expression? If so, do they also change thinking that goes beyond overt language use in bilinguals? These questions are addressed here with innovative verbal and nonverbal experiments. This study aims to explore a) the ways and the extent to which linguistic routines influence the processing of negation; b) whether the way in which bilinguals process negation changes towards an L2-like pattern or else. There were four experiments. In verbal experiments, English and Chinese monolingual and Chinese-English bilingual participants answered positive/negative questions. Before the verbal experiments, half of the same participants were randomly selected in a nonverbal agree-disagree task, in which they were instructed to process positive/negative '='/'≠' symbols during equation verification (e.g., ▲≠■). Another sample of participants had a nonverbal facilitation task, in which they had to process same/different shapes with/without '='/'≠' symbols. English speakers showed a reaction-time advantage over Chinese speakers in negation conditions both in verbal and nonverbal contexts. These findings suggest language-specific processing of negation, and are interpreted as novel support for *linguistic relativity*. Bilinguals, like English speakers, were slowed down less by negative stimuli compared to positive stimuli than Chinese speakers in verbal and nonverbal contexts. These results suggest that the ways in which bilinguals process negative questions changed their L1-based habitual processing of negation in a nonverbal context.

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Author's Declaration

I declare that this thesis is a presentation of original work and I am the sole author. All sources are acknowledged as References. This work has not previously been presented for an award at the University of York, or any other institution. Part of the work contained in this thesis has been submitted as a co-authored article to be considered for publication in *Language, Cognition and Neuroscience* (project website https://osf.io/x4536/?view_only=74fb6c47a11143f7b1f400532a30f9c3).

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Chapter 1 Introduction

Routine answers to negative yes–no questions (e.g., Doesn't she like cats?) contrast sharply across languages. In English, the yes/no part of the answer is typically of the same polarity as the verb in the answer (e.g., Yes, she does/No, she *doesn't*). In Mandarin Chinese, however, *shi/shi de* ('yes') and *bu/bu shi/bu shi de* ('no'), typically oppose the polarity of the verb (e.g., *No, she does/Yes, she doesn't*). The answering system of Chinese speakers is known as *truth-based* while the answering system of English speakers is known as *polarity-based* (Holmberg, 2015). This crosslinguistic contrast is argued to arise because of language-specific negation in English and Chinese negative questions. Languages like Chinese structurally highlight attachment of negation to the statement and then reverse the truth value of the statement, i.e., *Doesn't she like cats?* -> 'Is it true that [she likes cats]' -> 'Is it true that [she doesn't like cats]'. In contrast, languages like English structurally highlight attachment of negation to the polarity of the question, i.e., *Doesn't she like cats?* -> 'Is it true or not that [she likes cats]'. The difference between attachment of negation in negative questions is theoretically anchored in Holmberg's (2015) distinction between high vs. middle negation, which will be explained in detail in Chapter 3. In high negation, typical in English, the form *n't* is attached to the question [Doesn't [she like cats]] whereas in middle negation, typical in Chinese, negation is attached to the statement of the question [Ta [bu [xi huan mao]] ma] i.e., [Does [she [not [like cats]]]].

English and Chinese speakers are assumed to take different routes when processing negation in negative questions. Although no direct evidence has yet been reported in support of the link between the answering systems and varied processing of negation, there is accumulating empirical work in favour of this assumption. One piece of evidence for this assumption is that differences in the verbal expression of negation may be linked to different mental routes to negative statements (Giora, Balaban, Fein, & Alkabets, 2004; Kaup, Lüdtke, & Zwaan, 2006). To illustrate, previous research (Kaup et al., 2006; Sherman, 1973, 1976) reported that it is more difficult to process *the umbrella is not open* compared to the *umbrella is closed*. *The umbrella is not open* is processed relatively slower because processing the negative statement (*not open*) in this case incurs an additional step after processing the positive statement (*open*). (Kaup et al., 2006). In light of this view, English and Chinese speakers may follow different routes to process negative questions due to variation in the attachment of negation. Another piece of evidence is the greater processing difficulty found in the processing of negative sentences compared to the processing of positive sentences (e.g., Akiyama, Brewer, & Shoben, 1979; Carpenter & Just, 1975; Clark & Chase, 1972; Dale & Duran, 2011; Fischler, Bloom, Childers, Roucos, & Perry, 1983; Kaup, Yaxley, Madden, Zwaan, & Lüdtke, 2007; Sherman, 1973, 1976). Many researchers attributed the greater difficulty in the former to an additional processing step compared to the latter (Clark & Chase, 1972; Carpenter & Just, 1975; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al., 2007). Given that Chinese speakers respond to negative statements of negative questions while English speakers respond to positive statements of negative questions, it is possible that Chinese speakers use an additional step compared to English speakers to process negative questions. The third piece of evidence for the assumed language-specificity in the processing of negation is the greater complexity reported in using the truth-based system in Japanese and Korean (Akiyama, 1979; Akiyama, Takie, & Saito, 1982; Akiyama & Guillory, 1983; Akiyama et al., 1979; Akiyama, 1992; Choi, 1991). The greater complexity may be accounted for by an additional step in the truth-based system compared to the polarity-based system. To the best of the author's knowledge, it has never been empirically investigated yet whether English and Chinese speakers process negation in negative questions in the same way or not. This is the first research gap this study aims to fill.

If, compared to English speakers, Chinese speakers use an additional step when they process negation in negative questions, this routine may persist in a nonverbal context. According to the *linguistic relativity hypothesis* (Whorf, 1956), 'cognition varies in accordance with people's language' (Everett, 2013, p.1). In relation to negation processing, if languages train their speakers to process negation in different ways in a verbal context, differences are likely to extend to a comparable nonverbal context. Specifically, Chinese speakers are expected to process negation in nonverbal context in the same way they process negation in negative questions. Despite growing evidence for the *linguistic relativity* hypothesis (Athanasopoulos & Bylund, 2013; Brown & Levinson, 1993; Bylund & Athanasopoulos, 2017; Casasanto, Boroditsky, Phillips, Greene, Goswami, Bocanegra-Thiel, 2004; Davidoff, Davies & Roberson, 1999; Fuhrman et al., 2011; Gordon, 2004; Levinson, 1996; Lucy, 1992; Lucy & Gaskins, 2001, 2003; Sera, Berge, & Pintado, 1994), to the best of the author's knowledge, it has not yet been examined in the domain of negation. This is the second research gap this study aims to fill, i.e., in what ways and to what extent language can influence the processing of negation in nonverbal contexts.

This study also extends the exploration in the processing of negation in English and Chinese monolingual speakers to Chinese-English bilinguals. In answering negative questions and other comparable domains, some empirical studies revealed that bilinguals can show L1-like performance when using their L2 (Alonso, 2016; Bassetti, Clarke, & Trenkic, 2018; Hohenstein, Eisenberg, & Naigles, 2006; Pavlenko & Jarvis, 2002; Vanek & Selinker, 2017; von Stutterheim, 2003). Nonetheless, empirical studies also indicated that bilinguals, when using their L1, can show L2-like performance and diverge from native speakers of their L1 (Akiyama, 1979; Bylund & Jarvis, 2011; Choi, 2014; Hohenstein et al., 2006; Pavlenko & Jarvis, 2002; Pavlenko & Malt, 2011; von Stutterheim, 2003). Given the interactions between bilinguals' two languages, if the processing of negation in negative questions is language-specific, Chinese-English bilinguals may differ from English or Chinese monolingual speakers when processing negative questions. Furthermore, there is growing empirical evidence (Athanasopoulos, 2009; Athanasopoulos, Damjanovic, Krajciova, & Sasaki, 2011; Athanasopoulos, Bylund, Montero-Melis, Damjanovic, Schartner, Kibbe, Riches, & Thierry, 2015; Athanasopoulos & Kasai, 2008; Bassetti et al., 2018; Brown & Gullberg, 2008; Bylund & Athanasopoulos, 2017; Cook, Bassetti, Kasai, Sasaki, & Takahashi, 2006; Kersten, Meissner, Lechuga, Schwartz, Albrechtsen, & Iglesias, 2010; Park & Ziegler, 2014; Vanek & Selinker, 2017) suggesting that L2 acquisition may lead to conceptual changes. In light of this view, what characterizes bilinguals' processing of negation in a nonverbal context will also be examined. If bilinguals approximate to L1-based pattern when they process negation in negative questions, they are expected to process negation in a nonverbal context like Chinese speakers. Alternatively, if bilinguals approximate to L2-based pattern when they process negation in negative questions, they would process negation in a nonverbal context like English speakers.

Chapter 2. The processing of negation

2.1. Introduction

Not a negligible number of studies demonstrated that the processing of negative sentences is more demanding than the processing of positive sentences (Akiyama et al., 1979; Carpenter & Just, 1975; Clark & Chase, 1972; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al., 2007; Sherman, 1973, 1976). Greater demand to process negative sentences has been attributed to an additional processing step (Clark & Chase, 1972; Carpenter & Just, 1975; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al., 2007). According to this view, when English speakers process a negative statement *She doesn't like cats*, they first need to process *She likes cats,* and then process *She doesn't like cats.* The reasons for using an additional step in processing negative sentences have been explained in different ways. Some scholars proposed that the processing of a negative statement (*She doesn't like cats)* is to verify the positive statement (*She likes cats*) in the first step and then reverse its truth value (Carpenter & Just, 1975). Other scholars argue that English speakers mentally simulate the positive state of affairs (*She likes cats*) before moving on to the corresponding simulation of the negative state of affairs (*She doesn't like cats)* (Kaup et al., 2007). A more recent explanation is that English speakers first process the underlying pragmatic purpose of a negative statement, which is *whether she likes cats,* before they process *She doesn't like cats* (Tian et al., 2010, 2016). These explanations converge on an important point, which is that negation is processed sequentially in two steps, moving from positive to negative state of affairs.

Although numerous empirical studies suggest that the processing of negation takes two steps, there is fast accumulating experimental evidence from different measures including RTs (Tian et al., 2010), eye fixations (Tian et al. 2016; Orenes et al., 2014), computer-mouse trajectories (Dale & Duran, 2011), ERPs (Nieuwland & Kuperberg, 2008) and fMRI (Tettamanti et al., 2008) in support of the view that negation can be processed in one step. To illustrate, the claim of a one-step model is that English speakers can process *She doesn't like cats* immediately in one step without having to initially process *She likes cats*. Scenarios where speakers of the polarity-based system tended to process negation in a single step include (a) negation in context (Nieuwland & Kuperberg, 2008), (b) negation in alignment with the speakers' expectations (Tian et al., 2010, 2016), and (c) when the negated positive statement was presented with an alternative statement (e.g., *She doesn't like cats* under the condition that she likes either cats or dogs) (Orenes et al., 2014). This thesis aims to bring new evidence to this debate by examining the way in which English and Chinese speakers process negative questions and negative equations. Empirical evidence for processing negation in one step and in two steps is presented in section 2.2 in this chapter.

It is important to explore the processing of negation from a crosslinguistic perspective since a great amount of empirical evidence suggests that the processing of negation is closely related to its verbal expressions and specific languages. Experimental studies (Carpenter & Just, 1975; Sherman, 1973, 1976; Wason & Jones, 1963) showed that the use of varied forms of negation can lead to different processing difficulties. For example, Sherman (1973, 1976) found that it is more difficult for English speakers to process *the umbrella is not open* compared to *the umbrella is closed.* This varied difficulty, according to Giora et al. (2004) and Kaup et al. (2006), is due to different mental routes to negative statements. To illustrate, *the umbrella is not open* was found to be processed relatively slower arguably because processing of negative statement (*not open*) in this case incurs an additional step after processing the positive statement (*open*) (Kaup et al. 2006). Also, crosslinguistic evidence revealed that processing of negation is not of the same difficulty for speakers of different languages. Compared to Korean and Japanese speakers, it is less difficult for English speakers to process negative questions (Akiyama, 1979; Akiyama et al., 1982; Akiyama & Guillory, 1983; Akiyama et al., 1979; Akiyama, 1992; Choi, 1991). Given the crosslinguistic evidence, Chinese speakers, who use a truth-based system to answer negative questions like Korean and Japanese speakers, may find it more difficult to process negative questions compared to English speakers as well. The empirical evidence suggesting the link between language and the processing of negation is discussed in section 2.3 in this chapter.

2.2. Processing negation in two steps vs. one step

2.2.1. Evidence for the two-step model

To explore how English speakers process negation, Clark and Chase (1972) designed a sentence-picture match verification paradigm to test reaction times (RT). They instructed English speakers to verify positive/negative sentences (e.g., A *plus is/isn't above star*) against picture stimuli (see Table 2.1) as quickly as possible. The researchers grouped sentences into four conditions based on the combinations of the truth value (true × false) and the polarity (positive × negative) of the sentences, namely True-Affirmative (TA), False-Affirmative (FA), True-Negative (TN) and False-Negative (FN) (see Table 2.1).

Table 2. 1 Sentence-picture pairs adapted from Clark and Chase (1972)

polarity of sentence	truth value	sentence	picture
affirmative	true	*A plus is above star.*	+ ☆
affirmative	false	*A star is above plus.*	+ ☆
negative	true	*A star isn't above plus.*	+ ☆
negative	false	*A plus isn't above star.*	+ ☆

Results showed a main effect of polarity on RT, indicating that English speakers were significantly faster verifying positive than negative sentences. The researchers also found a main effect of truth value on RT. Critically, a significant interaction between polarity and truth value was found. This interaction showed that it took English speakers shorter to verify a positive sentence if it was true than false (i.e., FA>TA); unlike for positive sentences, it took English speakers longer to verify a negative sentence when it was true than when it was false. (i.e., TN>FN). In order to explain the asymmetric RT pattern for positive and negative sentences, the researchers argued that English speakers processed positive statements first when processing negation. Following the first step, English speakers reversed the truth value of negated positive statements. To illustrate, English speakers processed a FN statement A *plus isn't above star* with two conceptual steps: first, they process the truth value of the positive statement 'Is it true that [a plus is above a star]'-> 'It is true'; second, they reverse the truth value of the positive statement 'it is false that [it is true]', i.e., false (a plus is above a star). According to Clark and Chase (1972), to verify a negative statement as true means to perform two negations and it therefore takes longer than to verify a negative statement as false. For an illustration, if *A star isn't above a plus* is true, then the first negation would be over the positive statement of the question 'Is it true that [a star is above a plus]'-> 'It is false', followed by the second negation over the truth value of the positive statement 'it is false that [it is false]', i.e., true (a star isn't above a plus) (see Tian et al., 2016 for a discussion). This asymmetric RT pattern for positive and negative sentences were confirmed by Carpenter and Just (1975) in a similar sentence-picture match verification paradigm (Experiment 1). If English and Chinese speakers in this study show an RT pattern comparable to that observed in Clark and Chase (1972) and Carpenter and Just (1975), it will suggest that they are likely to process negation following the two-step model.

Alongside the behavioural measure of RTs, Fischler and colleagues (1983) pioneered the investigation of how English speakers process negation measuring event-related potentials (ERPs). The researchers instructed English speakers to verify TA (*A robin is a bird*), FA (*A robin is a tree*), TN (*A robin is not a tree*) and FN (*A robin is not a bird*) sentences as quickly as possible. They observed RT asymmetry for positive and negative sentences, replicating previous results (Carpenter & Just, 1975; Clark & Chase, 1972). Besides the RT results, Fischler and colleagues observed that the brain potentials were significantly more negative for FA than TA sentences around 400 ms after the offset of the stimuli. In contrast, brain potentials were significantly more negative for TN than FN sentences 400 ms after the offset of the stimuli, which suggested that English speakers first processed the corresponding positive statements of the negative sentences. Based on the RT and ERP results, the researchers argued that English speakers did not process negation immediately in one step otherwise the N400 effect would have been symmetric (i.e., the brain potentials are significantly more negative for FN than TN sentences 400 ms after the offset of the stimuli). However, this study underwent criticism because of a design issue. According to Nieuwland and Kuperberg (2008), the N400 effect for negative sentences observed by Fischler et al., (1983) may be accounted for by the pragmatic infelicity of the comparison between a robin and a tree without any context (see later discussion in this chapter). Still, a recent study by Lüdtke, Friedrich, Filippis, and Kaup (2008) suggested that the conclusion of Fischler et al., (1983) that English speakers do not process negation immediately could be correct. Lüdtke et al., (2008) found that the processing of negation would appear out of the N400 window (see later discussion in this chapter). Although the results of Fischler et al., (1983) may not be conclusive, their argument is in line with the two-step model that English speakers process 'A robin is a tree' first when they process *A robin is not a tree.* If English speakers need to process the positive statement first before processing the negative statement as suggested by Fischler et al.'s (1983) results, then we might also expect that English speakers would take longer to process negative questions compared to positive questions.

Both Clark and Chase (1972) and Fischler et al., (1983) used sentence verification tasks to investigate the processing of negation. However, English speakers may not necessarily use the two-step model to process negation when there is no verification involved. For example, without any context, English speakers can process a negative sentence such as *She doesn't like cats* but not to verify it. Focusing on the processing instead of the verification of negation, Kaup and colleagues (2007) designed a probing recognition paradigm (Experiment 1). In each trial, English speakers read a negative sentence (e.g., *There was no eagle in the sky*) first. After a 250 ms interval, English speakers would see a picture probe matching/mismatching the shape of the object described in the sentence. For example, while *There was no eagle in the sky* matched an eagle with folded wings, it mismatched an eagle with outstretched wings (see Table 2.2).

Table 2. 2 Stimuli extracted from Kaup et al., (2007)

Sentence	Matched picture	Mismatched picture
There was no eagle in the sky.		

The task was to test how fast English speakers can recognize if the objects in the pictures were mentioned in the sentences. For the critical experimental sentences, the answer was always yes. Results showed that it took English speakers significantly shorter to recognize the pictorial probes when the probes mismatched the shape of the objects described in the sentences (e.g., an eagle with outstretched wings for *There was no eagle in the sky*) than when they matched them (e.g., an eagle with folded wings for *There was no eagle in the sky*). Kaup and colleagues (2007) concluded that English speakers first simulated positive state of affairs for processing negation.

A similar probing effect has also been reported by Kaup, Lüdtke, and Zwaan (2006) and Tian, Breheny, and Ferguson (2010) (see later discussion in this Chapter). Notably, previous studies (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983) argued that English speakers process negation by reverting the truth value of negated positive statements. Similarly, Kaup's simulation theory argued that

English speakers replace the simulation of positive state of affairs with its negative counterpart for processing negation. Both theories converge on that English speakers take two conceptual steps to process negation via its positive counterpart. As a result, processing a negative statement is more difficult compared to the one-step processing of a positive statement. Based on Kaup et al., (2007), English speakers in this study can process negation in two steps. Also, considering previous investigations of negation processing using tasks with verification (Clark & Chase, 1972; Fischler et al., 1983) and without verification (Kaup et al., 2007), two different experiments were designed in this study to address the processing of negation with and without verification.

The probing effect found in Kaup et al. (2007) was supported by Lüdtke, Friedrich, Filippis, and Kaup (2008). Lüdtke and colleagues tested the RTs and ERPs of German speakers in a sentence-picture comparison task. In each trial, participants first saw a sentence stimulus (e.g., *In front of the tower there is a/no ghost.*) in a word-by word format. After either a short (250 ms) or a long (1500 ms) interval, German speakers would see a picture stimulus (e.g., a ghost/lion in front of the tower) (see Table 2.3). The task was to verify whether the picture matched the sentence or not. If negative sentences are not processed immediately in one step, effect of negation was expected to be different for conditions with short and long intervals because participants would not have sufficient time to process negation when the interval was short. RT results showed a main effect of negation, truth value and the interaction between the two variables regardless of short or long intervals replicating previous studies. Moreover, at the short-interval condition, greater N400 effect was found when the objects in the pictures were not mentioned in the sentences than mentioned for both positive and negative sentences, which corresponds to Fischler et al.'s (1983) results. For instance, a picture of a lion in front of a tower elicited greater N400 effect for *In front of the tower there is a/no ghost* than that of a ghost (see Table 2.3).

Table 2. 3 Stimuli extracted from Lüdtke et al. (2008)

Sentence	Object mentioned	Object not mentioned
In front of the tower there is a/no ghost.		

Critically, the effect of negation appeared 550 ms after the onset of a picture for conditions with short intervals. In contrast, for conditions with long intervals, the effect of negation was observed as early as 250 ms after the onset of a picture. Lüdtke and colleagues explained that German speakers had enough time for integrating negation in their processing in the condition with long intervals. Based on the RT and ERP results, the researchers concluded that negative statements are not processed in one step. Lüdtke, et al. (2008) gives further support for the claim that it takes two steps to process negation.

Dale and Duran (2011) (Experiment 1) reported convincing evidence for the two-step processing of negation. The asymmetric RT pattern for positive and negative stimuli can suggest but not unambiguously confirm the two-step model. To compensate this flaw, Dale and Duran (2011) tracked participants' computer-mouse trajectories of responses when verifying sentences. English participants were instructed to verify sentences such as *Elephants are small/not small*. They would see one word at a time by clicking a circle at bottom of a screen to proceed. They chose their response by clicking either *true* or *false* at the top corners of the screen (see Fig 2.1).

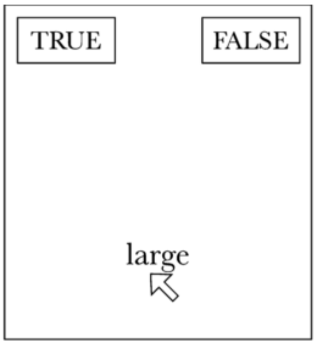

Figure 2. 1 The screenshot illustrating the interface of the experiment of Dale and Duran (2011)

Results showed that there were significantly more abrupt shifts between the response alternates when English speakers verified negative sentences compared to positive sentences. The greater number of shifts suggests that there is increased cognitive demand to process negative statements, and this added demand can be interpreted as an additional step to reverse the truth value of positive statements. The mouse-tracking evidence confirms previous RT and ERP results of Carpenter and Just (1975), Clark and Chase (1972), Fischler et al. (1983), Kaup et al. (2007) and Lüdtke et al. (2008). In this study, if English and Chinese speakers need two steps to process negative statements as suggested by Dale and Duran (2011), it would take them longer to process negative questions compared to positive questions. Still, results of Experiment 3 in Dale and Duran (2011) suggested that English speakers can take one step to process negative statements when sufficient context is provided (see later discussion in this chapter).

2.2.2. Evidence for the one-step model

Despite the great amount of evidence suggesting that negative sentences are more difficult to process than positive sentences, it does seem "effortless" (Nieuwland and Kuperberg, 2008, p.1214) for English speakers to process negation in communications. In order to test if English speakers can process negation immediately in one step, Nieuwland and Kuperberg (2008) examined the ERPs of English speakers processing what they called the "pragmatically licensed negation" (e.g., *With proper equipment, scuba-diving isn't very dangerous*). Pragmatically licensed negation was designed with context (*with proper equipment*) provided before the onset of the TA (e.g., *Scuba-diving is very safe*), FA (e.g., *Scuba-diving is very dangerous*), TN (e.g., *Scuba-diving isn't very dangerous*) and FN (e.g., *Scuba-diving isn't very safe*) sentences. The researchers also tested the processing of pragmatically unlicensed negation without context. Critically, FN sentences elicited significantly greater N400 effect than TN sentences for pragmatically licensed negation. This result of negative sentences was comparable to the processing of positive sentences that FA elicited significantly greater N400 effect than TA sentences. In contrast, FN and TN stimuli triggered similar N400 effect for pragmatically unlicensed negation. Nieuwland and Kuperberg argued that English speakers can process negative statements in one step, similar to the processing of positive statements. According to Nieuwland and Kuperberg (2008), English speakers can but not always process the negative statements in two steps via the positive statements in the first step. As the one-step model is an option available for English speakers, they may use this approach when processing negation in this study.

Tettamanti et al., (2008) used functional magnetic resonance imaging (fMRI) technique to examine brain activity of Italian speakers while they listen to positive and negative sentences. The sentences were either be action-related (e.g., *push /not push the button*) or abstract (e.g., *appreciate /not appreciate the loyalty*). Results showed that action-related sentences elicited the activation of motor regions in the brain compared to abstract sentences. Critically, the motor regions of the brain were significantly less activated by a negative action-related sentence (e.g., *not push the button*) in comparison to a positive one (e.g., *push the button*). These results may suggest that speakers of Italian process negation in one step. The rationale is that if

Italian speakers had processed negation sequentially in two steps, negative sentences would first have activated the brain's motor regions to a similar extent than positive sentences, and the activation level would then have decreased a step later. Nonetheless, the authors did not interpret these results as direct evidence for an immediate processing of negative statements because the temporal resolution of fMRI data may not be fine enough to capture the distinction between one-step and two-step negation processing. Tettamanti et al. (2008) aligns with the argument of Nieuwland and Kuperberg (2008) that negation can be processed in one step.

Tian, Breheny, and Ferguson (2010) also investigated whether English speakers can process negation in one step. The researchers designed a picture probing experiment following Kaup et al. (2007), using cleft (e.g., *It was Jane who didn't cook the spaghetti*) and simple (e.g., *Jane didn't cook the spaghetti*) negative sentences. The researchers designed negative cleft sentences with the attempt to elicit negative presupposition that someone did not cook the spaghetti. Besides the sentences, the researchers also designed pictorial probes matching/mismatching the state of the affairs in the sentences. For example, a picture of uncooked spaghetti matched a simple negative sentence *Jane didn't cook the spaghetti* and its cleft negative counterpart *It was Jane who didn't cook the spaghetti* (see Table 2.4). A picture of cooked spaghetti mismatched the two sentences (see Table 2.4).

Table 2. 4 Stimuli extracted from Tian et al., (2010)

Sentence type	Example	Matched picture	Mismatched picture
Cleft	*It was Jane who didn't cook the spaghetti*		
Simple	*Jane didn't cook the spaghetti*		

In each trial, English speakers saw a cleft/simple sentence first followed by a matching/mismatching picture. They were instructed to judge whether the object in the picture was mentioned in the preceding sentence or not as quickly as possible. Results showed that English speakers responded faster when pictorial probes mismatched (i.e., cooked spaghetti) simple negative sentences than when they matched them (i.e., uncooked spaghetti); In contrast, they responded faster when pictures matched cleft negative sentences than when they mismatched them. The match effect of cleft sentences was interpreted as evidence that English speakers processed negative cleft sentences immediately, without having to process the positive statement (*It was Jane who cooked the spaghetti*) first. On one hand, the results of simple negative sentences in Tian et al. (2010) replicated the probing effect observed in Kaup et al. (2007), and confirmed the argument that English speakers can use two steps to process negative statements. On the other hand, Tian et al. (2010) showed that English speakers can also process negation in cleft sentences in one step. Namely, English speakers preferred using two steps to process negative simple sentences while one step to process negative cleft sentences. This result suggests that verbal expressions may influence the processing of negation, which is further discussed with more empirical evidence in section 2.3.1.

Dale and Duran (2011) conducted another experiment (Experiment 3) similar to their Experiment 1 (see section 2.2.1) to test the possible one-step processing of negation in English speakers. Considering the results of Nieuwland and Kuperberg (2008), detailed context was provided with the aim to build participants' expectation for negation (e.g., *'You want to lift an elephant?' the mother said to her child, 'but elephants are not small'.*). This time, the shifts of computer-mouse trajectories of responses did not increase as a function of negation and falsity when English speakers verified sentences. The researchers concluded that the effect of context was not an acceleration of the two-step processing of negation. Rather, it enhanced the integration of negation so that English speakers could directly process the target negative statement in one step. Dale and Duran (2011) disentangled the one-step and the two-step models for negation processing by observing concrete shifts of computer-mouse trajectories. In light of their results, the one-step model is available for English speakers.

Orenes and colleagues (2014) further confirmed that negative statements can be processed in one step. The researchers tested the eye-fixations of Spanish speakers. In each trial, Spanish speakers would hear a contextual sentence first. The contextual sentence could set either a binary (e.g., *The figure could be red or green*) or a multiple condition (e.g., *The figure could be red, or green, or blue, or yellow*). At the offset the contextual sentence, they would see four coloured items (see Fig. 2.2).

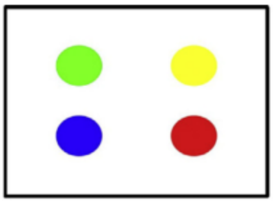

Figure 2. 2 Visual stimuli extracted from Orenes et al (2014)

After a 1000 ms interval, they would hear a target sentence (e.g., *The figure was not red).* Orenes and colleagues observed that the Spanish speakers focused on the colours mentioned in the target sentence in the multiple condition. For instance, they attended to the red circle after hearing *The figure was not red* in the context *The figure could be red, or green, or blue, or yellow*. However, the Spanish speakers focused on the available opposite in the binary condition. That is to say, they attended to the green circle after hearing *The figure was not red* in the context *The figure could be red or green*. The researchers concluded that there are two models for Spanish speakers to process negation, either immediately in a single step as observed in the binary condition, or sequentially via the positive statement as observed in the multiple condition. Importantly, in a binary yes-no-like condition similar to this study, Spanish speakers showed a tendency to process negative statements in a single step. Orenes et al. (2014) gives further support to the claim that it can only take one step to process negative statements. Furthermore, like Tian et al. (2010), Orenes et al. (2014) also suggested that there is a link between the verbal expressions and the processing of negation as Spanish speakers preferred using one step when there is an available opposite as green to red in the binary condition while they preferred using two steps in the multiple condition. This idea is discussed in section 2.3.1.

Tian and colleagues (2016) recently confirmed their behavioural results using an eye-tracking paradigm. They instructed English speakers to listen to simple (e.g., *Matt hasn't shut his dad's window*) and cleft sentences (e.g., *It* was *Matt who hasn't shut his dad's window*) similar to that in Tian et al. (2010). While listening to the audio stimuli, English speakers saw pictures matching/mismatching the state of the objects in the sentences. The researchers observed that it did not take any longer for English speakers to focus on the matching pictures (i.e., a closed window) for negative cleft sentences compared to positive ones. However, for simple negative sentences, English speakers looked at both matching and mismatching pictures first. It took them 900 ms longer to focus on the matched pictures for negative simple sentences compared to positive counterparts. Tian et al. (2016) provided additional support to their earlier argument (Tian et al., 2010) that English speakers processed negative cleft sentences immediately in one step. Moreover, the researchers further argued that the two-step model does not mean two discrete steps as argued before (e.g., Clark & Chase, 1972). Rather, English speakers relied on the negated positive statement "in parallel with" (Tian et al., 2016, p. 694) the processing of simple negative sentences. Unlike Clark and Chase (1972), Tian et al. (2016) tested negation processing without verification. Considering the different tasks, it is still possible that English speakers may use two discrete steps when they process negation with verification. Considering the results of Tian et al. (2016), it seems that the one-step and the two-step models are not mutually exclusive for English speakers but are a preference.

Following previous explorations in the processing of negation, this study also designed a verification task (Experiment 3) and tested RTs to investigate the processing of negation. Moreover, this study designed four conditions based on the combinations of the truth values (true × false) and the polarities (positive × negative) of the stimuli in Experiments 1-3 as previous studies did. Still, some different features are implemented. First, this study not only tests English but also Chinese speakers. This is the first time to directly compare the processing of negation of two groups of adult monolingual speakers to the best of the author's knowledge. By collecting crosslinguistic evidence, the two models can be differentiated by comparing the RTs of English and Chinese speakers. If one group of monolingual speakers (English or Chinese) show greater preference for the one-step model over the other, the former is expected to have shorter RTs for processing negation than the latter. If both English and Chinese speakers prefer using the two-step model, the two groups would both show an asymmetric RT pattern for positive (FA>TA) and negative stimuli (FN<TN) found in previous studies (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983; Lüdtke et al., 2008). If English and Chinese speakers prefer using the one-step model, neither groups would show the asymmetric RT pattern for positive and negative stimuli. Second, the verification and processing of negation are mixed together in previous studies. To compensate for this imperfection, this study designed two individual experiments with and without verification (Experiments 3 & 4). Third, unlike the sentence-picture comparison paradigm, this study separates the verbal and nonverbal contexts by using verbal stimuli in Experiments 1-2 and nonverbal stimuli in Experiments 3-4. This design is to test to what extent language can influence the processing of negation. The possible link between language and negation processing has been mentioned (e.g., Orenes et al., 2014; Tian et al., 2010). Next, empirical evidence suggesting this link is discussed.

2.3. Influence of language on the processing of negation

2.3.1. Different verbal expressions within a language, different routes

Negation encoded in language at lexical level is referred to as lexical negation (e.g., *The umbrella is closed*) and that at sentential level is referred to as negative particles (e.g., *The umbrella is not open*). The hypothesis that different forms of negation are associated with varied processing difficulties can be dated back to the 1960s. Wason and Jones (1963) tested the RTs of English speakers when they verified the overt negative particle *not* (e.g., *7 not an even number*) and a nonsense syllable MED that reverses the truth values of positive statements (e.g., *7 MED an even number*). Not only did they find a main effect of polarity and truth value as reported by later studies (Carpenter & Just, 1975; Clark & Chase, 1972), but also an interaction between polarity and the use of *not/MED*. This interaction indicated that it took English speakers significantly longer to process the negative particle *not* (440 ms longer than positive sentences) than the nonsense syllable MED (80 ms longer than positive sentences). This result was accounted for by the cognitive cost for processing the connotations of the negative particle *not*. In light of the different response speed when processing *not/MED*, the language-specific forms of negative questions in English and Chinese speakers (see chapter 3) may lead to varied processing difficulty of negation.

A similar argument for the link between the verbal expressions of negation and processing difficulties was reported a decade later. Sherman (1973, 1976) tested the RTs of English speakers when they verified positive sentences (e.g., *She was happy*) and negative sentences with implicit negation (e.g., *She was sad*), lexical negation (e.g., *She was unhappy*) and negative particles respectively (e.g., *She was not happy*). Sherman found that it took English speakers a similar amount of time to process the lexical negation *unhappy* and the implicit negation *sad*. Critically, it took English speakers significantly shorter to process the lexical negation *unhappy* (310 ms longer than positive sentences) than the negative particle *not* (520 ms longer than positive sentences). In Sherman's view, lexical negation such as *unhappy* provided a shortcut for English speakers to process negation considering that the reversal of word meaning is easier than that of sentence meaning. Sherman (1973, 1976) gives further support to the argument that the difficulty of negation processing is linked to how is it verbally expressed in language.

What makes the processing of the negative particle *not* or the reversal of sentence meaning in Sherman's words difficult? One answer is provided by Carpenter and Just's (1975) "constituent comparison model". According to this model, the expression of negation is closely associated with its scope, and the smaller the scope of negation, the smaller its difficulty. The researchers argued that the propositional structure of negation with a larger scope is more complicated than that with a smaller scope (see Table 2.5). To test this hypothesis, the researchers conducted a sentence-picture comparison task (Experiment 1) similar to Clark and Chase (1972). In the experiment, English speakers were instructed to verify pairs of pictures and sentences displayed simultaneously. The researchers designed negative markers with large scope (e.g., *It isn't true that the dots are red.*) and small scope (e.g., *It's true that the dots aren't red.)* in four conditions TA, FA, TN and FN. Carpenter and Just found the asymmetric RT pattern for positive (FA>TA) and negative sentences (FN<TN) comparable to Clark and Chase (1972). Furthermore, they also observed that it took English speakers 500 ms longer to process negative particles with the large scope than that with the small scope. The model proposed by Carpenter and Just (1975) can explain the results of Sherman (1973, 1976) that it took English speakers longer to process *she was not happy* than *she was unhappy*. With a smaller scope compared to the negative particle *not*, lexical negation such as *unhappy* thus provides a shortcut for English speakers to process negation. Based on Carpenter and Just's (1975) model, since the scopes of the negative marker are different in English and Chinese negative questions (see chapter 3), this difference can lead to language-specific processing difficulties.

Table 2. 5 Propositional structures according to the Constituent Comparison Model for the stimuli in Carpenter and Just (1975)

Positive sentence	Structure	Negative sentence	Structure
It’s true that the dots are red.	[AFF, (RED, DOTS)]	*It’s true that the dots aren’t red.*	[NEG, (RED, DOTS)]
		It isn’t true that the dots are red.	{NEG, [AFF, (RED, DOTS)]}

Recent empirical evidence suggests that the RT differences between the processing of varied expressions of negation may arise from different processing of negation, i.e., the one-step and the two-step models. Giora and colleagues (2004) designed a sentence priming task to test the processing of negation in different forms. The researchers examined the effect of positive sentences (e.g., *The instrument is sharp*), negative sentences with the negative particle (e.g., *The instrument is not sharp*) and negative sentences with lexical negation (e.g., *The instrument is blunt*) on the processing of semantically related (e.g., *piercing*) and unrelated (e.g., *leaving*) words. They instructed Hebrew speakers to read the positive/negative sentences first in a word-by-word fashion according to their own pace in each trial. 100 ms later to the offset of the stimulus, the participants were instructed to judge whether a probe is a word or a non-word. The researchers found that a negative sentence *the instrument is not sharp* facilitated the processing of *piercing,* which is comparable to the effect of a positive sentence *the instrument is sharp.* In contrast, *the instrument is blunt* did not facilitate the processing of *piercing.* Based on these results, Giora and colleagues (2004) argued that Hebrew speakers did not suppress the positive statement *sharp* when they processed the negative sentence *The instrument is not sharp*. These results were taken as evidence for processing the positive statement first before processing the negative statement in the second step by Kaup et al. (2006). In regards to the contrast in the processing of *not sharp* and *blunt,* the researchers argued that they differ at the initial stage of processing as the negativity of the former was weaker than that of the latter. This argument suggests that, unlike *not sharp,* the processing of the lexical negation *blunt* may not involve a first step to process the positive statement *sharp.* Hence, the processing of the lexical negation *blunt* may follow the one-step model. Together, results of Giora and colleagues (2004) suggest that Hebrew speakers may prefer taking two steps to process the negative particle while one step to process the lexical negation. In other words, different routes could underlie the different processing difficulties associated with varied expressions of negation as observed in Wason and Jones (1963) and Sherman (1973, 1976). In light of this idea, it is possible that crosslinguistic differences in English and Chinese answers to negative questions (see chapter 3) may linguistically pave different routes when they process negative questions.

This possibility that different expressions of negation are linked to different routes is further supported by Kaup, Lüdtke, and Zwaan, (2006). The researchers tested German speakers with a probing recognition paradigm. In each trial, participants were shown a positive/negative sentence (e.g., *The umbrella is open/not open*) first, after which they were presented with a picture matching/mismatching the state of the object depicted in the previous sentence (e.g., an open umbrella/a closed umbrella for *The umbrella is open*). Intervals between the stimulus and the pictorial probe were either short (750 ms) or long (1500 ms). If negative sentences are processed in one step, the effect of negation was predicted to be the same for the two conditions. Participants were instructed to name the object in the picture as quickly as possible and their naming latencies were analysed. A matching effect was observed for positive sentences with short intervals showing that participants were significantly faster when the two stimuli were matched *(e.g.,* an open umbrella for *The umbrella is open*) than mismatched *(e.g.,* a closed umbrella for *The umbrella is open*). In contrast, the matching effect for negative sentences was observed with long intervals showing that participants were significantly faster to name the probes when the two stimuli were matched *(e.g.,* a closed umbrella for *The umbrella is not open*) than when they were mismatched *(e.g.,* an open umbrella for *The umbrella is not open*). The researchers interpreted the interval effect for negative sentences by arguing that the negative particle is not processed in one step. If the negative particle is processed immediately, the matching effect should have been observed in conditions with short intervals. The matching effect for long intervals suggested that German speakers only processed negation at later step. Moreover, based on the matching effect with different intervals for the negative particle and the lexical negation (i.e., short interval for *The umbrella is closed* and long interval for *The umbrella is not open)*, Kaup and colleagues argued that the processing of the negative particle differs from that of lexical negation because the former requires an extra step via positive statements. In contrast, the target negative statements may be processed in one step when in the given language they are verbally expressed as lexical negation. Kaup et al. (2006) gives further support to the link between the processing of negation and its verbal expressions. According to Kaup et al., (2006), German speakers may prefer taking two steps to process the negative particle while one step to process the lexical negation. Given the relatively greater difficulty found in using two steps to process negation compared to processing negation in one step (Giora et al., 2004; Kaup et al., 2006; Sherman 1973, 1976; Wason & Jones, 1963), in this study, if English speakers are more likely to use one step to process negation than Chinese speakers, it is expected to take the former shorter than the latter when they process negative questions.

2.3.2. Different languages, different routes

English speakers typically use the polarity-based system (-*Doesn't she like cats?* -*Yes, she does/No, she doesn't*) when they answer negative questions. In contrast, Chinese speakers typically use the truth-based system (- *No, she does/Yes, she doesn't*) when they answer negative questions, and so do Japanese speakers (Akiyama, 1992;

Holmberg, 2015) and Korean speakers (Choi, 1991; Holmberg, 2015). Critically, crosslinguistic evidence from developmental studies suggests that responding to negative questions using the truth-based system is more difficult than using the polarity-based system. Akiyama (1979) investigated the responses to negative questions (e.g., *Can't you eat a block?*) in Japanese and English children (3-6 years old). He observed that Japanese children made significantly more errors (*-Can't you eat a block? -No.* The correct answer is *Yes, I can't* following the truth-based system.) compared with English children. Akiyama interpreted the late acquisition of Japanese system as evidence that it is more difficult to answer negative questions with a truth-based answer than with a polarity-based answer.

Like Akiyama (1979), Choi (1991) examined early language production in Korean and English children. She designed a longitudinal study and a cross-sectional elicitation study. In the longitudinal study, Choi asked two English children (1, 11-3, 2; 1, 7-3, 0) and two Korean children (1, 9-3, 3; 1, 7-2, 5) to answer yes-no questions such as *Isn't it a bird?* when they looked at pictures of animals. In the cross-sectional elicitation study, a different sample of English and Korean children (age range 1,9-3,0) first saw picture cards. Then they were instructed to answer yes-no questions and to match the picture cards with the same pictures on a board. To illustrate, when the researcher asked *Isn't it a bird* while holding a picture card of a bird in her hand, participants were expected to verbalize their answer to the question and match the picture card with the picture of a bird. The researcher found that Korean children gave more elaborate responses (e.g., Q: *isn't it a bird? A: a bird*.) instead of *yes/no* answers (see examples 1-2) when they answered negative questions than English children did.

1) Example of answering *yes* to Korean negative questions:

Q:	ike	say-ka	an-i-ya?
	this	bird-Subject	Neg-be-Ending form

"Isn't this a bird?

A: - ɨng [the referent is a butterfly]

Yes

'No'

2) Example of answering *no* to Korean negative questions:

Q: ike say-ka an-i-ya?

this bird-Subject Neg-be-Ending form

"Isn't this a bird?

A: - ani [the referent is a bird]

No

'Yes'

Comparable to Akiyama (1979), Choi (1991) attributed the late acquisition of the Korean system to greater difficulty in the truth-based system with an additional processing operation compared to the polarity-based system. To illustrate the additional operation in the truth-based system, when the negative question is *Isn't it a bird?*, Korean speakers need to first process 'Is it true that [it is a bird]' and then process 'Is it true that [it isn't a bird]'. In contrast, English speakers process the same negative questions in one step, i.e., *Isn't it a bird?* -> 'Is it true or not that [it is a bird]'. Choi (1991) and Akiyama (1979) suggest that processing negative questions is more difficult and therefore less direct in children acquiring the truth-based system than the polarity-based system. Here the exploration is whether greater difficulty in processing negation also shows in adult speakers of a truth-based system. To date, there is no crosslinguistic evidence showing that the processing of negative questions would be more difficult for Chinese speakers than it is for English speakers, which is the prediction based on available research findings. In light of Choi's (1991) argument, if we assume that English speakers tend to process negative questions in one step, then Chinese speakers are expected to process negative questions in two steps.

Other support for the idea that speakers of the truth-based system process negative statements less directly than speakers of the polarity-based system comes from research on denials. Akiyama (1985, 1992) asked 4-year-old Japanese and English children to say the opposite to positive statements such as *A lady bug is large.* The researcher explained to the children that they can either say *A lady bug is not large* or *A lady bug is small* in the practice trials in a counterbalanced order. The frequencies of negative particles (e.g., *not large*) and lexical negation (e.g., *small*) were calculated. English children showed significantly greater preference for lexical negation (50% of the time) in comparison to Japanese children (23% of the time). The observations in Akiyama (1985, 1992) suggest that Japanese and English children follow different routes in negation processing, which vary in cognitive demands. Recall that in section 2.3.1, related research with speakers of Hebrew, German and English (Giora et al., 2004; Kaup et al., 2006; Sherman, 1973, 1976) provides evidence that it is more difficult to process less direct negation *A ladybug is not large* than more direct lexical negation *A ladybug is small*. Given the link between the one-step and the two-step routes and varied forms of negation (Giora et al., 2004; Kaup et al., 2006), Akiyama's (1985, 1992) results can suggest that English speakers more typically process negative statements in one step while Japanese speakers in two steps. In order to better understand the more universal versus the more language-specific features in the cognitive demands of the processing of negation, this study explores a typically truth-based system in a direct comparison with a polarity-based system.

Empirical evidence suggesting that using the truth-based system is more difficult than using the polarity-based system also comes from the comparisons between answering negative questions and verifying negative sentences. In the view of Carpenter and Just (1975), answering negative yes-no questions can be regarded as comparable to verifying negative sentences since both answering questions and sentence verification require a comparison between two sources of information. However, as mentioned earlier, English speakers typically answer a negative question such as *Doesn't she like cats* with *Yes, she does/No, she doesn't*, contradicting to the *False, she does/True, she doesn't* answers for verifying the corresponding negative sentence *She doesn't like cats*. Puzzled by the contradicting responses of English speakers to negative questions and sentences, Akiyama, Brewer, and Shoben (1979) examined whether English speakers process negative questions and negative sentences in the same way. English speakers were instructed to verify one block of sentences in TA (e.g., *A robin is a bird*), FA (e.g., *A robin is a rock*), TN (e.g., *A robin isn't a rock*) and FN (e.g., *A robin isn't a bird*) conditions and another block of corresponding questions (e.g., *Is/Isn't a robin a bird/rock?*). The order of the two blocks was counterbalanced. Results showed that it took participants significantly shorter to answer positive questions than verifying positive sentences. Critically, it took participants significantly shorter to process negation in negative questions than in negative sentences. An interaction between polarity and truth value was observed for the verification block. For answering questions, it took shorter to answer *yes* than *no* regardless of the polarity. The researchers concluded that it was more difficult for English speakers to verify negative sentences than answering negative questions. Although Akiyama did not test Japanese adult speakers, he and his colleagues revealed that it is more difficult for Japanese children to answer negative questions than verifying negative sentences.

Akiyama and colleagues (Akiyama & Guillory, 1983; Akiyama et al., 1982; Akiyama, 1992) conducted a series of experiments to test error rates of English (4-7 years old) and Japanese children (4-5 years old) when they answered negative questions (e.g., *Aren't you a baby?*) and verified negative sentences (e.g., *You aren't a baby*). Results showed that English children made significantly more errors when they verified sentences than when they answered questions, especially when the polarity of the stimuli was negative. 4-year-old English children showed a prominent gap of error rates between the verification of positive and negative sentences, which narrowed down for the 7-year-olds. No difference was observed between answering positive and negative questions throughout this age span. In contrast, Japanese children showed significantly higher error rates for answering questions than for verifying sentences. The researchers confirmed their claim (Akiyama, 1979) that the verification of negative sentences is more difficult than answering negative questions for English speakers. Unlike English speakers, it is more difficult for Japanese speakers to answer negative questions compared to verifying negative sentences. By comparing the relative difficulty of answering negative questions compared to verifying negative sentences, Akiyama and colleagues suggested that using the truth-based system is more difficult and less direct than using the polarity-based system. Based on this view, we can predict that it may be more difficult for Chinese speakers to answer negative questions compared to English speakers in this study. However, the experiments conducted by Akiyama and colleagues including Akiyama et al. (1979), Akiyama and Guillory (1983), Akiyama et al. (1982) and Akiyama (1992) did not compare the processing of negative questions or the processing of negative sentences crosslinguistically. To compensate this flaw, this study tested both English and Chinese speakers when answering negative questions and compared their performance.

Chapter 3. Crosslinguistic differences in answering systems

3.1. Introduction

Simple *yes/no* answers to negative yes-no questions (e.g., *Doesn't she like cats?*) lead to a sharp crosslinguistic contrast. In response to negative questions, English speakers typically answer *Yes, she does/No*, *she doesn't*. However, Chinese speakers typically answer *No, she does/Yes, she doesn't*. The answering system of English speakers is referred to as *polarity-based* while the answering system of Chinese speakers is called *truth-based* in this study. What are the crosslinguistic differences underlying the language-specific *yes/no* answers? One argument is that when answering negative questions such as *Doesn't she like cats?*, English speakers typically respond to the positive statement of the question (e.g., *She likes cats*) (Choi, 1991; Holmberg, 2015) while Chinese speakers typically respond to the negative statement of the question (e.g., *She doesn't like cats*) (Holmberg, 2015; Huang, 2007; Lu, 2005). Another argument is that *yes/no* in English can indicate positive/negative poles (Huddleston et al. 2002; Roelofsen & Farkas, 2015) but not in Chinese in which *yes/no* can only mean 'It is the case' and 'It is not the case' respectively in terms of their effects (Li & Thompson, 1981). This chapter aims to explore the two arguments by examining the negative questions and answering systems in English and Chinese.

This chapter is organized in the following sequence. The contrasts in answers to negative questions is presented in section 3.2. Language-specific preferences for *yes/no* to negative questions are well-documented in the literature (Akiyama, 1979, 1992; Choi, 1991; Hinds, 1986; Holmberg, 2014, 2015; Li & Thompson, 1981; Lu, 2005). Then, in section 3.3., the statements of negative questions in English and Chinese are investigated respectively. In English, one claim is that negative questions such as *Doesn't she like cats?* can highlight the positive statement 'She likes cats' or the negative statement 'She does not like cats' depending on context (Ladd, 1981; Quirk et al., 1985; Huddleston et al., 2002; Romero & Han, 2004). Unlike this cliam, Holmberg (2013, 2014, 2015) argued that a negative question such as *Doesn't she like* *cats?* has a high negation. High negation means attaching negation to the polarity of the question [Doesn't [she like cats]] and highlights the positive statement 'She likes cats'. To evaluate the context-based and the syntactically-attached claims, an intuitive judgment task was designed to test English speakers i.e., choosing a preferred negative question out of three choices in a given context. Results of this task is discussed in section 3.3. In Chinese, negative questions are claimed to typically express negative statements (Holmberg, 2015; Huang, 2007; Lu, 2005). According to Holmberg (2015), this is because Chinese uses middle negation. Middle negation means attaching negation to the statement of the question [Ta [bu [xi huan mao]] ma] i.e., [Does [she [not [like cats]]]]. Lastly in section 3.4., the way in which English and Chinese speakers answer negative questions are investigated. While English speakers have two ways to formulate *yes/no* answers (Holmberg, 2015; Roelofsen & Farkas, 2015), i.e., by referring to polarity values (e.g., positive pole: *yes, she does*/negative pole: *No*, *she doesn't*) or truth values (e.g., true: *yes, she doesn't*/false: *no, she does*), the former way is not available in Chinese speakers (Holmberg, 2015; Li & Thompson, 1981). With the attempt to examine the prevalence of the contrast in using *yes/no* to answer negative questions between English and Chinese speakers, corpus analyses were used and the results are discussed (see section 3.4.). Table 3.1 summarizes the literature mainly referred to in this chapter on English and Chinese questions and answers.

Table 3. 1 Studies on the components of answering systems

Component	Language	Literature	Claim
negative questions	English *Doesn't she like cats?*	Holmberg (2013, 2014, 2015)	positive statements
		Huddleston et al. (2002); Ladd (1981); Quirk et al. (1985);	positive & negative statements

		Romero and Han (2004)	
	Chinese *Does she not like cats?*	Holmberg (2015); Huang, 2007; Lu (2005)	negative statements
yes/no answers	English *yes/no*	Huddleston et al. (2002)	polarity values
		Holmberg (2013, 2014, 2015); Roelofsen and Farkas (2015)	polarity values & truth values
	Chinese *shi (de)* 'yes'/ *bu (shi de)* 'no'	Holmberg (2014, 2015); Li and Thompson (1981)	truth values

Corpus data in the this chapter comes from the British National Corpus (BNC)[1], the Modern Chinese Corpus founded by the Center for Chinese Linguistics of Peking University (PKU-CCL-CORPUS)[2] and the World Atlas of Language Structures Online (WALS)[3]. The BNC is a national corpus which covers 100 million words of written text (90%) and transcripts of speech (10%) (Xiao, 2008). Another Chinese corpus of similar size to BNC is the Modern Chinese Language Corpus (MCLC) according to Xiao's (2008) survey of current influential corpora. However, the MCLC is not suitbale for this research because of the lack of contextual information which is indispensible for the discussion of *yes/no* answers to yes-no questions. Instead, the PKU-CCL-CORPUS comprsising of 264 million Chinese charaters (Xiao, 2008) was used for corpus analysis. The online query system of the PKU-CCL-CORPUS which facilitates fast and precise searching (Zhan et al., 2006) makes it optimal for locating

1 http://www.natcorp.ox.ac.uk/

2 http://ccl.pku.edu.cn:8080/ccl_corpus/index.jsp

3 http://wals.info/

yes/no answers to neagtive questions to meet the aim of this chapter. The WALS is a mutilingual atlas covering 2679 languages which was used for exploring the typical forms of Engish and Chinese questions.

3.2. Distinctions between typical English and Chinese answers

3) Example of typical English answers to negative questions:

Q: Doesn't she like cats?

A:	-**Yes**, *(she does).*	[She likes cats.] (negative-true condition)
	-**No**, *(she doesn't).*	[She doesn't like cats.] (negative-false condition)

4) Example of typical Chinese answers to negative questions:

Q:	Ta	bu	xi	huan	mao	ma?
	She	not	like		cat	**Q**

'Does she not like cats?'

A:	-Bu,	(ta	xi	huan)		[She likes cats.]
	No	(she	likes)			(negative-true condition)

'**Yes**, she does.'

-Shi,	(ta	bu	xi	huan)	[She doesn't like cats.]
Yes	(she	not	likes)		(negative-false condition)

'**No**, she doesn't.'

One difficulty for Chinese learners of English in their L2 acquisition, also pointed out by Holmberg (2015), is that opposite *yes/no* answers are used in L1

Chinese and L2 English respectively in response to negative yes-no questions (examples 3-4). According to the results of a corpus analysis in this chapter (see section 3.4.), in response to a negative question such as *Doesn't she like cats*, English speakers prefer answering *yes* if the case is that 'She likes cats' while Chinese speakers favour the Chinese equivalent of *no*, i.e., *bu (shi de)*. In turn, English speakers frequently answer *no* to indicate the case that 'She doesn't like cats' in response to *Doesn't she like cats* while Chinese speakers habitually answer the Chinese equivalent of *yes*, i.e., *shi (de)*.

There are four conditions of yes-no questions. They were classified based on the polarity of the question (positive/negative) and the state of affairs (she likes cats = true; she doesn't like cats = false). Following this rule, a negative question that typically elicits *yes* in English and *bu (shi de)* 'no' in Chinese is categorized as negative-true condition (examples 3-4). Analogously, this study refers to the circumstance that typically elicits *no* in English and *shi (de)* 'yes' in Chinese as the negative-false condition (examples 3-4). In this study, the answering system of English speakers is referred to as polarity-based (i.e., the *yes/no* part of the answer is typically of the same polarity as the verb in the answer) while the answering system of Chinese speakers is called truth-based (i.e., the *yes/no* part of the answer is typically of opposite polarity as the verb in the answer).

3.3. Yes-no questions

A yes-no question expresses two opposite state of affairs and asks the addressee to choose the correct one (Farkas & Bruce, 2009; Holmberg, 2015). For instance, the question *Does/Doesn't she like cats?* asks the addressee to confirm that either the positive state of affairs (i.e., She likes cats) or the negative state of affairs (i.e., She doesn't like cats) is true. However, a narrower definition of yes-no questions for this study is that a question "to which the expected answer is the equivalent of 'yes' or 'no'" (Dryer, 2013). The narrower definition is adopted here because the focus is *yes/no* answers to negative questions. Following this definition, questions such as the Chinese A-not-A structure (example 5) that expresses two opposite state of affairs yet rarely answered with *yes/no* answers is beyond the scope of the present study. According to Holmberg (2015), *yes/no* answers can be used to respond to yes-no questions because there is a polarity variable [±Pol] in the syntax of this type of question (example 6), to which *yes* can assign positive value [+Pol] (example 7) and *no* can assign negative value [-Pol] (example 8).

5) Example of Chinese A-not-A structure:

Ta	xi	bu	xi	huan	mao?	[“A-not-A” structure]
She	like	not	like		cat	

‘Does she like cats or not?’

6) Example of the polarity variable [±Pol] in a yes-no question:

[Does [she [±Pol] like cats]]

7) Example of assigning positive value [+Pol] to a yes-no question:

[She [+Pol] likes cats]

8) Example of assigning negative value [-Pol] to a yes-no question:

[She [-Pol] likes cats]

3.3.1. English yes-no questions

English questions have various forms according to the descriptions of English functional grammar. “Yes-no questions are usually formed by placing the operator before the subject and giving the sentence a rising intonation” (Quirk et al.,1985, p.807). In this study, questions formed this way are referred to as simple questions. Besides this common method of subject-operator inversion, yes-no questions are available in other forms in English. For instance, example (9) demonstrates a question in the form of a declarative sentence rather than an interrogative question; example (10) shows an interrogative question appended to a sentence, known as tag questions (Ladd, 1981). Also, a yes-no question can be either positive or negative. There are two methods to formulate negative questions given the restricted positions for the negative markers - by inserting a full negative marker *not* or an enclitic negative marker *n't* in positive questions (examples 11-12) (Huddleston et al., 2002; Quirk et al., 1985). The difference between the two forms of negative markers is that full negative markers are "considered rather formal and therefore enclitic is usually preferred in spoken English" (Quirk et al., 1985, p.809).

9) Example of a question in the form of a declarative sentence:

   She likes cats?

10) Example of a tag question:

   She likes cats, doesn't she?

11) Example of a negative question with *n't:*

   Doesn't she like cats?

12) Example of a negative question with *not:*

   Does she not like cats?

Positive and negative yes-no questions have been claimed to be semantically similar but pragmatically different. While positive questions are regarded as neutral questions without bias towards positive or negative statements, negative questions highlight positive or negative statements and therefore are also known as biased questions (Quirk et al., 1985; Huddleston et al., 2002). Still, positive questions can suggest addressers' bias in some circumstances. For example, the employment of the word *something* with assertive connotation instead of the negative *anything* (Huddleston et al., 2002) in example (13) implies that the addressee expected to need something to drink. Also, the addresser chose the positive question instead of the variable question *What's the day today* in example (14) because he/she believed it should be Tuesday. Nonetheless, negative questions (examples 15-16), in comparison to positive questions, may suggest a comparatively stronger bias towards positive statements.

13) Example of a positive question with *something:*
Do you need something to drink?

14) Example of a positive question instead of a variable question:
Is it Tuesday today?

15) The negative counterpart of example (13):
Don't you need something to drink?

16) The negative counterpart of example (14):
Isn't it Tuesday today?

Some researchers (Ladd, 1981; Quirk et al., 1985; Huddleston et al., 2002; Romero & Han, 2004) argued that negative questions in English can express a positive or a negative statement depending on the context. To illustrate, the negative question in example (17) suggests that David would like to check his belief that 'Jack needed to study'; in contrast, the negative question in example (18) indicates that David wanted to confirm the negative statement that 'Jack wasn't coming for a run'. Ladd (1981) refers to the negation in example (17) as outside the statement while that in example (18) as inside the statement. Notably, as the pragmatics of yes-no questions is not the focus of this study, neutral contexts in the sense that they are unlikely to trigger any biases (e.g., *Mr. Fox stole a roast duck from a farm.*) were adopted in the experimental design to control the variable of context.

17) Example of expressing a positive statement of a negative question:
Both David and Jack had a paper due in two days. When David was burying himself in his homework, he noticed that Jack was playing computer games. David believed that Jack should be working on his paper, so he asked Jack "*don't you need to study?*"

18) Example of expressing a negative statement of a negative question:
Jack made his New Year resolution that he would run five miles every morning in the coming year. The next day when David wanted to ask Jack to run with him, he found Jack still in his pyjamas. Suspecting that Jack would not keep his resolution, David asked him "*aren't you coming for a run?*"

Although neutral contexts were used in the experimental design, the effect of context on the processing of negative questions should be addressed. To justify the use of neutral contexts in the experimental design, there are neutral contexts in which a speaker might choose a negative over a simple question. One circumstance is making a suggestion. To illustrate using an example from the BNC, one speakers made a suggestion using a negative question "Shouldn't we … ?' and the other person answered "No. There is no point now". Another circumstance is to show politeness. To illustrate using another example from the BNC, one person asked a negative question "Can't you be more precise?" and the addressee answered "No. Sorry". Still, in natural conversations, it is likely that a biasing context is a precondition for a speaker to choose a negative rather than a simple question. The difference between processing negative questions in a neutral context and those in a biased context is the statement under discussion. When English speakers process negative questions in a neutral context, the positive statement is likely to be the topic under discussion, i.e., negation is not attached to the statement. However, when English speakers process negative questions in a biased context, they could question either the positive or the negative statement (Ladd, 1981), i.e., negation can be attached to the statement. That is, context can influence the way in which English speakers attach negation when they process negative questions. Arising from the difference in processing negative questions in neutral and biased contexts, the linguistic influence on routinized cognitive processing could be that English speakers are highly flexible at negation attachment.

In contrast to the context-based argument, Holmberg (2015) claimed that statements of negative questions to be responded are determined by the syntax of negation. Holmberg (2013, 2014, 2015) argued that there are three readings of negation in English - high negation (example 19), middle negation (example 20) and low negation (example 21). According to Holmberg's analysis (2013, 2014, 2015), high negation which usually appears in the form of *n't* in English is under CP and out of PolP, negating the whole sentence; middle negation takes the NegP position under TP and out of VP with a sentential scope; low negation in the form of *not* is exclusively under VP, negating the components under VP. Critically, Holmberg (2013, 2014, 2015) argued that the statements of negative questions are closely associated with the position of negation. High negation is attached to the polarity of a question while middle negation is attached to the statement of a question. As a result, high negation asks an addressee to confirm either S 'She likes cats' or ¬ S 'She does not like cats' while middle negation implies ¬ S 'She does not like cats' or ¬ (¬ S) 'It is not the case that she does not like cats' (Holmberg, 2015). Based on this claim, in example (17) which is repeated here as example (22), David was likely to ask Jack *Don't you need to study?* to check the positive statement, i.e., 'You need to study'. In contrast, he should ask *Are you not coming for a run?* (example 18 is repeated in 23) to check the negative statement, i.e., ‘You are not coming for a run’.

19) Example of high negation:

[$_{CP}$ Does**n’t** [$_{IP}$ she like cats]]

20) Example of middle negation:

[$_{CP}$ Does [she [$_{NegP}$ **not** [$_{vp}$ like cats]]]]

21) Example of low negation:

[$_{CP}$ Does [she sometimes [$_{vp}$ **not** like cats]]]

22) Example of expressing a positive statement of a negative question:

Both David and Jack had a paper due in two days. When David was burying himself in his homework, he noticed that Jack was playing computer games. David believed that Jack should be working on his paper, so he asked Jack “*don’t you need to study?*”

23) Example of expressing a negative statement of a negative question:

Jack made his New Year resolution that he would run five miles every morning in the coming year. The next day when David wanted to ask Jack to run with him, he found Jack still in his pyjamas. Suspecting that Jack would not keep his resolution, David asked him “*aren’t you coming for a run?*”

This study designed an intuitive judgment task to test the context-based and syntactically-attached claims. In the task, 20 English native speakers were given a questionnaire with ten texts and one blank to be filled in. They were instructed to choose only one answer that is the most appropriate out of the three choices provided. Half of the ten texts elicited positive statements (example 24) and the other half negative statements (example 25). On one hand, results showed that the predominant question form for implying positive statements was high negation (82%), which gave support to the link between the attachment of negation and positive/negative statements of negative questions. On the other hand, context also seems to play a role in denoting statements in negative questions as the frequency for high negation in negative contexts was 46% of the time. The same questionnaire was also distributed to 20 Chinese learners of English whose results turned out to resemble that of English speakers with 88% of high negation for positive statements and 59% high negation for negative statements.

24) Example of expressing a positive statement of a negative question:

Both David and Jack had a paper due in two days. When David was burying himself in his homework, he noticed that Jack was playing computer games. David believed that Jack should be working on his paper, so he asked Jack "________________"

A. Don't you need to study?

B. Do you not need to study?

C. Do you need not to study?

25) Example of expressing a negative statement of a negative question:

Mary ordered tea for David and herself but coffee for Jack. Assuming that Jack does not drink tea, David asked Mary "________________"

A. Does Jack not drink tea?

B. Does Jack drink not tea?

C. Doesn't Jack drink tea?

Given the various forms of negative questions in English, the most common form is used in this study to examine the most typical way in which English speakers answer negative questions. The most common form of English negative questions was investigated by using corpora. According to the WALS, English questions are typically formulated by changing the word order of declarative sentences i.e., subject-verb (auxiliary) inversion (Dryer, 2013). As for the types of negation, a diagnostic analysis of corpus data was conducted. The procedure was that after the search command[4] was input under the case-sensitive mode in BNC, results were screened individually from the first hit. According to the results, the frequency of negative questions with high negation was 47 out of 50 (94%) and that of middle negation was 3 out of 50 (6%)[5]. Based on this result, in this study, English questions are referred to simple yes-no questions, and negative questions mean simple yes-no questions with high negation.

3.3.2. Chinese yes-no questions

Chinese functional grammar describes three forms of yes-no questions. It is claimed that the most common forms of questions in Chinese are the *ma* structure (example 26), the *ba* structure (example 27) and a declarative sentence in an interrogative intonation (example 28) (Li & Cheng, 2008). *Ma* and *ba* are question markers. The difference between the two is that *ba* is claimed to solicit agreement while *ma* is regarded as a "plain question marker" (Li & Thompson, 1981, p. 306). The three structures also have negative forms (examples 29-31).

26) Example of Chinese *ma* structure:

Ta	xi	huan	mao	ma?
She	like		cat	**Q**

[4] The search command was ({Have} | {Do} | {Will} | {Can} | {Is} | {Are} | Ca | Wo | Should | Would | Did | Had | Could) ***** (not | n't) +************ \? ** (Yes | No).

[5] Accessed on October 5th, 2016.

'Does she like cats?'

27) Example of Chinese *ba* structure:

Ta xi huan mao ba?

She like cats **SA**[6]

'She likes cats, don't you agree?'

28) Example of a Chinese declarative sentence in interrogative intonation:

Ta xi huan mao?

She like cats

'Does she like cats?'

29) Example of Chinese negative *ma* structure:

Ta bu xi huan mao ma?

She not like cat **Q**

'Doesn't she like cats?'

30) Example of Chinese negative *ba* structure:

Ta bu xi huan mao ba?

She not like cats **Q**

'Doesn't she like cats?'

31) Example of a Chinese negative declarative sentence in interrogative intonation:

Ta bu xi huan mao?

She not like cats

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[6] Solicit agreement.

‘Doesn’t she like cats?’

Notably, Chinese “A-not-A” (example 32) and *hai shi* structures (example 33) which are referred to as “affirmative and negative questions” and “alternative questions” respectively by Chinese functional grammar (e.g., Li & Cheng, 2008) are not considered yes-no questions in the present study. Holmberg (2015) categorized “A-not-A” and *hai shi* structures as yes-no questions given that they express two opposite state of affairs. However, he also claimed that these two structures are rarely responded with *yes/no* answers and do not have negative forms. So “A-not-A” and “hai shi” structures are beyond the scope of this study. What should be mentioned is that the *shi-bu-shi* structure is a special case of the “A-not-A” structure as it can be answered with *yes/no* answers. The *shi-bu-shi* structure is an “A-not-A” structure in nature when *shi* serves as a finite verb (example 34). *Shi-bu-shi* can also function as a parenthesis (example 35) or a focus marker according to Wu (as cited in Homberg, 2015) when *shi* does not function as a finite verb since it has no content meaning and thus can be ommitted.

32) Example of Chinese A-not-A structure:

Ta xi bu xi huan mao?

She like not like cat

‘Does she like cats or not?’

33) Example of Chinese *hai shi* structure:

Ta xi huan hai shi bu xi huan mao?

She like or not like cat

‘Does she like cats or not?’

34) Example of Chinese *shi-bu-shi* structure:

Ta shi bu shi xue sheng?

She is not is student

'She is a student or not a student?'

35) Example of Chinese *shi-bu-shi* structure:

Ta (shi bu shi) [7] xi huan mao?

She is not is like cat

'Is it true that she likes cats?'

Unlike English negative questions, Chinese negative questions are claimed to highlight negative statements (Holmberg, 2015; Huang, 2007; Lu, 2005). One reason is that Chinese lacks high negation. Recall that English have high/middle/low negations while Chinese only has middle/low negations (Holmberg, 2015). Middle negation is attached to the statement of a question [Ta [bu [xi huan mao]] ma] i.e., [Does [she [not [like cats]]]]. Examples 36-37 illustrate Chinese negative questions with low/middle negations respectively and example 38 indicates the absence of the high negation. Since low negation is not a sentential negation with a scope only over VP, Chinese negative questions are only formulated with middle negation. The syntax of negative *ma* question in example (39) is illustrated in example (40). As the PolP has negative value in Chinese negative questions, negative *ma* questions highlight the negative statement and ask an addressee to verify either ¬ S 'She does not like cats' or ¬ (¬ S) 'It is not the case that she does not like cats' (Holmberg, 2015).

36) Example of low negation in Chinese:

Ta you shi hou bu xi huan mao ma?

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[7] A parenthesis or a focus marker.

She sometimes not like cat **Q**

"Does she sometimes not like cats?"

37) Example of middle negation in Chinese:

Ta bu xi huan mao ma?

She not like cat **Q**

'Does she not like cats?'

38) Illustration of the lack of high negation in Chinese:

*Bu ta xi huan mao ma?

Not she like cat **Q**

'Doesn't she like cats?'

39) Example of Chinese negative questions with *ma*:

Ta bu xi huan mao ma?

She not like cat **Q**

'Does she not like cats?'

40) Syntax of the negative question in example (39):

[[$_{PolP}$ Ta [−Pol] bu xi huan mao] [±Pol]][8]

Like English questions, the most common form of Chinese questions is used here. The aim is to examine the most typical way in which Chinese speakers answer negative questions. According to the WALS, the most typical Chinese questions are formulated by "adding question particles to a corresponding declarative sentence to indicate that it is a question" (Dryer, 2013). Besides the description from the WALS, a

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8 Cited from Holmberg (2015).

diagnostic analysis of corpus data was conducted using the PKU-CCL-CORPUS[9] to explore which question particle, i.e., either *ma* or *ba* structure is the most common in Chinese yes-no questions. The first 50 yes-no questions out of the 86 results are shown in Table 3.2, according to which the most typical form of Chinese yes-no questions is the *ma* structure accounting for nearly half of the results. Thus, Chinese questions in this study refer to the *ma* structure and Chinese negative questions are the *ma* structure with middle negation.

Table 3. 2 Forms of the randomly selected 50 yes-no questions in PKU-CCL-CORPUS

Form	Number	Percentage
with question particle *ma*	23	46%
declarative sentence with interrogative intonation	11	22%
with question particle *ba*	6	12%
shi-bu-shi structure	6	12%
with question particle *ne*	2	4%
with question particle *me*	1	2%
hai shi structure	1	2%
Total	50	100%

Chinese negative questions can highlight positive or negative statements depending on question forms and contexts. Despite the argument that Chinese negative yes-no questions usually highlight negative statements (Holmberg, 2015, Lu, 2005), a diagnostic analysis of the first 50 negative questions from PKU-CCL-

[9] The search command was ?$0”$10 (shide|en|bushide|shi, |bu,).

CORPUS[10] revealed that the frequency of positive statements (27 out of 50) and that of negative statements (23 out of 50) were similar[11]. The adverbials *nan dao* (example 41) and *bu shi* (example 42) are frequently used among the 27 negative questions to imply a positive bias. In the experimental design, adverbials such as *nan dao* or *bu shi* were avoided and absolute bias-free contexts were adopted (e.g., Mr. Fox stole a roast duck from a farm) in order to be comparable to the English context.

41) Example of negative questions with the adverbial *nan dao:*

Nan	dao	zhen	de	mei	ren	zhong	tian	le ma?
		really		not	people	farming		Q

'Won't people farm anymore?'

[file name: \当代\报刊\人民日报\1995 年人民日报\11 月份.txt]

42) Example of negative questions with the adverbial *bu shi :*

Ni bu shi yao	pai	wo	ban gong shi de	zhao pian ma?	
You not is want	photograph	my	office	picture	Q

'Didn't you want to take pictures of my office?'

[file name: \当代\报刊\作家文摘\1993\1993B.txt]

3.4. Answering yes-no questions

3.4.1. The English system

How do English speakers typically answer negative questions? One claim is that the choice between *yes/no* "depends simply on the polarity of the answers - not, for example, on agreement vs disagreement with what may be suggested by the question"

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[10] The search commands were: (mei)$10?$10(shide|en|bushide); (mei)$10?$10(shi,|bu,); (bu)$10(ma|ba)$0?$10(shide|en|bushide) and (bu)$10(ma|ba)$0?$10(shi,|bu,).

[11] This result was independently-checked by another Chinese native speaker.

(Huddleston et al., 2002, p. 848). According to this view, the polarity of questions and the choice between *yes/no* are not related (examples 43-44). Moreover, answers can be *yes/no* alone or expanded with clauses. In expanded answers, the polarity of the *yes/no* part is supposed to be consistent with the polarity of the clauses, which is an indication of the polarity concord rule in English (Huddleston et al., 2002). That is to say, *yes, she doesn't* and *no, she does* (example 45) are considered "ungrammatical as single clauses"[12] (Huddleston et al., 2002, p.848) since *yes/no* do not correspond to the polarity of the following clauses, violating the alleged polarity concord rule.

43) Example of *yes/no* answers to English positive questions:

Q: Does she like cats?

A:	-Yes, (she does).	[she likes cats.]
	-No, (she doesn't).	[she doesn't like cats.]

44) Example of *yes/no* answers to English negative questions:

Q: Doesn't she like cats?

A:	-Yes, (she does).	[she likes cats.]
	-No, (she doesn't).	[she doesn't like cats.]

45) Example of ungrammatical *yes/no* answers to English negative questions:

Q: Doesn't she like cats?

A:	-*Yes, she doesn't.	[she doesn't like cats.]
	-*No, she does.	[she likes cats.]

[12] indicated by asterisks in the examples

Despite the claimed polarity concord rule, evidence from a corpus analysis showed that English speakers do sometimes respond to the negative statements of negative questions. To illustrate, in example (46), the addressee confirmed the negative statement that ‘He/she hasn’t got a nightgown’. Also, English speakers can formulate polarity-inconsistent responses such as *yes, it doesn’t matter* in example (47). In contrast to Huddleston et al. (2002), Holmberg (2013, 2014, 2015) believed that English speakers show agreement/disagreement with positive statements when they answer negative questions. To illustrate, in example (48), *yes* indicates that ‘It is true’ (she likes cats), while *no* means ‘It is false’ (she doesn’t likes cats). In this case, *yes/no* alone are not ambiguous. However, in response to a negative question with middle negation (example 49), one-word answer *yes* is ambiguous in the sense that it can mean ‘She likes cats’ or ‘She doesn’t like cats’ (Holmberg, 2015). The use of *yes* and *no* is neutralized in example (49) as both *yes* and *no* can mean that ‘She doesn’t like cats’, which is known as “negative neutralization” (Kramer & Rawlins, 2009).

46) Example of English speakers responding to a negative statement of a negative question extracted from the BNC (accessed on 2016-07-08):

Q: ‘You haven't got a nightgown?’ [CK9:357]

A: ‘Oh yes. Yes, I forgot. I haven't got a nightgown.’ [CK9:358-360]

47) Example of English speakers using polarity-inconsistent answers extracted from the BNC (accessed on 2017-03-21):

S: It doesn't matter if these two people here, these two appointments are a bunch of wombats or they hate you, or you just, it doesn't matter. [KGL: 508]

A: Yes, it doesn't matter. [KGL: 509]

48) Example of agreement/disagreement with a positive statement of a negative question:

Q: Doesn't she like cats?

A: -Yes, (she does). [She likes cats.] [It is true]

-No, (she doesn't). [She doesn't like cats.] [It is false]

49) Example of ambiguous *yes* to negative questions:

Q: Does she not like cats?

A: -?? Yes. [she likes cats.]/ [She doesn't like cats.]

-No. [She doesn't like cats.]

In sum, English speakers can formulate truth-based or polarity-based answers to yes-no questions. There are two systems for using yes/no answers, one of which is known as the polarity-based system (or the positive/negative system) that "the choice between yes and no depends simply on the polarity of the answers" (Huddleston et al., 2002, p. 848) as discussed earlier; the other is called the truth-based system (or the agree/disagree system) according to which answers "are determined by agreement with the truth value of the statement which is implied by the question" (Jones,1999: as cited in Holmberg, 2015). The truth-based system is also known as the agree-disagree system because answers can be regarded as agreeing or disagreeing with the speaker's anticipated answer (Holmberg, 2015). Holmberg (2015) reports 44 languages that follow the truth-based system and 49 languages that do not follow the truth-based system based on the typicality of answers by analysing the online data base of

SSWL[13] and the native speakers' intuitions by questionnaires[14]. Based on his survey, the English language (Germanic, Indo-European) falls into the category that does not follow the truth-based system while Mandarin Chinese (Chinese, Sino-Tibetan) belongs to the group of languages following the truth-based system (Holmberg, 2015). To distinguish the English and Chinese answering systems, the English-typical answers *yes, she does/no, she doesn't* are referred to as polarity-based while the Chinese-typical answers *no, she does/yes, she doesn't* are referred to as truth-based in this study.

In line with Holmberg's (2015) argument for the English hybrid system, *yes/no* are claimed to have "double functions" by Roelofsen and Farkas (2015)– marking "absolute polarity features" and "relative polarity features". In terms of absolute polarity features, *yes* indicates the positive pole [+] of the answers while *no* indicates the negative pole [−] of the answer. In regards to relative polarity features, *yes* is also used to show agreement [agree] with the statement of the question while *no* is used to reverse the statement of the question. For an illustration, in example (50), *yes* can indicate the positive pole that 'She likes cats' or the agreement with the statement that 'It is true' (she likes cats). Analogously, *no* can show the negative pole that 'She does not like cats' or reverse the statement, i.e., 'It isn't false' (she doesn't like cats). As for negative questions such as example (51), *yes* can be used to indicate the positive pole that 'She likes cats' or agreement with the statement that 'It is true' (doesn't like cats); *no* can be used to illustrate the negative pole that 'She does not like cats' or reverse the statement as 'It isn't false' (she likes cats). According to Roelofsen and Farkas (2015), the answer is either *yes* or *no* when the absolute polarity features coincide with the relative polarity features i.e., [+, agree] and [−, reverse]. In contrast, answers can be both *yes* and *no* when there is a clash between the absolute polarity features and the relative polarity features i.e., [+, reverse] and [−, agree]. This argument

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[13] Syntactic Structures of the World's Languages.

[14] Holmberg (2015) did not provide examples of the questionnaire.

explains why *no, she does* and *yes, she doesn't* are considered ungrammatical in example (50) and the negative neutralization in example (51).

50) Example of absolute polarity features and relative polarity features of *yes/no*:

Q: Does she like cats?

A: -Yes, she does. / *No, she does. [+]/[agree] [She likes cats.]

-No, she doesn't. / *Yes, she doesn't.[−]/[reverse][She doesn't like cats.]

51) Example of negative neutralization:

Q: Does she not like cats?

A: -Yes, she does. / No, she does. [+]/[reverse] [She likes cats.]

-No, she doesn't. / Yes, she doesn't. [−]/[agree] [She doesn't like cats.]

A diagnostic analysis of corpus data was conducted with the attempt to check the validity of claims about the typical answers of English speakers when they answer negative questions. The procedure of the corpus analysis was that after search command was input, results were screened individually from the first hit and the *yes/no* answers to the first 50 negative-true and negative-false questions[15] were analysed. The searching restrictions were set to optimize precision given that the purpose of the diagnostic analyses of corpus data in this chapter was to investigate the relative percentages of different *yes/no* answers to negative questions. For the diagnostic analysis of English corpus data, the search command[16] was input under the case-sensitive mode in BNC. Results showed that answers to the 13 negative-true

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15 The question types were determined according to the contexts.

16 The search command was ({Have} | {Do} | {Will} | {Can} | {Is} | {Are} | Ca | Wo | Should | Would | Did | Had | Could) ***** (not | n't) +************ \? ** (Yes | No).

questions were 100% *yes* and those to the 37 negative-false questions were 100% *no*. Example (52) was extracted from the 50 tokens analysed as an illustration for typical answers to negative-true questions, in which the English answer *yes* indicates that the addressee (Lucy) likes the referent in that discourse; example (53) shows answers to negative-false questions in which the answer *no* means that the Roman army did not use conkers in their catapults. However, the BNC is limited in genre, and scope, and many such instances (e.g., -*Don't you love me?- No, I do.*; -*Do you not want to do it?* -*No , I do*.) can be found in large, more recent corpora that contain informal speech registers, such as the BYU film and television corpora https://www.english-corpora.org/.

52) Example of typical answers in the negative-true condition extracted from the BNC (accessed on 2016-07-8):

Q: 'Didn't you like that?' [AOL:2219][17]

A: '**Yes**, yes,' said Lucy, as if brushing ash from her skirt. [AOL: 2220]

53) Example of typical answers in the negative-false condition extracted from the BNC (accessed on 2016-07-8):

Q: 'Didn't the Roman army use conkers in their catapults?' [ACK:2838]

A: '**No**,' said Nigel, 'they used boulders in their ballistas.' [ACK:2839]

The frequencies of bare *yes/no* answers/expanded answers/polarity-inconsistent answers in response to negative yes-no questions were analysed. As illustrated in Table 3.3, among answers to randomly selected 50 negative questions, the frequency

[17] Token reference number.

of *no* was 76%, higher than that of *yes* which was 24%. The frequency of bare *yes* answers was half of the frequency of expanded *yes* answers (*yes, she does*), which supports the claim of Holmberg (2015) that English speakers prefer expanded answers for *yes* answers. Unlike *yes* answers, English speakers prefer *no* alone (62%) to expanded *no* answers (14%). The acceptance for bare *no* answers may be higher than that for bare *yes* answers, which is in line with Roelofsen and Farkas (2015). Also, no polarity-inconsistent answers were found in this diagnostic analysis, which suggests that English speakers prefer polarity-consistent answers despite the double functions of *yes/no* and negative neutralization discussed earlier.

Table 3. 3 Frequencies of various types of English answers in response to negative yes-no questions (accessed on 2017-3-21)

answer form	number	percentage
yes	4	8%
yes, she does	8	16%
yes, she doesn't	0	0
no	31	62%
no, she doesn't	7	14%
no, she does	0	0
total	50	100%

3.4.2. The Chinese system

Now consider the way in which Chinese speakers answer negative questions. According to Chinese functional grammar (Liu, 2001; Huang, 2007), responses to Chinese yes-no questions are formulated by confirming or negating the truth of the statements. Li and Thompson (1981, p.563) described the Chinese system as "to confirm or negate the truth of a statement to which the question particle is added". To confirm the truth of a statement, responses can be *shi (de)* ‘yes’, *dui* ‘right’, *en* ‘yes’ and nodding; to negate the truth of a statement, the responses include *bu (shi de)* ‘no’, *mei you* ‘not’ and shaking head. *Yes/no* answers *shi (de)* ‘yes’ and *bu (shi de)* ‘no’ mean “It is the case” and “It is not the case” respectively in terms of their pragmatic meaning (Li & Thompson, 1981, p. 561). For an illustration, the negative statement in example (54) is that ‘She does not like cats’. Thus, the answer *shi (de)* ‘yes’ means that the addressee confirms the negative statement ‘She doesn’t like cats’-> ‘It is true’ i.e., *Yes* (*she doesn’t like cats*); the answer *bu (shi de)* ‘no’ shows that the addressee negates the negative statement ‘She doesn’t like cats’-> ‘It is false’ i.e., *No* (*it is false that she doesn’t like cats* i.e., *she likes cats*).

54) Example of typical Chinese answers to negative questions:

Q: Ta bu xi huan mao ma?
She not like cat **Q**
‘Does she not like cats?’

A: - Bu, (ta xi huan). [She likes cats.]
no (she like)
‘Yes, she does.’

- Shi, (ta bu xi huan). [She doesn’t like cats.]
yes (she not like)
‘No, she doesn’t.’

There is an alternative way of answering yes-no questions in Chinese - by giving echo answers (examples 55-56). Chinese echo answers are often formulated by repeating the finite verbs with or without a negative marker and subjects and objects can be omitted (Li, 2008; Holmberg, 2015). Echo answers are mentioned here in order to justify the instructions in this study. The instructions asked participants to include *shi (de)* 'yes' and *bu (shi de)* 'no' in their answers whenever possible. This step was taken in case Chinese participants use echo answers instead of *yes/no* answers.

55) Example of echo answers to Chinese positive questions:

Q: Ta xi huan mao ma?

She like cat **Q**

'Does she like cats?'

A: -(ta) xi huan [She likes cats.]

(she) like

'Yes, she does.'

- (ta) bu xi huan [She doesn't like cats.]

(she) not like

'No, she doesn't.'

56) Example of echo answers to Chinese negative questions:

Q: Ta bu xi huan mao ma?

She not like cats **Q**

'Does she not like cats?'

A: -(ta) xi huan [She likes cats.]

(she) like

'Yes, she does.'

- (ta) bu xi huan [She doesn't like cats.]

(she) not like

'No, she doesn't.'

While English speakers can formulate either polarity-based or truth-based answers, Chinese speakers only mark the truth values of statements of negative questions. As a result, Mandarin Chinese (Chinese, Sino-Tibetan) belongs to the group of languages following the truth-based system. Recall that Chinese negative questions are argued to highlight the negative statement and ask an addressee to verify either ¬ S 'She does not like cats' or ¬ (¬ S) 'It is not that she does not like cats'. Therefore, in example (57), the answer *shi (de)* 'yes' means that ¬ S 'She does not like cats' is correct while *bu (shi de)* 'no' indicates that ¬ S is not correct i.e., the case should be ¬ (¬ S) 'It is not the case that she does not like cats'. Polarity-based answers are absent in Chinese (Huang, 2007; Holmberg, 2015) (example 58). Chinese answer *shi (de)* 'yes' and *bu (shi de)* 'no' are semantically related to the statements of the questions. Namely, the answer *bu (shi de)* 'no' alone is argued to be ambiguous for Chinese negative questions (example 59) as an indication of negative neutralization in Chinese (Holmberg, 2015) in the sense that both *shi (de)* 'yes' and *bu (shi de)* 'no' can refer to the case that 'She does not like cats'.

57) Example of truth-based *yes/no* in response to Chinese negative questions:

Q: Ta bu xi huan mao ma?
She not like cat **Q**
'Does she not like cats?'

A: - Bu, (ta xi huan). [She likes cats.]
no (she like)
'Yes, she does.'

- Shi, (ta bu xi huan). [She doesn't like cats.]

yes (she not like)

‘No, she doesn’t.’

58) Illustration of the lack of polarity-based *yes/no* in response to Chinese negative questions:

Q: Ta bu xi huan mao ma?

She not like cat **Q**

“Does she not like cats?”

A: - *Shi, (ta xi huan). [She likes cats.]

yes (she like)

‘Yes, she does.’

- *Bu, (ta bu xi huan). [She doesn’t like cats.]

No (she not like)

‘No, she doesn’t.’

59) Example of ambiguous *no* to Chinese negative questions:

Q: Ta bu xi huan mao ma?

She not like cat **Q**

‘Does she not like cats?’

A: - ??Bu. [She likes cats.] / [She doesn’t like cats.]

no

‘Yes, she does.”/ “No, she doesn’t.’

- Shi. [She doesn’t like cats.]

yes

'No, he doesn't.'

To examine the typical Chinese answers to negative questions, similar procedures to that of the analysis of English data were adopted using the Chinese corpus PKU-CCL-CORPUS. Results showed that *bu (shi de)* 'no' was the dominant answer to the 28 negative-true questions (23 out of 28) and *shi (de)* 'yes' was the majority answer to the 22 negative-false questions (15 out of 22). These results confirmed the typical *yes/no* answers to Chinese negative questions. Example (60) shows the typical Chinese answer in a negative-true context, in which the Chinese equivalent of *no* indicates disagreement with the negative statement that 'The addressee has not taken his/her bath'. Example (61) illustrates preferred answers of Chinese speakers to negative-false questions, in which the Chinese equivalent of *yes* confirms the negative statement that 'The addressee is not married'. A special searching strategy was used to locate Chinese *yes/no* answers to negative-true and negative-false questions. Setting the appropriate search command was challenging for diagnostic analysis of Chinese corpus data with two main obstacles: First, the answer *shi (de)* 'yes' also serves as the verb to be ("be") in Chinese e.g., *ta shi xue sheng* 'He is a student'; second, the other answer *bu (shi de)* 'no' can be used as a negative marker in Chinese e.g., *ta bu shi xue sheng* 'He is not a student'. Considering these two restrictions, lots of irrelevant tokens without *yes/no* answers could have resulted if the search command was set to search for *shi (de)* 'yes' and *bu (shi de)* 'no' alone. Thus, the searching strategy adopted was using *pi liang cha xu*n 'batch searching' i.e., inputting several search commands at the same time beginning with the one that is most likely to yield *yes/no* answers to negative questions.

60) Example of typical answers in the negative-true condition extracted from the PKU-CCL-CORPUS (accessed on 2016-07-8):

Q: 'Zen me, ni mei xi zao?' [negative-true condition] what you not bath

'What, have you not taken your bath yet?'

A: 'Bu, wo xi zao de shi hou mei chuan shui yi.'

No I bath A[18] time not wear pyjamas

'**Yes**, (I did), but I did not wear my pyjamas when I took my bath.'

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61) Example of typical answers in the negative-false condition extracted from the PKU-CCL-CORPUS (accessed on 2016-07-8):

Q: 'Ni hai mei jie hun ?' [negative-false condition]

You still not marry

'Are you still not married?'

A: 'Shi de,' ta dian dian tou.

Yes she nodded

'**No**' she nodded.

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In sum, with evidence from corpus analyses, English and Chinese speakers prefer opposite *yes/no* answers when they answer negative questions. The crosslinguistic difference underlying the language-specific answers is different negations. English speakers typically attach negation to the polarity of the question and respond to positive statements of negative questions. Chinese speakers typically attach negation to the statement of the question and respond to negative statements of negative questions. Another crosslinguistic difference that is likely to contribute to the

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[18] Associative marker.

language-specific answers is that while English can use a polarity-based system and follow the polarity concord rule, this system is absent in Chinese. To date, what characterizes the English and Chinese systems has not been tested yet with controlled stimuli and in neutral contexts. In light of the crosslinguistic differences between English and Chinese, this study will proceed to test whether English and Chinese speakers process negative questions differently in the experimental Chapter 5.

Chapter 4. Influence of Language on Cognition

4.1. Introduction

It is commonly held that the exploration of whether language influences thinking started from the anecdotal observation of Benjamin Lee Whorf. Whorf observed that factory workers felt comfortable smoking around oil drums which were labelled *empty*. However, there was gas in the so-called empty drums, which are more explosive than the drums full of oil. The word *empty* misled workers to think there was nothing in the drums. Regarding the possible link between language and thinking, some researchers (Jackendoff, 1996; Pinker, 1994) believed that speakers of different languages think alike; some (Slobin, 1987, 1996; Papafragou et al., 2008; von Stutterheim; 2003) reckoned that language can influence thinking during speech planning; some (Athanasopoulos & Bylund, 2013; Brown & Levinson, 1993; Casasanto, 2008, 2010, 2016; Casasanto et al., 2004; Fuhrman et al., 2011; Lucy, 1992; Lucy & Gaskins, 2001, 2003; Levinson, 1996; Sera, Berge, and Pintado, 1994) argued that thinking can be language-mediated even in a nonverbal context (e.g., picture categorization); Some (Gordon, 2004) claimed that language determines the boundary of thinking. This thesis aims to provide new evidence to this debate by examining to what extent language can influence the processing of negation.

The *linguistic universalist approach* suggests that thinking is universal across speakers of different languages and cultural backgrounds. Jackendoff (1996) proposed a model to explain the mechanism underlying the way in which we express what we see. According to his model, there are several modules in the mind for processing different information. For instance, there is a syntax module where syntactical information is processed. In particular, Jackendoff specifically introduced a conceptual structure module. He defined the conceptual structure as “an encoding of linguistic meaning that is independent of the particular language whose meaning it encodes” (1996, p. 5). This definition suggests that speakers of different languages conceptualize any verbal expressions in a universal manner. In other words, according to Jackendoff (1996), crosslinguistic differences only exist at the modules for phonology and syntax processing, but not at the modules for processing conceptual representations. However, growing empirical evidence goes against the argument that thinking is alike among all human beings. For example, Athanasopoulos and Bylund (2013) tested the categorization of motion events (e.g., a person walking towards a building) in English and Swedish speakers. The researchers revealed that Swedish speakers habitually attend more to endpoints when they process motion events than English speakers do. These results demonstrated that thinking, influenced by language, can be diversified.

The linguistic universalist approach predicts language-independent processing of negation in this study. English speakers would process the negation in a negative question such as *Doesn't she like cats?* in a similar manner as Chinese speakers process its corresponding Chinese translation *Ta bu xihuan mao ma?* ‘*Doesn't she like cats?*’. However, this prediction based on the linguistic universalist approach is unlikely to hold true. As discussed in previous chapter 3, when answering negative questions, the typical English answers *Yes, she does/No, she doesn't* systematically vary from those in Chinese *No, she does/Yes, she doesn't*. Besides the processing of negation in negative questions, the processing of negation in a comparable nonverbal context such as an unequal equation (e.g., ▲≠■) is also predicted to be similar in English and Chinese speakers according to the linguistic universalist approach.

Back to the start of the debate on the link between language and cognition, Whorf's original idea was barely testable and mainly based on his personal observations like the empty-oil-drum story mentioned earlier. He described the connection between language and thinking in this way:

> *"We cut nature up, organize it into concepts, and ascribe significances as we do, largely because we are parties to an agreement to organize it in this way – an agreement that holds throughout our speech community and is codified in the patterns of our language."* (Whorf, 1956, p. 213).

Nowadays, Whorf's idea has evolved into three testable interpretations, namely *thinking for speaking, linguistic relativity* and *linguistic determinism*. While all three interpretations converge on that language can influence thinking, they diverge on the strength of language mediation.

The *thinking for speaking* hypothesis is most concerned with the strength of language mediation on thinking during language use. Slobin (1996), when proposing his well-known *thinking for speaking* hypothesis, claimed that "the world does not present 'events' and 'situations' to be encoded in language. Rather, experiences are filtered through language into verbalized events" (p.75). Differing from the linguistic universalist approach, *thinking for speaking* argues that, when speakers of different languages prepare to express their perception in words, they would think differently by selectively attending more to some features of their perception and less to others. For example, Slobin (1987, 1996) tested the way in which speakers of English, Spanish, German and Hebrew speakers describe the same pictures of motion events (e.g., *A boy fell from a tree and a dog running away*). He found language-specific distinctions of progressiveness versus completeness of motion events among the four groups. In this study, Slobin's (1996) view that language influences thinking for speaking predicts language-specific processing of negation in a verbal context. If this hypothesis holds true, one can expect English and Chinese speakers diverge when they answer negative questions such as *Doesn't she like cats?*.

The *linguistic relativity hypothesis* is defined following Everett (2013) that “cognition varies in accordance with people’s language” (p.1). The *linguistic relativity* hypothesis explores the possible link between language and “thinking itself” which is “beyond the conscious act of speaking” (Bylund & Athanasopoulos, 2014, p. 956). One crucial issue is how to test thinking without language. To tackle this problem, linguistics such as John Lucy (1992; Lucy & Gaskins, 2001, 2003) started using nonverbal contexts. Differing from a verbal context, a nonverbal context requires no language production or language processing (Bylund & Athanasopoulos, 2014). For example, Lucy (1992; Lucy & Gaskins, 2001, 2003) designed a nonverbal triads-matching task. In each trial, participants would see a target triad (e.g., a metal nail) and two alternate triads with the same material (a scrap of metal) or the same shape (a wooden pencil) compared to the target. The task was to choose an alternate triad that participants thought most resembled the target triad. The use of nonverbal contexts can help researchers avoid falling into a circularity which is arguing that people who speak differently would think differently with only evidence that they speak differently (Athanasopoulos & Albright, 2016; Bylund & Athanasopoulos, 2014; Casasanto, 2016; Everett, 2013). Moreover, researchers can benefit from using nonverbal contexts in differentiating evidence for *thinking for speaking* and *linguistic relativity*. If crosslinguistic differences are found in nonverbal contexts, *linguistic relativity* would be the most relevant theoretical anchor.

To date, accumulating evidence for relativistic effects has been reported in domains such as grammatical number (Lucy, 1992; Lucy & Gaskins, 2001, 2003), motion events (Athanasopoulos & Bylund, 2013), time (Casasanto et al., 2004; Fuhrman et al., 2011), grammatical gender (Sera, Berge, and Pintado, 1994), colour (Athanasopoulos, Damjanovic, Krajciova, & Sasaki, 2011) and space (Brown & Levinson, 1993; Levinson, 1996). However, it has not yet been attested in the domain of negation to the best of the author’s knowledge. In this study, the *linguistic relativity* hypothesis predicts language-specific processing of negation extending from a verbal to a nonverbal context. If this hypothesis holds true, one can expect English and Chinese speakers diverge when they process negation in negative question such as *Doesn't she like cats?*. Moreover, English and Chinese speakers are also expected to process negation in a comparable nonverbal context such as an unequal equation (e.g., ▲≠■) differently.

The hypothesis of *linguistic determinism* is defined following Gordon (2004) as the lack of a verbal expression "precludes the speakers of one language from entertaining concepts encoded by the words and grammar of the other language" (p. 496). That is, speakers of a particular language cannot conceptualize an object or an event because their language lacks corresponding verbal expressions. By definition, *linguistic determinism* and *linguistic relativity* diverge on whether language influences or determines thinking (see Everett (2013) for a discussion). Gordon (2004) argued in his study that Pirahã speakers, who cannot elaborate numbers larger than two in their language, are unable to conceptualize numbers larger than two as a direct result. This argument for *linguistic determinism* was criticised by Casasanto (2016), pointing out detrimental flaws in the experimental design e.g., the problematic "same match" in the instruction. To the best of the author' knowledge, there is no evidence supporting the *linguistic determinism* hypothesis.

With the aim to establish a theoretical frame for the current exploration that to what extent the processing of negation can be language-specific, this chapter centres on presenting empirical evidence for *thinking for speaking* and *linguistic relativity* hypotheses.

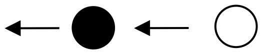
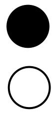
4.2. Evidence for thinking for speaking

Slobin (1987, 1996) found empirical evidence to support his *thinking for speaking* hypothesis. To explore whether speakers of different languages show language-specific patterns when they express motion events, he tested the way in which speakers of English, Spanish, German and Hebrew speakers describe the same pictures of motion events. English and Spanish are aspectual languages, whose grammars require their speakers to verbally express progressiveness and completeness of motions events with different aspects. For example, English speakers can say *The boy* FELL *from the tree and the dog was* RUNNING *away*. In contrast, German and Hebrew are non-aspectual languages, whose grammars lack aspectual device for marking progressiveness. For example, German speakers can only say *The boy* FELL *from the tree and the dog* RAN *away* in German. In the experiment, the four groups of participants were instructed to observe the same pictures carefully and describe them out loud. Slobin found that while English and Spanish speakers typically distinguished progressiveness versus completeness of motion events in their description, German and Hebrew speakers did not. He concluded that German and Hebrew speakers do not consider the difference between the state of ‘run’ and ‘running’ relevant for speech since their grammars lack the aspectual device for progressiveness. However, he further argued that German and Hebrew speakers may have perceived this difference when they looked at the pictures. In contrast, English and Spanish speakers not only perceived but also selectively attended to the difference between the state of ‘run’ and ‘running’ because they must express it in their verbalization.

Although Slobin interpreted the crosslinguistic differences in production as evidence for the thinking for speaking hypothesis, it may be insufficient to differentiate thinking for speaking and the linguistic universalist approach using the production results alone. In light of the circularity pointed out by Athanasopoulos and Albright (2016), Bylund and Athanasopoulos (2014), Casasanto (2016) and Everett (2013), arguing for language-specific thinking for speaking with production results alone means that arguing people who speak differently think differently with only evidence that they speak differently. It is possible that speakers of aspectual and non-aspectual languages think about progressiveness versus completeness of motion events in the same way. The use of language-specific expressions may simply because their languages require them to. It appears that in order to argue that language can influence thinking for speech, it is crucial to use implicit measures (e.g., reaction times, eye-tracking) other than production alone.

To investigate if thinking rather than speaking is language-specific, Boroditsky (2001) examined the reaction times (RT) of English and Chinese speakers when they processed the truth value of temporal relations (e.g., *March comes earlier than April)*. English speakers typically use horizontal spatial metaphors (e.g., *the good times ahead of us*) to describe temporal relations, while Mandarin Chinese speakers use both vertical metaphors (e.g., *shang* 'up' as in *shang ge yue* 'last month') and horizontal metaphors. Boroditsky designed a priming task to investigate if English speakers tend to think of time horizontally while Chinese speakers vertically corresponding to their verbal expressions. In each trial, participants first saw a prime, either horizontal (two horizontally arranged balls) or vertical (two vertically arranged balls) (see Table 4.1). Then they were instructed to verify a following statement such as *March comes earlier than April* as quickly as possible. Results showed that English speakers were significantly faster verifying temporal relations after the horizontal primes compared to the vertical primes. In contrast, Chinese speakers responded faster after the vertical primes compared to the horizontal primes. Based on the contrasts found between English and Chinese speakers, Boroditsky concluded that the frequent mapping of language-specific spatiotemporal metaphors influences the way speakers conceptually represent time. Boroditsky (2001) did not provide evidence for *thinking for speaking* since there was no speech planning involved in her experimental design. Still, Boroditsky (2001) can serve as an example of using the measure of RT to test possible language influence on thinking. If the linguistic universalist approach holds true that thinking is language-independent, it is unlikely that there should be any between-group differences in response speed. Although Chen (2007) and January and Kako (2007) later failed to replicate the findings in Boroditsky (2001), recent empirical studies using nonverbal contexts (Casasanto, 2016; Casasanto et al., 2004; Fuhrman et al., 2011) further confirms the link between the verbal expressions and the processing of time (see 4.3 in this chapter).

Table 4. 1 Horizontal and vertical primes adapted from Boroditsky (2001)

Horizontal prime	Vertical prime
	
The black ball is ahead of the white ball.	The black ball is above the white ball

To further investigate Slobin's (1987, 1996) conclusion that language can influence thinking for speaking in event construal, von Stutterheim (2003) tested the responses and RTs of English (with grammatical aspect) and German speakers (without grammatical aspect) when they described motion events. English and German speakers were instructed to first watch video clips of motion events and then verbalize "what is happening?". In the video clips, subjects of the motion events did not reach any endpoints, but the endpoints of the motion events could be inferred by the participants (e.g., two people walking along the road toward a house). Results showed that English speakers mentioned significantly fewer endpoints of motion events (e.g., *two people were walking on the road*) than German speakers (e.g., *two people walked toward a house*). Also, it took English speakers significantly shorter (0.7s) to start speaking after the onset of a stimulus compared to German speakers. Von Stutterheim concluded that thinking for describing motion events is language-specific. While speakers of non-aspectual German conceptualized the complete motion events by including the endpoints, English speakers focused on the progressiveness of the events without the endpoints. The conclusion that English and German speakers selectively organize relevant information according to their languages for motion event construal gives support to the *thinking for speaking* hypothesis. However, the longer RTs in German speakers are not necessarily due to their conceptualization of endpoints. It could also be more complicated morphosyntax or word order in German.

The claim for language-specific processing of motion events was confirmed by von Stutterheim and Carroll (2006) who tested the eye fixations of English and German speakers when they described motion events. Following the paradigm of von Stutterheim (2003), von Stutterheim and Carroll (2006) instructed English and German speakers to watch video clips of motion events and to describe what was happening in the videos they saw. Comparable to the design in von Stutterheim (2003), each video clip showed a motion event with a potential endpoint in the background (e.g., a car driving down a road bypassing a house). The researchers found that while German speakers fixated on the endpoints before their verbalization, English speakers started to describe the events before they looked at the endpoints. Stutterheim and Carroll confirmed the conclusion of von Stutterheim (2003) that German speakers, compared to English speakers, are more likely to include the endpoints of the motion events in their conceptual representation for event construal. In other words, the eye-tracking evidence suggest that German and English speakers conceptualized language-specific information during speech panning, in line with the argument of the *thinking for speaking* hypothesis.

Stutterheim and colleagues used RT (von Stutterheim, 2003) and eye fixations (von Stutterheim & Carroll, 2006) together with language production to examine if speakers of different languages think differently when they describe motion events. Comparably, to investigate whether language mediates the processing of negation in negative questions, this study will examine responses and measure response speed of English and Chinese speakers when they process negative questions. If language influences thinking for speaking as suggested by Slobin (1987, 1996), von Stutterheim (2003), and von Stutterheim and Carroll (2006), the two groups of monolingual speakers are expected to differ in their responses as well as their response speed.

4.3. Evidence for linguistic relativity

Lucy (1992; Lucy & Gaskins, 2001, 2003) is one of the pioneers of using nonverbal contexts to investigate the strength of language mediation on cognition. He focused on crosslinguistic differences in grammatical number. It is obligatory for English speakers to distinguish countable and mass nouns (e.g., nails versus sand), but not for Yucatec Maya speakers living in Mexico. Lucy designed a triads-matching task to explore the possible link between the grammatical number marking system and categorization. In each trial, English and Yucatec adults and children (7 & 9 years old) saw a target triad (a metal nail) and two alternate triads (a wooden pencil and a scrap of metal) (see Fig.4.1). The task was to choose an alternate triad they thought most resembled the target triad. Participants could choose the scrap of metal based on similarity in substance. Alternatively, they could choose the wooden pencil based on similarity in shape. Aside from stable objects, the target could also be a malleable object such as sand (see Fig. 4.2). Like the stable objects, participants could categorize the target C-shaped pile of sand with either the substance alternate triad (a pile of D-shaped sand) or the shape alternate triad (a pile of C-shaped salt). The prediction was that English speakers would show greater preference for shape in the solid condition than in the malleable condition due to distinguishing count/mass nouns while Yucatec speakers would prefer material in both conditions.

Lucy observed language-specific categorization in adults and the 9-year-olds. English adults showed greater preference for the shape alternates in the stable condition than the malleable condition. In contrast, Yucatec adults showed similar preference for the substance alternates in the malleable and the stable conditions. The contrasts found in English and Yucatec adults were confirmed by the developmental data. At first, there was no difference between English and Yucatec 7-year-olds. All the 7-year-olds chose the shape alternates more frequently in the solid condition than in the malleable condition. However, while English 9-year-olds continued to choose the shape alternates more frequently in the solid condition than in the malleable condition, their Yucatec peers showed similar preference for the substance alternates in the malleable and in the stable conditions. Lucy concluded that the asymmetric categorization pattern of English speakers in the stable and the malleable conditions suggested that they established a concept of individuality. This concept can be linked to the obligatory distinction between countable and mass nouns in English. In contrast, Yucatec speakers showed symmetric categorization pattern for the stable and the malleable conditions because of the lack of countable and mass nouns in Yucatec. Lucy (Lucy, 1992; Lucy & Gaskins, 2001, 2003) linked crosslinguistic difference with language-specific behaviours in a nonverbal context, thus giving support to *linguistic relativity*. Based on the rationale for using a nonverbal context in investigating the link between thinking and grammatical number, the hypothesis of this study that language can influence the processing of negation will gain support if the performance of English and Chinese speakers in a nonverbal context corresponds to their language distinctions.

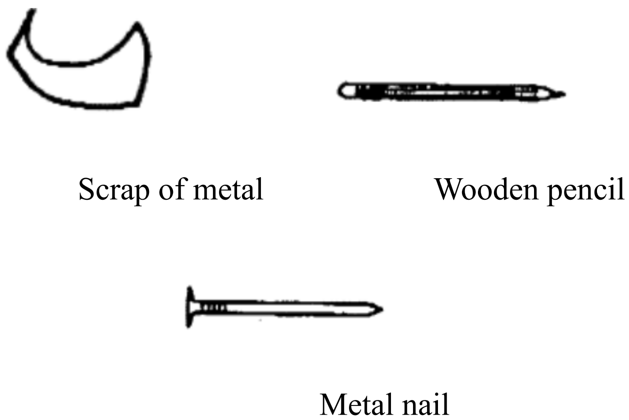


Figure 4. 1 Stimuli for the stable condition extracted from Lucy and Gaskins (2003)

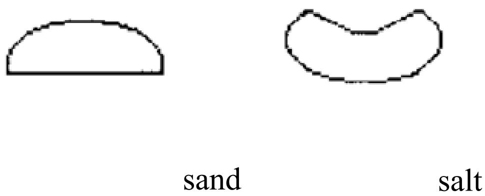


Figure 4. 2 Stimuli for the malleable condition extracted from Lucy and Gaskins (2003)

Levinson (Brown & Levinson, 1993; Levinson, 1996) also designed a nonverbal task to test the possible link between the verbal expressions and the conceptual representations of spatial relations. While English and Dutch speakers typically use relative spatial relation such as *left/right*, these expressions are lacking in Tzeltal Maya. Instead, Tzeltal speakers use absolute spatial coordinates that are similar to English *north/south* in terms of function. Based on this crosslinguistic difference, Levinson deigned what he called an "animal recall task". In the experiment, Tzeltal and Dutch speakers first saw an array of three animals on table 1 (see Fig. 4.5). Then they rotated 180 degrees, standing in front of table 2. Their task was to remake the same array of animals on table 2 according to the array they saw on table 1. Participants could make an array based on the relative spatial relation (e.g., the white sheep was at the left side on table 1) as demonstrated by 'REL' on table 2 in Fig. 4.5. Alternatively, they could rely on the absolute spatial relation (e.g., the white sheep was facing south on table 1) as shown by 'ABS' on table 2 in Fig. 4.5. Levinson and colleagues found that while almost all Dutch speakers rotated the animals for 180 degrees making REL array on table 2, Tzeltal speakers predominantly kept the new array of animals in the same absolute locations as on table 1 i.e., making ABS array. These results suggested that, in a nonverbal context, Dutch and Tzeltal speakers processed spatial relations in language-specific ways. Similar to Lucy (1992; Lucy & Gaskins, 2001, 2003), Levinson interpreted his results as evidence for the *linguistic relativity* hypothesis. However, Levinson's conclusion was questioned by Li, Abarbanell, and Papafragou (2005), and Ünal and Papafragou (2016). Li et al. (2005) and Ünal and Papafragou (2016) pointed out that the instructions in Brown and Levinson (1993) and Levinson (1996) were ambiguous. Tzeltal and Dutch speakers may have different interpretations of "the same array" (Casasanto (2016) made similar criticism to Gordon (2004)). Tzeltal speakers could have considered two arrays pointing to south as the same.

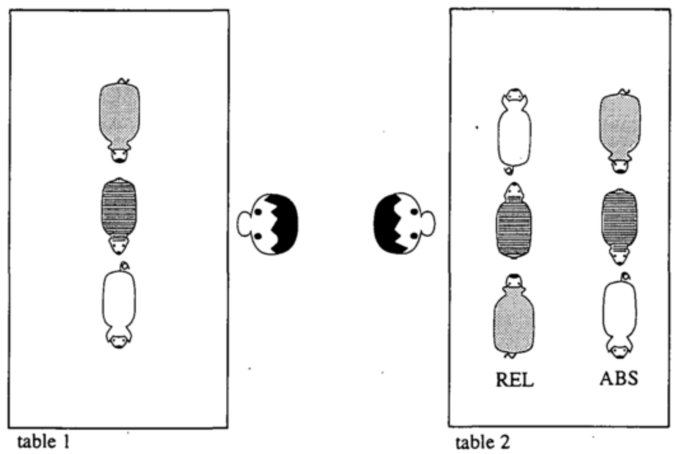


Figure 4. 3 Paradigm of the animals recall task extracted from Brown and Levinson (1993)

In order to test whether the language-specific results found in Brown and Levinson (1993) and Levinson (1996) were due to instructions or not, Li et al. (2005) specifically asked Tzeltal speakers to remake an array according to relative and absolute spatial relations respectively in their study. This time, Tzeltal speakers also managed to rotate the animals for 180 degrees making REL array. Despite the flaw in the instruction, results of the animal recall task in Brown and Levinson (1993) and Levinson (1996) may still support the *linguistic relativity* hypothesis because the findings suggested that English and Tzeltal speakers differ in how they habitually process spatial relations, i.e., the former are likely to use relative spatial relations while the latter use the absolute spatial relations. Accordingly, in this study, it is justifiable to hypothesize that if English and Chinese speakers differ in the processing of negation in a verbal context, the processing differences may extend to a comparable nonverbal context.

Sera, Berge, and Pintado (1994) designed a verbal and a nonverbal task to investigate whether the presence/absence of grammatical gender in language affects thinking. In Spanish, nouns are arbitrarily assigned a grammatical gender, either masculine (e.g., *el pez* 'the fish') or feminine (e.g., *la mesa* 'the table'), except some with natural gender in semantics (e.g., *hombre* 'man' is masculine). In contrast, English is a language lacking grammatical gender. In Experiment 1, the researchers instructed English and Spanish speakers to categorize pictures of objects without natural genders (e.g., fish, table) as masculine or feminine. Moreover, in order to address the influence of grammatical gender on categorization, the researchers used pictures both with and without explicit linguistic labelling of the objects. They observed that Spanish speakers assigned gender to the objects according to the grammatical gender in their language significantly more frequently than English speakers. This tendency was more pronounced when there was explicit linguistic labelling compared to when there was not. However, it is possible that Spanish speakers could have processed that the word *pez* 'fish' is masculine rather than the concept of 'fish'. To further explore if participants think of objects as having masculine or feminine features, the researchers designed another task (Experiment 2), in which they asked participants to assign male or female voice for the pictures of objects in Experiment 1. Results showed that Spanish speakers were more likely to assign male/female voice to the objects based on the Spanish grammatical genders compared to English speakers, which confirmed the results of Experiment 1. The researchers concluded that the presence of the grammatical gender in Spanish verbal expressions influences the categorization of objects in Spanish speakers. As a result, Spanish speakers tended to conceptualize objects as having the properties arbitrarily assigned by their language. This conclusion gave further support to the *linguistic relativity* hypothesis that language can influence thinking in a nonverbal context, in light of which, language specificities in the processing of negation in a verbal context may as well persist in a comparable nonverbal context. However, it is possible that Spanish speakers silently verbalized the word for a picture and assigned male/female voice according to the word. To illustrate, they could assign a male voice to the picture of a fish because they silently verbalized the word *pez* 'fish' which is masculine.

Casasanto (Casasanto, 2016; Casasanto et al., 2004) provided evidence supporting the influence of language on thinking in a nonverbal context from the domain of time. While English speakers typically describe time in the same way they talk about length (e.g., *a long time* as in *a long stripe*). In contrast, Greek speakers typically use volume to describe time (e.g., *a big time* as in *a big box*). To examine whether speakers who use language-specific spatiotemporal metaphors perceive time differently, Casasanto designed a paradigm of nonverbal tasks in which the stimuli were an increasing line or a gradually filled container. The duration and the length/size of the stimuli were independent in the sense that longer lines may not necessarily have longer durations. Casasanto instructed English and Greek speakers to judge the durations of the stimuli while ignoring the length of a line distractor or the fullness of a container distractor. Results showed that English speakers were significantly more strongly interfered by the length of linear stimuli whereas Greek speakers by the fullness of volume stimuli. Casasanto concluded that English and Greek speakers were interfered by linear and volume distractors respectively as a function of their verbal expressions of time. English speakers had difficulty suppressing the nontarget growing lines as they think of time as length. In contrast, it was relatively easy for English speakers to suppress the gradually filled container but not for Greek speakers who habitually think of time as volume. By arguing that English and Greek speakers process time according to their verbal expressions, Casasanto (Casasanto, 2016; Casasanto et al., 2004) gives support to the *linguistic relativity* hypothesis which predicts that language can influence the processing of negation in nonverbal contexts in this study.

Comparable to Casasanto (2016) and Casasanto et al. (2004), Fuhrman and colleagues (2011) designed another nonverbal context using the measure of RT to explore if frequent mapping of language-specific spatiotemporal metaphors influences the processing of time. Recall the crosslinguistic difference in the way English and Chinese speakers describe time in Boroditsky (2001). While English speakers frequently use horizontal spatial metaphors (e.g., *the good times ahead of us*) to describe temporal relations, Mandarin Chinese speakers use vertical metaphors (e.g., *shang* ‘up’ as in *shang ge yue* ‘last month’) besides horizontal metaphors. In Fuhrman et al. (2011), English and Chinese speakers first saw a picture representing a middle-point state in terms of time (e.g., *a half-peeled banana*). Following the first picture, participants saw a second picture illustrating either a temporarily-earlier (e.g., *a whole banana*) or a temporarily-later state (e.g., *a banana peel*). They were instructed to judge whether the second state occurred earlier or later than the first state. To respond, participants needed to press keys which were transversely (left / right), vertically (up/ down) and sagittally (front / back) arranged respectively. The researchers found that while English speakers did not show any preference for vertically arranged keys, it took Chinese speakers significantly shorter RTs when the upper key represented ‘earlier’ than the bottom key. There was no between-group contrast for transversely or sagittally arranged keys. The ‘upper-for-earlier’ preference of Chinese speakers corresponds to the vertical spatiotemporal metaphors in Chinese. These results suggested that Chinese speakers processed time as vertical more frequently than English speakers. Fuhrman et al. (2011) together with Casasanto (Casasanto, 2016; Casasanto et al., 2004) and Boroditsky (2001) suggested that verbal expressions can influence the processing of time in verbal and nonverbal contexts. This argument provides rationale for this study to use a verbal and a nonverbal context to explore the strength of language on the processing of negation.

Aside from the processing of time, Papafragou, Hulbert and Trueswell (2008) investigated the influence of language on thinking of motion events. Motion verbs can encapsulate different information. For example, while English verbs typically express the manner of motions (e.g., *skate*), Greek verbs typically express the path of motions (e.g., *beno* 'enter'). Papafragou and colleagues examined eye-fixations of English and Greek speakers while they were watching video clips of motions events. The prediction was that, compared to English speakers who would focus more on manner, Greek speakers would focus more on path. In each trial, participants watched a video clip first (e.g., a man skating to a snowman). The critical point was that, the last frame of each video clip would freeze on the screen for 2 seconds. After watching all the video clips, participants would see a series of screenshots extracted from previous video clips. Critically, the researchers designed a verbal task and a nonverbal task. In the verbal task, English and Greek speakers were instructed to describe what they had seen after watching each video clip. In the nonverbal task, they were instructed to examine the last frame of each video carefully and judge whether the screenshots were the same or not as the video clips. For example, participants could see a screenshot of a man skating with or without a snowman and compare it with the video clip of a man skating to a snowman. Eye-tracking data showed that Greek speakers allocated significantly more attention to the end of path (i.e., the snowman) in comparison to English speakers in the verbal task as predicted. However, in the nonverbal task, English and Greek speakers showed comparable gaze patterns whilst watching the video clips. When they were studying the last frames, Greek speakers allocated comparable attention to manner regions (i.e., the man) and the end of path (i.e., the snowman) while English speakers focused on the end of path. Based on all the results, the researchers concluded that language can influence thinking only when English and Greek speakers were preparing to speak. The researchers also argued that results of the nonverbal task contradicted the *linguistic relativity* hypothesis because participants focused on features that are not typically expressed in their languages.

Papafragou et al. (2008) confirms the hypothesis that language can influence thinking for over language use as language-specific gaze patterns in the verbal task corresponded to the different verbal expressions in English and Greek. However, what Papafragou et al. (2008) considered counterevidence to the *linguistic relativity* hypothesis may suggest that language can influence thinking in a nonverbal context. According to Athanasopoulos and Albright (2016), English and Greek speakers automatically encode features of motion events that are typically expressed in their languages (i.e., manner for English speakers whereas path for Greek speakers). Consequently, they focused on features that are not automatically encoded with the attempt to memorize them for the task. In light of the language-specific (i.e., when participants were studying the last frames) as well as the universal results (i.e., when participants were watching the videos) of the nonverbal task, Papafragou et al. (2008) suggested that thinking can be language-specific in a nonverbal context that requires encoding visual information (e.g., storing information in memory). Otherwise, thinking may be universal if a nonverbal context requires little help of the language system such as watching the video clips in the nonverbal task in Papafragou et al. (2008). The influence of language on thinking in nonverbal contexts with different involvement of implicit verbal encoding has been further confirmed by Athanasopoulos and Bylund (2013).

Athanasopoulos and Bylund (2013) designed a series of categorization tasks (Experiments 2a, 2b and 2c) to examine to what extent verbal expressions of aspects can affect the processing of motions events. Recall that English is an aspectual language (see earlier discussions of Slobin (1987, 1996)). In contrast, Swedish is not an aspectual language since it only has lexical means to mark the distinction between progressiveness and completeness of motion events. Following the paradigm of previous categorization tasks (e.g., Lucy (1992); Lucy & Gaskins (2001, 2003)), the researchers designed a target video clip and two alternates in each trial. Each target showed a motion event with a potential endpoint in the background (e.g., a person walking towards a car). One alternate that is labelled as [-endpoint] showed a motion event without any immediate endpoint (e.g., a person walking along a road with a car in far distance). The other [+endpoint] alternate showed a subject reaching an endpoint of motion events (e.g., a person walking to and reaching a car). English and Swedish speakers were instructed to choose one out of two alternates they thought most resembled the target video clip. Considering Papafragou et al. (2008) who suggested that thinking may be universal if a nonverbal context requires little help of the language system, the researchers further included a variable of simultaneous/sequential presentation of stimuli in their experimental design. In the condition of simultaneous presentation, the target and alternates were displayed at the same time while in the condition of sequential presentation, one alternate was displayed followed by the other alternate and lastly the target. With such design, participants were less likely to encode visual information to store in the working memory in the simultaneous condition compared to the sequential condition.

Athanasopoulos and Bylund found an interaction between group and simultaneous/sequential presentation. This result revealed that Swedish speakers showed significantly greater preference for matching the target clip with [+endpoint] alternates than English speakers when the stimuli were sequentially presented. There was no between-group contrast in the simultaneous condition. Besides the language-specific performance in the sequential condition, within groups, both Swedish and English speakers matched the target clip more frequently with the [-endpoint] than the [+endpoint] alternates. Athanasopoulos and Bylund concluded that both English and Swedish speakers perceived the progressiveness of motion events; however, the progressiveness of motion evets was more salient for English speakers than for Swedish speakers. This saliency can be linked to the English grammatical aspects that require differentiation between progressiveness and completeness of motion events. Moreover, the saliency only emerged when a nonverbal task requires storing visual information with the help of language (i.e., the sequential presentation). To further test the link between language and the processing of motion events in the sequential condition, Athanasopoulos and Bylund (2013) designed a sequential categorization task with concurrent language interference (Experiment 2c). If language-specific patterns only emerge when a nonverbal task requires storing visual information with the help of language, then crosslinguistic differences would disappear with concurrent language interference. English and Swedish speakers would hear a string of digits at the onset of the first alternate clip. They were instructed to repeat the string of digits continuously till the offset of the target clip. With concurrent language interference, the between-group contrast found between English and Swedish speakers in the sequential condition disappeared as predicted. The researchers confirmed their argument for the link between language and the processing of motion events. However, it is also possible that the participants got distracted from the categorization task by the digit-repeating task so that no between-group differences were found.

So far, empirical evidence suggesting that language influences thinking in a nonverbal context in different domains has been reviewed. Notably, speakers of a particular language can still conceptualize an event even when their language lacks corresponding verbal expressions. For example, Swedish speakers can process the difference between ongoing and completeness of motion events without grammatical aspects in their language (Athanasopoulos & Bylund, 2013). On the basis of the universal processing, the effect of language is to highlight certain features. For example, the differences between stable and malleable objects are highlighted for English speakers as a function of their distinction between countable and mass nouns (Lucy, 1992; Lucy & Gaskins, 2001, 2003).

Growing evidence suggests that language can influence thinking in verbal and nonverbal contexts. In a verbal context, speakers of different languages can attend to language-specific information according to their verbal expressions (von Stutterheim, 2003; von Stutterheim & Carroll, 2006; Slobin, 1987, 1996). Moreover, speakers of different languages can process the same stimuli in language-specific ways in a nonverbal context (Athanasopoulos & Bylund, 2013; Brown & Levinson, 1993;

Casasanto et al., 2004; Casasanto, 2016; Fuhrman et al., 2011; Lucy, 1992; Lucy & Gaskins, 2001, 2003; Papafragou et la., 2008; Sera et al., 1994). All the language-specific results pose challenge to the linguistic universalist approach (Jackendoff, 1996). Besides previous explorations, the link between language and cognition has never been attested in the domain of negation. This study innovatively investigates the extent to which language influences the processing of negation in English and Chinese speakers. Following previous paradigms, this study tests responses and RTs in verbal and nonverbal experiments. If language does not influence the processing of negation at all, the two groups of monolinguals would only differ in their responses in the verbal experiments while they would show comparable RT patterns in both verbal and nonverbal experiments. If language only influences the processing of negation with overt language use, English and Chinese speakers are predicted to show language-specific response and RT patterns in the verbal experiments but not the nonverbal experiments. If English and Chinese speakers process negation differently in a verbal context and also when no overt verbal encoding is needed, they are predicted to differ in their responses and RT patterns in both verbal and nonverbal experiments.

Chapter 5. Language-speicifc processing of negative questions[19]

5.1. Introduction

In response to negative questions such as *Doesn't she like cats?*, English speakers typically use a polarity-based system (->*yes, she does/no, she doesn't*) while Chinese speakers use a truth-based system (->*no, she does/yes, she doesn't*) (see Chapter 3). The sharp crosslinguistic contrast between English and Chinese speakers may be associated with language-specific processing of negation in negative questions. One piece of evidence for this assumption is that greater difficulty has been reported in using the truth-based system compared to the polarity-based system (Akiyama, 1979; Akiyama et al., 1982; Akiyama & Guillory, 1983; Akiyama et al., 1979; Akiyama, 1992; Choi, 1991). Choi (1991) attributed this greater complexity to an addition processing operation in the truth-based system compared to the polarity-based system. Choi (1991) may suggest that, when processing negative questions, speakers of the truth-based Chinese use two steps (i.e., process the positive statement of a negative questions in the first step and then process the negative statement of the negative question) while English speakers use only one step. This assumption is built on the empirical evidence suggesting that negation can be processed in one step without a detour via its positive counterpart (Dale & Duran, 2011; Nieuwland & Kuperberg, 2008; Orenes et al., 2014; Tettamanti et al., 2008; Tian et al., 2010, 2016) and in two steps via the corresponding positive statement (Clark & Chase, 1972; Carpenter & Just, 1975; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al., 2007).

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[19] Part of the work contained in this chapter has been submitted as a co-authored article to be considered for publication in *Language, Cognition and Neuroscience* (project website https://osf.io/x4536/?view_only=74fb6c47a11143f7b1f400532a30f9c3).

Another piece of evidence supporting the assumption that English may diverge from Chinese speakers when they process negative questions is the link between the expressions and the processing of negation. Previous empirical studies (Carpenter & Just, 1975; Sherman, 1973, 1976; Wason & Jones, 1963) showed that when the forms of negation are different, the processing difficulties would as well vary. Carpenter and Just (1975) found that it is more difficult for English speakers to process *It isn't true that the dots are red* compared to *It's true that the dots aren't red*, with the two sentences differ in the position of negation. Sherman (1973, 1976) and Kaup et al. (2006) reported that it is more difficult to process *the umbrella is not open* compared to *the umbrella is closed,* which also differ in the position of negation. Now, consider the negative questions in English and Chinese with focus on negation. The crosslinguistic difference associated with contrasts in *yes/no* answers is that English negative questions use high negation *Doesn't she like cats?* while Chinese negative questions use middle negation *Does she not like cats?* Considering the findings in Carpenter and Just (1975), Sherman (1973, 1976), and Wason and Jones (1963), the varied negation in English and Chinese negative questions would lead to processing differences. Moreover, according to Giora et al. (2004) and Kaup et al. (2006), the varied difficulties in the processing of *not open* and *closed* is due to two-step versus one-step routes. In light of this argument, English and Chinese speakers would process negative questions following different routes.

The research question of this chapter is whether English and Chinese speakers process negation in negative questions differently. The aim of this chapter is to investigate whether language influences the processing of negation in negative questions. Language mediation on thinking has been suggested in other comparable domains. For example, Slobin (1987, 1996) argued that language influences the thinking for event construal. He asked speakers of aspectual languages (English and Spanish) and non-aspectual languages (German and Hebrew) to describe the same pictures of motion events (*A boy fell on the ground from a tree while a dog was* *running away*). He found language-specific descriptions as speakers of aspectual languages distinguished progressiveness versus completeness of motion events while speakers of non-aspectual languages did not. Analogous to Slobin (1987, 1996), von Stutterheim (2003) argued that language affects the processing of motion events. She found that, when instructed to describe motion events (e.g., two people walking along the road toward a house), it took English speakers shorter to start speaking compared to German speakers because the latter tend to conceptualize motion events including endpoints (a house). In this study, if language influences the processing of negation in negative questions, English and Chinese speakers are expected to show language-specific answers and response speed.

The different processing of negation in English and Chinese speakers is expected to manifest itself as a variation in answers to negative questions. If the assumption holds true that English and Chinese speakers process negative questions differently, English speakers are predicted to use the polarity-based system while Chinese speakers use the truth-based system when they answer negative questions. However, examining answers to negative questions alone cannot provide sufficient evidence for exploring whether language influences the processing of negative questions. First, given that the semantic meanings of *yes/no* differ in English and Chinese (see chapter 3), the two groups of speakers can show language-specific answers while they process negative questions in the same way. Second, production results alone are not conclusive enough for the influence of language on thinking. It means arguing that speakers of different languages think differently with only evidence that they speak differently, which has been pointed out as problematic by many researchers (Athanasopoulos & Albright, 2016; Bylund & Athanasopoulos, 2014; Casasanto, 2016; Everett, 2013).

To better interpret the production results, the response speed of English and Chinese speakers is also measured in this chapter. If Chinese speakers process negative questions in two steps while English speakers process negative questions in one step, it is expected to take Chinese speakers longer to answer negative questions. This prediction is based on a great number of empirical studies that attributed the greater difficulty in the processing of negative statements compared to positive statements to an additional processing step in the former (Clark & Chase, 1972; Carpenter & Just, 1975; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al., 2007). Moreover, on the within-group level, if Chinese speakers process negative questions in two steps while English speakers process negative questions in one step, it would only take Chinese speakers longer to answer *yes* than *no* to negative questions. This prediction is built on Clark and Chase (1972) who argued that verifying a negative sentence as true is to perform two negations and therefore takes longer compared to verifying a negative sentence as false.

Two alternative hypotheses about the strength with which language mediates the processing of negation in negative question are proposed.

a) *Language-independent processing of negation.* The first hypothesis is that English and Chinese speakers use the same number of steps when they process negative questions. If this hypothesis holds, one would expect speakers of both languages to show similar response speed when they answer negative questions. If both language groups use two steps to process negative questions, then it would take them longer to process negative questions compared to positive questions. Also, on the within-group level, it is expected to take both groups longer to answer *yes* than *no* to negative questions, which is built on the view that verifying a negative sentence as true is to perform two negations and therefore takes longer compared to verifying a negative sentence as false (Clark & Chase, 1972). If both language groups use one step to process negative questions, then it would take them a similar amount of time to process negative questions compared to positive questions. Also, on the within-group level, it would not take English or Chinese speakers longer to answer *yes* than *no* to negative questions. With regards to responses to negative questions, English speakers are predicted to use the polarity-based system while Chinese speakers use the truth-based system (see Table 5.1).

Table 5. 1 Polarity-based and truth-based answers in English and Chinese speakers

Question type	Example (The case is that *she likes cats.*)	Responses	
		polarity-based	truth-based
Positive (control)	*Does she like cats?*	*yes*	*yes*
Positive (control)	*Does she like dogs?*	*no*	*no*
Negative (critical)	*Doesn't she like cats?*	***yes***	***no***
Negative (critical)	*Doesn't she like dogs?*	***no***	***yes***

b) *Language-specific processing of negation in a verbal context.* The second hypothesis is that Chinese speakers typically use two processing steps while English speakers typically use one step when they answer negative questions. If this hypothesis holds true, then in comparison to English speakers, Chinese speakers will be slowed down more when processing negative questions. On the within-language level, if English speakers typically use the one-step route to answer negative questions, it would not take them longer to answer *yes* than *no* to negative questions. If Chinese speakers typically use two steps to answer negative questions, it would take them longer to answer *yes* than *no* to negative questions. As for responses, English speakers are predicted to use the polarity-based system while Chinese speakers use the truth-based system (see Table 5.1)

To test the validity of these two competing hypotheses, a production experiment (Expt. 1) and a *yes/no* choice experiment (Expt. 2) were designed in this chapter. In Expt. 1, English and Mandarin Chinese monolingual speakers were instructed to answer the same set of negative questions (critical trials) and positive questions (control trials) out loud in English and Chinese respectively in fully comparable neutral contexts. Their responses were recorded. In Expt. 2, English and Chinese speakers answered negative questions (critical trials) and positive questions (control trials) with yes/no button presses. In this case, both their responses and response speed were recorded.

5.2. Experiment 1. English versus Chinese monolinguals' processing of negative questions in a *yes/no* production experiment

5.2.1. Participants

40 English (31 females) and 40 Chinese (38 females) monolingual speakers took part in this experiment. The English participants were recruited from a university in the UK (mean age 19.40, range 5 years) and the Chinese participants were recruited from a vocational college of preschool education in China (mean age 20.50, range 3 years). All participants were right-handed and reported no fluency in any language other than their L1.

5.2.2. Materials

The instruments for this task consisted of 24 sentences, 48 core questions and 24 fillers in English and Chinese. All English sentences were checked for authenticity (i.e., *Do these sentences and questions sound natural or not?*) by an English native speaker to ensure that potentially ambiguous or infelicitous sentences were excluded from the stimuli. Two Chinese-English bilinguals then checked all the Chinese translations from English for authenticity, and only translations for which a consensus was reached were included in the experiment.

In stimulus preparation, 12 sentences out of a total of 24 (see examples 62-63), were combined with the yes-no questions (see Table 5.2) and the other 12 with filler items. The syntactic structure of all the sentences within a language was kept the same. The sentences and yes–no questions appeared in four conditions (see Table 5.2). Each sentence (N = 12) was transformed into four types of yes–no questions for each condition.

62) Example of an English sentence:

Mr. Fox stole a roast duck from a farm.

[$_{TP}$ Mr. Fox [$_{VP}$ stole [$_{NP}$ a roast duck] from a farm.]]

63) Example of a Chinese sentence:

Hu li xian sheng cong nong chang tou le yi zhi kao ya.

fox sir from farm steal a roast duck

'Mr. Fox stole a roast duck from a farm.'

[$_{TP}$ Hu li xian sheng [$_{VP}$ cong nong chang tou le [$_{NP}$ yi zhi kao ya]]]

Table 5. 2 Examples of questions in English and Chinese. The sentence was "Mr. Fox stole a roast duck from a farm."

Question type	Condition	Language	answer	*Example*
positive	positive-true	English	*yes*	*Did Mr. Fox steal a roast duck from a farm?*
		Chinese	*shi (de)* 'yes'	*Hu li xian sheng cong nong chang tou le yi zhi kao ya ma?* fox sir from farm steal a roast duck Q 'Did Mr. Fox steal a roast duck from a farm?'
positive	positive-false	English	no	*Did Mr. Fox steal a roast chicken from a farm?*
		Chinese	*bu (shi de)* 'no'	*Hu li xian sheng cong nong chang tou le yi zhi kao ji ma?* fox sir from farm steal a roast chicken Q 'Did Mr. Fox steal a roast chicken from a farm?'
negative	negative-true	English	yes	*Didn't Mr. Fox steal a roast duck from a farm?*
		Chinese	*bu (shi de)* 'no'	*Hu li xian sheng mei cong nong chang tou le yi zhi kao ya ma?* fox sir Neg from farm steal a roast duck Q 'Did Mr. Fox not steal a roast duck from a farm?'
negative	negative-false	English	no	*Didn't Mr. Fox steal a roast chicken from a farm?*
		Chinese	*shi (de)* 'yes'	*Hu li xian sheng mei cong nong chang tou le yi zhi kao ji ma?* fox sir Neg from farm steal a roast chicken Q 'Did Mr. Fox not steal a roast chicken from a farm?'

The 48 yes–no questions were grouped into four lists (A, B, C and D). For counterbalancing purposes, within each list the yes–no questions come from different sentences. The conditions were classified based on the polarity of the question (positive/negative) and the state of affairs (Mr Fox stole a roast duck = true; Mr Fox stole a roast chicken = false) as positive-true, positive-false, negative-true, or negative-false (for instance, the four yes-no questions in Table 5.2 are in different lists). Each list (see Appendix 1 for the full lists) consisted of 12 yes-no questions, 3 from each of the 4 conditions (3 positive-true + 3 positive-false + 3 negative-true + 3 negative-false). There were two levels of randomisation. Each participant was randomly assigned to one list. Another level of randomisation was that each participant saw the sentence-question pairs in a random order.

24 filler (i.e., other than yes/no questions, see examples 64-65) were included to mask the purpose of the experiment and minimise possible strategic answers. Each participant saw 12 yes–no questions and 24 filler stimuli in total.

64) Example of an English Filler:

Who received a letter from his grandpa? (Mr. Dog /Mr. Fox)

65) Example of a Chinese Filler:

Shei shou dao le ta ye ye ji lai de xin? (gou xian sheng/hu li xian sheng)

who receive his grandpa send letter (dog sir fox sir)

'Who received a letter from his grandpa? (Mr. Dog /Mr. Fox)'

5.2.3. Procedure

Participants were tested individually. They were asked to carefully read the instructions on a computer screen. They were informed that they would see one sentence at a time. After each sentence, they saw and heard one question. Their task was to read each sentence carefully and answer each question (including *yes/no* whenever possible) aloud accurately and as quickly as possible. Participants received a brief training (4 items) on the computer before the experimental session. Only after the participants confirmed that they had understood the task and the procedure did the experimenter start the computerised test.

During the training and the experimental session (set up in E-Prime 2.0), participants first read one sentence displayed on the screen for 8 seconds (see

Fig.5.1). The 8-second interval was kept constant across sentences in order to ensure that each participant had the same amount of time reading them. Then, a corresponding question followed automatically (see Fig.5.1). Participants were not able to go back to the sentence once the question appeared. Their answers were audio recorded. When a participant did not specifically give *yes/no* answers in his/her response for a core question, the experimenter would remind the participant to give a *yes/no* answer (i.e., include *yes/no* in your answer whenever possible) before moving to the following trial. When a participant completed a trial, the experimenter would press the space key to proceed to the next trial.

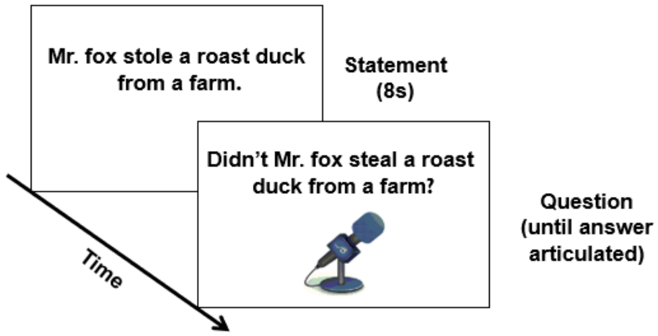

Figure 5. 1 Protocol of Experiment 1

For the analyses, responding with a positive answer (i.e., *yes* in English and *shi (de)* 'yes' in Chinese) was scored 1 point; a negative answer (i.e., *no* in English and *bu* (*shi de)* 'no' in Chinese) was scored 0 points. Answers in each condition were analysed separately and the mean score for each condition was used to show the proportion of *yes* answers.

5.2.4. Results

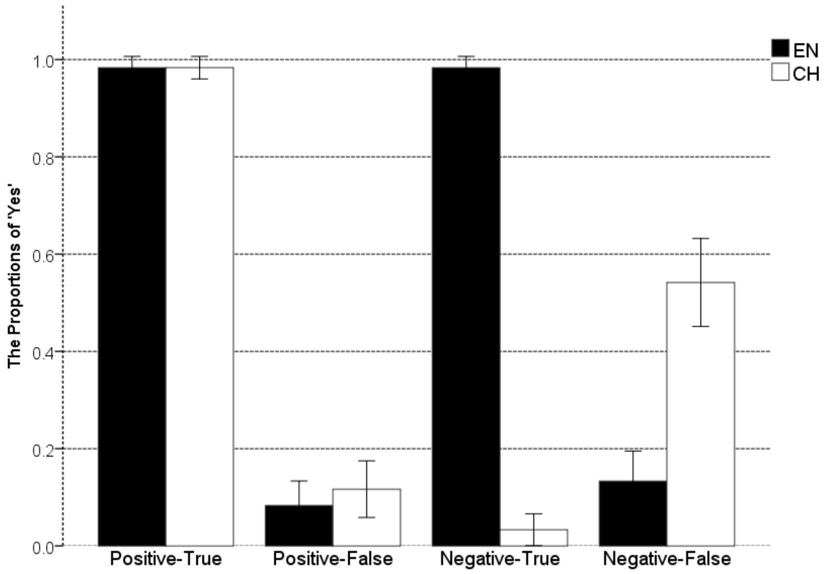

Figure 5. 2 Group mean proportions of *yes* answers of English and Chinese speakers in Experiment 1 (error bars = 95% confidence interval).

Figure 5.2 shows responses of English and Chinese speakers in Expt. 1. In the critical negative-true condition, English speakers predominantly answered *yes* (M = .98, SD = .13) while Chinese speakers seldomly answered *shi (de)* 'yes' (M = .03, SD = .18). These results align with the idea that the English speakers attach negation to the polarity of the question 'Is it true or not that [Mr Fox stole a duck]', whereas Chinese speakers attach negation to the statement 'Is it true that [Mr Fox didn't steal a duck]'. In the critical negative-false condition, English speakers rarely answered *yes* (M = .13, SD = .34), suggesting that here too they attach negation to the polarity of the question 'Is it true or not that [Mr Fox stole a chicken]'. Chinese speakers, however, showed no clear preference for either *shi (de)* 'yes' (M = .54, SD = .50) or *bu (shi de)* ‘no’. Slightly over half of the Chinese participants responded *shi (de)* ‘yes’, in line with what is expected if they attach negation to the statement ‘Is it true that [Mr Fox didn’t steal a chicken]’. For the remaining 46%, it is likely that the task of responding to a negative question about a false state of affairs was cognitively too complex and the processing broke down. In contrast, in the control positive-true condition, both English (M = .98, SD = .13) and Chinese speakers (M = .98, SD = .13) almost exclusively answered *yes*. In the control positive-false condition, both English (M = .08, SD = .28) and Chinese speakers (M = .12, SD = .32) rarely answered *yes*.

To test the effect of language group on the proportion of *yes/no* answers in each condition, mixed-effect regression models were built using the lme4 package (Baayen, Davidson, & Bates, 2008) in the R software (Version 3.5.1; R Development Core Team 2018). The first examination was whether language group significantly predicts variation in answers to questions in the negative-true condition as expected. The random effect factors with random intercepts were *Participant* and *Item*, the binary dependent variable was *Answer* (*yes*/*no*) and the fixed effect factor was *Group* (English/Chinese). The model glmer(answer~group + (1|participant) + (1|item)) confirmed that language group significantly predicted variation in *yes/no* answers to questions in the negative-true condition (β = 7.44, *SE* = 0.88, *Z* = 8.50, p <.001) with significantly higher probability of *yes* answer for English speakers. The second examination was whether language group also predicts answers to questions in the negative-false condition, using the same random and fixed effects structure. The model glmer(answer~group + (1|participant) + (1|item)) confirmed that language group significantly predicted the proportion of *yes/no* answers (β = -2.10, *SE* = 0.36, *Z* = -5.75, p < .001), with a significantly higher probability of *yes* answers for Chinese speakers. *Group* was not described in the model (i.e., glmer(answer~ (1|participant) + (1|item)) for either of the two control conditions (positive-true and positive-false) as predicted.

5.2.5. Discussion

This chapter set out to investigate whether English and Chinese speakers process negation in negative questions differently. The results showed that English and Chinese speakers significantly differed when they answered negative questions. The answers typical of English speakers followed a polarity-based pattern. Specifically, English speakers almost exclusively answered *yes* in the negative-true condition and *no* in the negative-false condition. These preferred answers suggest that English speakers are highly likely to respond to the positive statement of a negative question (Choi, 1991; Holmberg, 2015). One interpretation is that English speakers attach negation to the polarity of the question i.e., *Didn't he steal a duck?* -> 'Is it true or not that [he stole a duck]'. An alternative explanation is that English speakers use the polarity values (positive/negative poles) of *yes/no* answers when they answered negative questions. This explanation is in line with Huddleston et al. (2002). In contrast, answers typical of Chinese speakers followed the truth-based pattern. Specifically, Chinese speakers predominantly answered *bu (shi de)* 'no' in the negative-true condition. In the negative-false condition, the proportion of *shi (de)* 'yes' given by Chinese speakers, was significantly higher than that of *yes* responded by English speakers. Answers typical of Chinese speakers suggest that Chinese speakers respond to the negative statement of a negative question (Holmberg, 2015; Huang, 2007). The interpretation here is that Chinese speakers attach negation to the statement of the question and then reverse the truth value of the statement i.e., *Didn't he steal a duck?* -> 'Is it true that [he stole a duck]'-> 'Is it true that [he didn't steal a duck]'.

Answering negative questions can be viewed as a one-step or two-step process. Giora et al. (2004) and Kaup et al. (2006) suggested that differences in the verbal expression of negation may be linked to different mental routes to negative statements. In light of this link, the sharp contrasts between English and Chinese speakers when they answered negative questions may indicate that the two groups do not process negation in negative question in the same way. Moreover, crosslinguistic evidence showed that the polarity-based system is less difficult compared with the truth-based system (Akiyama, 1979; Akiyama et al., 1982; Akiyama & Guillory, 1983; Akiyama et al., 1979; Akiyama, 1992; Choi, 1991). This is because, according to Choi (1991), there is an additional processing operation in the truth-based system. Considering Choi's (1991) argument, the use of the polarity-based system by English speakers may suggest that they take a more direct route compared to Chinese speakers who typically use the truth-based system. In other words, English speakers may process negation in one step, which is in line with Nieuwland and Kuperberg (2008) and Tian et al. (2010) while Chinese speakers process negative questions in two steps. For an illustration of the two-step model, to respond to *Didn't he steal X?*, the Chinese speakers would process 'Is it true that [he stole X]' in the first step, and then 'Is it true that [he didn't steal X] in the second step. In contrast, English speakers are more likely to process 'Is it true or not that [he stole X]' in response to a negative question straight away, in a single step. These interpretations are tested by the measure of RT (see section 5.3) as the production results alone are not transparent enough.

Language is likely to mediate the processing negation in negative questions. In relation to comparable crosslinguistic studies in a different domain, previous research on event construal (von Stutterheim, 2003; von Stutterheim & Carroll, 2006) shows that while speakers of non-aspectual German conceptualized completion of motion events by including the endpoints (e.g., two people walking along the road towards a house), English speakers focused on the progressiveness of the events without the endpoints (e.g., two people walking along the road). The researchers argued that the processing of motion events can be language-specific, affected by the presence/absence of grammatical aspect in the speakers' L1. Comparably, current study argues that English speakers who use the polarity-based answering system may process negative questions in one step while Chinese speakers who use the truth-based system may process negative questions in two steps. The language-specific processing of negative questions suggests the influence of language on thinking, which is in line with von Stutterheim (2003) and von Stutterheim and Carroll (2006), and brings new empirical support for the theory of *thinking for speaking* (Slobin, 1987, 1996).

An unexpected result is the interchangeable use of *yes/no* by Chinese speakers found in the negative-false condition where *yes* was predicted to be the dominant answer. For example, Chinese speakers showed a similar preference for *yes/no* to *Didn't he steal a chicken?* When the given sentence is *he stole a duck*. The most likely explanation is that using two steps to process 'Didn't he steal X?' is true is quite difficult. Chinese speakers need to process 'Is it true that [he stole X]'-> 'It is false' in the first step, and then reverse the truth value of the positive statement 'It is false that [it is false]' i.e., *Yes (he didn't steal X)*. There are two negations in this process causing increased difficulty (Clark & Chase, 1972). Given the increased difficulty, Chinese speakers' processing may break down. This argument is supported by the finding from the following Expt. 2, in which Chinese speakers showed prolonged response speed when they answered *shi de)* 'yes' to a negative question. Another possible explanation is that *bu (shi de)* 'no' may be used to indicate there is no sufficient evidence to judge *He did not steal a chicken* as true only based on the information *He stole a duck*. However, no Chinese participants expressed their concern (e.g., I could not give an answer according to the given fact) during or after the experiment. Also, if this explanation was correct, Chinese speakers should have shown similar hesitation between *shi de)* 'yes' and *bu (shi de)* 'no' when answering *Did he steal a chicken?* and the given sentence was *He stole a duck.* However, the results demonstrated that they predominantly answered *bu (shi de)* 'no'. The third possible explanation is that *bu (shi de)* 'no' may indicate the absolute polarity (i.e., [−]) as well as the relative polarity [reverse], which is proposed by Roelofsen and Farkas (2015) for the effects of *yes/no*. In other words, *bu (shi de)* 'no' in Chinese is similar to the semantic meaning of *no* in English. This explanation is in line with Holmberg (2015) who labelled this phenomenon as negative neutralization in the Chinese answering system (e.g., -*Doesn't she like cats?* - *Yes, she doesn't*/*No, she doesn't*), implying that the semantic meaning of *yes/no* is neutralized without further explanation. Then this explanation goes against to Li and Thompson (1981), who argued that Chinese answer *bu (shi de)* 'no' means 'it is not the case'. Still, Li and Thompson (1981) may be partially correct by arguing that *shi (de)* 'yes' means 'it is the case', differing from the semantic meaning of *yes* in English. This argument is supported by the result that Chinese speakers rarely answered *shi (de)* 'yes' in the negative-true condition (e.g., *Didn't he steal a duck?* and the given sentence was *he stole a duck*).

The limitation of this experiment is that examining response alone is not transparent enough for the investigation of the influence of language on the processing of negation. One reason is that *yes/no* in English and Chinese have different semantic meanings. It is possible that English and Chinese speakers process negative questions in the same way while they answer *yes/no* according to language-specific meanings. Another reason is that production results alone may not provide sufficient evidence for *thinking for speaking*. Arguing language-specific thinking for speaking with production results alone means to argue that people who speak differently think differently with the only evidence that they speak differently. This circularity has been pointed out by Athanasopoulos and Albright (2016), Bylund and Athanasopoulos (2014), Casasanto (2016), and Everett (2013). English and Chinese speakers used language-specific expressions may simply because their languages require them to. In order to test whether language influences thinking for overt language use, it is crucial to target at language processing rather than production. To strengthen the validity of the measure of response types, the response speed of English and Chinese speakers when they answer negative questions is measured in Experiment 2.

5.3. Experiment 2 English versus Chinese monolinguals' processing of negative questions in a *yes/no* choice experiment

Expt. 2 was designed on the basis of Expt. 1 to further test whether English and Chinese speakers process negative questions differently. Given the limitation of Expt. 1 that only responses to negative questions were examined, in Expt. 2, response speed of English and Chinese speakers when they answer negative questions would also be measured along with their *yes/no* choices. If the assumption of this study holds true that English speakers process negative questions in one step while Chinese speakers process negative questions in two steps, it is expected to take Chinese speakers longer compared to English speakers to answer negative questions. This prediction is based on the view that an additional step in the processing of negative statements compared to the processing of positive statements gives rise to a greater difficulty in the former (Clark & Chase, 1972; Carpenter & Just, 1975; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al., 2007). Also, on a within-group level, it is expected to take only Chinese speakers longer to answer *yes* than *no* to negative questions. This is because, when using two steps, it takes longer to verify negative sentences when they are true than when they are false (Clark & Chase, 1972; Carpenter & Just,1975; Fischler et al., 1983).

5.3.1. Participants

The same participants as in Experiment 1 were tested in Experiment 2 immediately after Experiment 1.

5.3.2. Materials

Materials of Experiment 2 were identical as those in Experiment 1, i.e., 24 sentences, 48 yes-no questions as well as 24 fillers.

5.3.3. Procedure

Participants were tested individually. They were asked to carefully read the instructions on the computer screen. They were informed that they would see one sentence first. After each sentence, one question and two answer choices (*yes/no*) appeared on the computer screen. Their task was to read each sentence and the subsequent question carefully and choose their preferred answer as quickly as possible. They were asked to press the '↑' key on the keyboard to choose *yes* or the '↓' key to choose *no*. For fillers, participants chose from the Mr Dog/Mr Fox type alternatives by pressing the '↑' key or the '↓' key corresponding to the position of answer choices (Mr Dog/Mr Fox) displayed on the screen. Participants received a brief training (4 items) before the experimental session. Only after the participants confirmed that they had understood the task and procedures did the experimenter start the computerised test.

During the training and the experimental session (set up in E-Prime 2.0), participants first read one sentence displayed on the screen for 8 seconds (see Fig 5.3). The 8-second interval was kept constant across sentences in order to ensure that each participant had the same maximum reading time. Then, a corresponding question followed automatically. Participants were not able to go back to the sentence once the question appeared. When a participant answered a question, i.e., once they pressed '↑' or '↓', the computerized task automatically continued with the next trial. Each answer and reaction time were recorded. At the end of the experiment, participants received £5 for taking part.

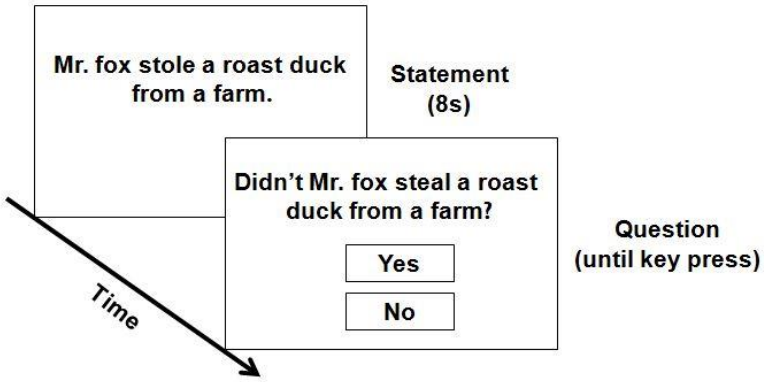

Figure 5. 3 Protocol of Experiment 2

For the analyses, selecting a positive answer (i.e., an up-pointing arrow '↑' press) counted for 1 point; a negative answer (i.e., a down-pointing arrow '↓' press) counted for 0 points. Answers in each condition were analysed separately and the mean score for each condition was used to show the proportion of positive answers.

5.3.4. Results

In this section, the responses of English and Chinese speakers are reported first and then their reaction times (RT) are presented. This is because the expected responses of English and Chinese speakers when they answer negative questions need to be first checked. Then RTs of the expected responses can be analysed. To compare RTs of only expected answers is to ensure crosslinguistic comparability of the RTs.

5.3.4.1. Responses of English and Chinese speakers

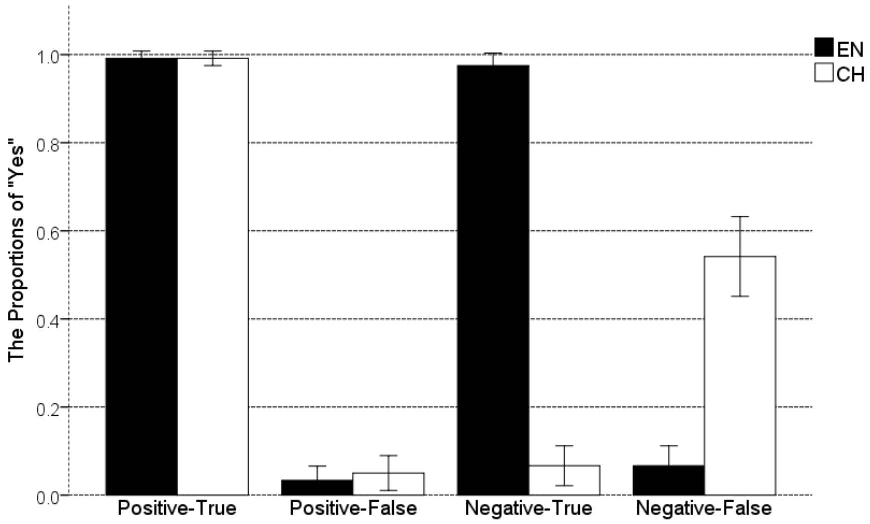

Figure 5. 4 Group mean proportion of *yes* answers of English and Chinese speakers in Experiment 2 (error bars = 95% confidence interval).

Figure 5.4 shows the responses of English and Chinese speakers when they answered negative questions in Expt. 2. In the critical negative-true condition, English speakers predominantly answered *yes* (M = .98, SD = .16) while Chinese speakers rarely answered *shi (de)* 'yes' (M = .07, SD = .25). In the critical negative-false condition, English speakers seldomly answered *yes* (M = .07, SD = .25), Chinese speakers, however, showed no clear preference for either *shi (de)* 'yes' (M = .54, SD = .50) or *bu* (*shi de)* 'no'. In the control positive-true condition, both English (M = .99, SD = .09) and Chinese speakers (M = .99, SD = .09) almost exclusively answered *yes*. In the control positive-false condition, both English (M = .03, SD = .18) and Chinese speakers (M = .05, SD = .22) very rarely answered *yes.*

To test the effect of language group on the proportion of *yes/no* answers in each condition, mixed-effect regression models were built using the lme4 package (Baayen, Davidson, & Bates, 2008) in the R software (Version 3.5.1; R Development Core Team 2018). Whether language group significantly predicts variation in answers to questions in the negative-true condition as expected was examined first. The random effect factors with random intercepts were *Participant* and *Item*, the binary dependent variable was *Answer* (*yes*/*no*) and the fixed effect factor was *Group* (English/Chinese). The model glmer(answer~group + (1|participant) + (1|item)) confirmed that language group significantly predicted variation in *yes/no* answers to questions in the negative-true condition (β = 8.66, *SE* = 2.05, *Z* = 4.23, *p* <.001) with significantly higher probability of *yes* answer for English speakers. Then whether language group also predicts answers to questions in the negative-false condition was examined, using the same random and fixed effects structure. The model glmer(answer~group + (1|participant) + (1|item)) confirmed that language group significantly predicted the proportion of *yes/no* answers (β = -4.40, *SE* = 0.94, *Z* = -4.67, *p* < .001), with a significantly higher probability of *yes* answer for Chinese speakers. *Group* was not described in the model (i.e., glmer(answer~ (1|participant) + (1|item)) for either of the two control conditions (positive-true and positive-false) as predicted.

5.3.4.2. Inclusion criteria for reaction times

Next, the reaction times from Expt. 2 were analysed. RTs of the expected English and Chinese answers for each condition were analysed. Specifically, RTs were only included in the analyses if an English answer was *yes* for the positive-true and the negative-true conditions. Analogously, RTs were only analysed if an English answer was *no* for the positive-false and the negative-false conditions. For the Chinese speakers, RTs were included in analyses if the answer was *shi (de)* 'yes' for the positive-true and the negative-false conditions and *bu* (*shi de)* 'no' for the positive-false and the negative-true conditions. Notably, for the negative-false condition, Chinese answers did not strictly follow the truth-based system, i.e., they were not clearly geared towards *shi (de)* 'yes', but distributed similarly as either *shi (de)* 'yes' or *bu (shi de)* 'no'. The analysis of the RTs only considers the *shi (de)* 'yes' answers for the negative-false condition because *shi (de)* 'yes' in Chinese speakers is the expected answer if the Chinese follow the truth-based system. There were a few outliers in each group. Following Keating and Jegerski (2015) and Norris (2015), for English participants, 10 data entries (2.2% of total RTs of typical English answers) were more than 2.5 standard deviations away from the group mean in each condition. These 10 outlier RTs were replaced by the cut-offs (group mean +/- 2.5 SDs). For the Chinese participants, 11 data entries (2.7% of total RTs of typical Chinese answers) were more than 2.5 standard deviations away from the group mean in each condition. These were also replaced by the cut-offs.

5.3.4.3. Reaction times of English and Chinese speakers

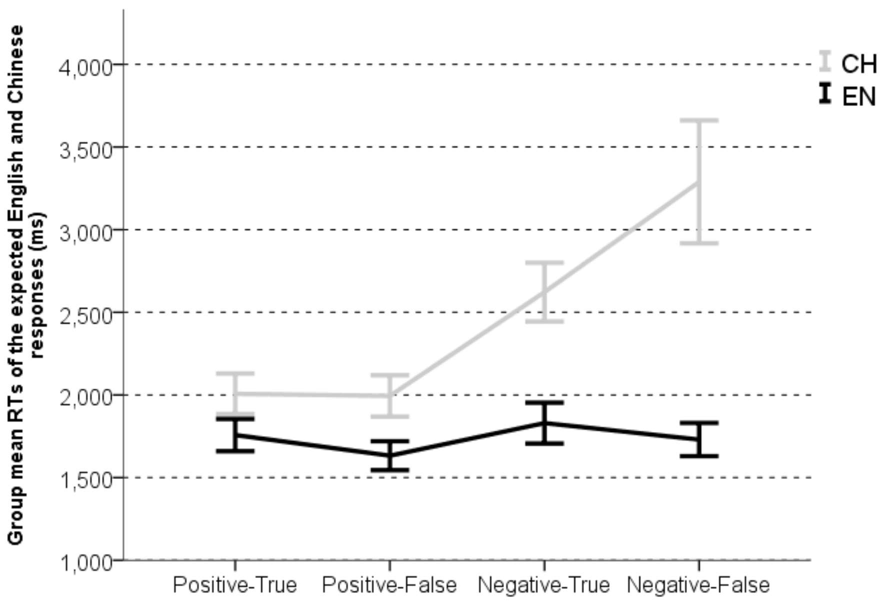

Figure 5. 5 Group mean RTs of English and Chinese speakers in Experiment 2 (Error bars = 95% confidence interval).

Figure 5.5 shows the mean RTs of English and Chinese speakers when they answered negative questions in Expt. 2. To select the optimal model, following the procedure of Cunnings (2012), I first listed all the possible models. Then I used the anova function to compare the models. The model with the lowest AIC (Akaike information criterion) was selected as AIC indicates the amount of information lost by a given model. The variables were coded for treatment. The mixed-effects model used to analyse reaction time data included *Group* (English/Chinese), *Question* (positive/negative) and *Truth* (true/false) as fixed effect factors, *Participant* and *Item* as random effect factors. Interactions between the fixed effects factors were also tested lmer(RT ~ question * truth + truth * group + question * group + question * truth * group + (1|item) + (1|participant)). The results are shown in Table 5.3. The intercept refers to the estimated mean RT of Chinese speakers answering negative questions when they were false. The model returned a simple effect of *Question,* which indicated that the participants spent significantly longer to answer negative (M = 2254, SD = 1072) than positive questions (M = 1848, SD = 616). Importantly, the simple effect was qualified by interaction with *Group*. As shown in Figure 5.5, this result revealed that it took Chinese speakers significantly longer (i.e., they were slowed down more) than English speakers to answer negative compared to positive questions. Specifically, it took Chinese speakers 2867 ms on average (SD = 1221) to answer negative questions and 2001 ms on average (SD = 674) to answer positive questions. For English speakers, the mean RT for answering negative questions was 1781 ms (SD = 613) and that for answering positive questions was 1696 ms (SD = 510). There was also a simple effect of *Group*. It demonstrated that the mean RT of English speakers (M = 1738, SD = 564) was significantly shorter than that of Chinese speakers (M = 2375, SD = 1041) when answering yes–no questions. Also, a significant simple effect of *Truth* and a significant interaction between *Question* and *Truth* were found, indicating that for both English and Chinese speakers the slowdown between reaction times to negative questions and positive questions was longer when the state of affairs was false. Critically, there was a significant interaction among the three independent variables. This interaction indicated that it only took Chinese speakers longer to answer negative questions when the state of affairs was false. In other words, it only took Chinese speakers longer to answer *yes* than *no* to negative questions.

Table 5. 3 Coefficients of a mixed effects model fitted to the RTs of English and Chinese speakers in Experiment 2

Fixed effects	Estimate	SE	t value	*p*
Intercept	3285.24	107.90	30.45	< .001**
Question (positive/negative)	-1284.60	97.87	-13.13	< .001**
Truth (true/false)	-691.57	98.19	-7.04	< .001**
Group (EN/CH)	-1557.24	138.93	-11.21	< .001**
Question × truth	700.30	127.08	5.51	< .001**
Group × truth	791.23	127.63	6.20	< .001**
Group × question	1181.15	127.51	9.26	< .001**
Group × question × truth	-662.41	171.07	-3.87	< .001**
Random effects	Variance		SD	
Participants (intercept)	192819		439.11	
Item (intercept)	6784		82.37	

Note: A single asterisk * indicates p < .05 and double asterisks ** indicate p < .001

5.3.5. Discussion

This experiment was designed on the basis of Expt.1 to further investigate whether English and Chinese speakers process negative questions in different ways. In terms of responses, English speakers were found to use different answers compared to Chinese speakers when they answered negative questions, which confirms the findings in Expt.1. Moreover, in regards to response speed, it took Chinese speakers longer to process negative questions in comparison to English speakers. Variations were also found in the response speed of English and Chinese speakers on the within-group level. The implications of these findings are discussed with reference to previous research and theory.

The crosslinguistic contrasts observed in reaction times suggest that the processing of negation is language-specific when English and Chinese speakers answer negative questions. It took Chinese speakers significantly longer than English speakers to process negative questions compared to positive questions. A large body of empirical evidence suggests that processing a negative sentence is more difficult than processing a positive sentence because the former incurs an additional step (Clark & Chase, 1972; Carpenter & Just, 1975; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al., 2007). In light of this view, the relatively longer slowdown in reaction time in Chinese speakers, compared with English speakers, can be explained as a result of a two-step process, in which a negative statement is typically processed via its positive counterpart. For an illustration of this process, to respond to *Didn't he steal X?* the Chinese speakers would process 'Is it true that [he stole X]' in the first step, and then 'Is it true that [he didn't steal X] in the second step. In contrast, English speakers are more likely to process 'Is it true or not that [he stole X]' in responses to a negative question in one step. If Chinese speakers also processed the negative statement straight away, we would have observed no contrast in the slowdown between English and Chinese speakers.

Reaction times within language groups provide the second piece of evidence for the claim that Chinese speakers have a stronger tendency to use two steps to process negation in negative questions than English speakers do. Only in the Chinese group did it take longer to respond *yes* than *no* to negative questions. One explanation is that in a truth-based answering system like Chinese it is more difficult to respond *yes* than *no* to negative questions because the *yes* response is derived from two negations (Clark & Chase, 1972). For an illustration of the two negations for the Chinese speakers, if the question is *Didn't he steal a chicken?*, then the first negation would be over the positive statement of the question 'Is it true that [he stole a chicken]'-> 'It is false', followed by the second negation over the truth value of the positive statement 'it is false that [it is false]', i.e., *Yes (he didn't steal a chicken)*. Relatively longer *yes* responses in this (negative-false) context can be attributed to the difficulty for Chinese speakers to use two negations to answer *shi (de)* 'yes' to negative questions (see Figure 5.5). For the same reason, it is not surprising that there was no interaction between *Question* and *Truth* for English speakers but there was for Chinese speakers. If English speakers typically used the two-step route to answer negative questions, it would have taken them longer to answer *yes* (i.e., in the negative-true condition) than *no* to negative questions. However, significantly longer response time for *yes* (in the negative-false condition) than *no* to negative questions was only observed in Chinese speakers.

Language-specific answers provide the third piece of evidence that English speakers may take a more direct route compared to Chinese speakers when they process negative questions. Comparing the responses across experiments 1 and 2, in both experiments the answers typical of English speakers followed the polarity-based pattern (*yes, she does/no, she doesn't*) and the answers typical of Chinese speakers followed the truth-based pattern (*no, she does/yes, she doesn't*). All the evidence consistently suggests that English and Chinese speakers are likely to process negative questions differently. Furthermore, given the crosslinguistic evidence suggesting greater complexity in the truth-based system (Akiyama, 1979; Akiyama et al., 1982; Akiyama & Guillory, 1983; Akiyama et al., 1979; Akiyama, 1992; Choi, 1991), it is more difficult for Chinese speakers to answer negative questions than English speakers do. The varied difficulty can be accounted for by an additional processing step in Chinese speakers compared to English speakers.

The underlying mechanism that explains the greater difficulty to process negative questions in the truth-based than the polarity-based system builds on language-specificity in the processing of negation in negative questions. In polarity-based English, processing negation in a negative question is immediate. To illustrate, in response to *Doesn't she like cats?*, when the case is that she likes cats, English speakers attach negation to the polarity of the question, and answer *yes* to the question in a single step, i.e., 'Is it true or not that [she likes cats]) -> 'It is true', i.e., *Yes (she likes cats*). In truth-based Chinese, speakers attach negation to the statement of the question and then reverse the truth value of the statement (*Doesn't she like cats?* -> 'Is it true that [she likes cats]' -> 'Is it true that [she doesn't like cats]'). Chinese speakers thus answer *no* in two steps, first, they process the corresponding positive statement of a negative question 'Is it true that [she likes cats]'-> 'It is true', and then the additional processing operation is a reversal of the truth value of the positive statement 'It is false that [it is true]', i.e., *No (she likes cats)*.

Analogously, when the question is *Doesn't she like cats?* and the case is that she doesn't like cats, English speakers answer *no* in a single step, i.e., 'Is it true or not that [she likes cats]) -> 'It is false', i.e., *No (she doesn't like cats)*. In contrast, Chinese speakers answer *yes* in two steps, first, they process the corresponding positive statement of a negative question 'Is it true that [she likes cats]'-> 'It is false', and second, they reverse the truth value of the positive statement 'It is false that [it is false]', i.e., *Yes (she doesn't like cats)*. Following this mechanism, the *yes* answer to a negative question in Chinese rests on two negations, which incurs an additional processing cost. This two-step mechanism when Chinese speakers process negative questions is in line with Choi (1991), who also attributed greater difficulty in the truth-based vs the polarity-based system to an additional processing operation in the former.

An alternative explanation could be that there is a same number of steps to process *Doesn't she like cats?* in Chinese and English. In this scenario, Chinese speakers would have to keep in mind the negated statement 'Is it true that [she doesn't like cats]' and compute the truth value over that statement, which is arguably more demanding than computing the truth value of the corresponding positive statement. This explanation may work for the observed response speed difference between groups but it could only be a partial account because it falls short in explaining reaction times between the negative-true and the negative-false conditions in the Chinese group. If Chinese speakers processed negative questions in a single step like English speakers, we would not expect variation in reaction times between the negative-true and the negative-false conditions in the Chinese group. Keeping in mind the negative statement may be used to explain crosslinguistic variation but it cannot be the only reason for language-specificity in response speed.

Other possible explanations for the longer response speed in Chinese speakers to answer *yes* than *no* to negative questions relate to the frequency of using negative questions and *yes/no* responses in Chinese. It is possible that Chinese speakers lack familiarity with the negative questions in the critical negative-false condition and/or with the alternatives they had to choose from. A brief diagnostic analyses of corpus data using the PKU-CCL-CORPUS and the British National Corpus was conducted (see chapter 3). From a sample of 50 randomly selected Chinese negative questions, 22 were in the negative-false condition while that frequency for English negative questions was 37 out of 50. Based on these frequencies, Chinese speakers may be less familiar with the negative-false condition compared with English speakers. Another possible reason for longer reaction times in *yes* than *no* to negative questions in Chinese speakers is that they may be more used to giving echo answers (e.g., -*Doesn't she likes cats?- She doesn't.*) (Li, 2008; Holmberg, 2015) rather than short *yes/no* answers to negative questions.

Results of this experiment suggest that language can influence the processing of negation without speaking. Unlike previous Expt.1, in this experiment, participants were not instructed to answer the questions out loud, but to choose an answer provided by pressing a key on the keyboard. The findings suggest that language affects the processing of negation when English and Chinese speakers process negative questions. While Chinese speakers are suggested to prefer using two steps to process negative questions, English speakers typically process negative questions in one step.

Processing false state of affairs may not be more difficult than processing true state of affairs provided sufficient context. Evidence from previous verification tasks showed that it was more difficult to verify a positive sentence when it is false than when it is true (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al. 1983). Likewise, Akiyama et al. (1979) observed that it took English speakers shorter to answer *yes* than *no* to positive and negative questions. Unexpectedly in the current study, it took similar time to answer *yes* and *no* to positive questions within the group of English speakers and the group of Chinese speakers. Also, it took English speakers shorter to answer *no* than *yes* to yes-no questions. The reduced difficulty for processing falsity (speed of *no* responses) in the current study may be due to the relative ease of the task used here. In comparison, the task in Akiyama et al. (1979) was to answer false questions such as *Is a robin a rock?* without any context, which is arguably more difficult. In contrast, participants in the the current study were provided with straightforward statements such as *Mr. Fox stole a roast duck from a farm* with abundant reading time (8 seconds) first. Based on the context, they were intructed to answer *Did Mr. Fox steal a roast chicken from a farm?*. Relevant contextual information can decrease the difficulty of negation processing (Dale and Duran, 2011; Nieuwland and Kuperberg, 2008). It may also help English and Chinese speakers to process falsity more efficiently. Besides the context in the experimental design, English speakers answer *no* more frequently than *yes* in response to yes-no questions according to the corpus analyses (see Chapter 3). This may also help them to answer *no* faster than *yes* to yes-no questions.

Chapter 6. Language-specific processing of negation in a nonverbal context[20]

6.1 Introduction

Empirical evidence supporting the idea that languages influence thinking in a nonverbal context has been reported in various domains including grammatical number (Lucy, 1992; Lucy & Gaskins, 2001, 2003), motion events (Athanasopoulos & Bylund, 2013), time (Casasanto et al., 2004; Fuhrman et al., 2011), grammatical gender (Sera, Berge, and Pintado, 1994), colour (Athanasopoulos, Damjanovic, Krajciova, & Sasaki, 2011) and space (Brown & Levinson, 1993; Levinson, 1996). Unlike a verbal context, there is no overt language production or language processing

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[20] Part of the work contained in this chapter has been submitted as a co-authored article to be considered for publication in *Language, Cognition and Neuroscience* (project website https://osf.io/x4536/?view_only=74fb6c47a11143f7b1f400532a30f9c3).

in a nonverbal context. For example, Lucy (1992; Lucy & Gaskins, 2001, 2003) designed a nonverbal triads-matching task to investigate whether speakers of languages with and without grammatical number focus on different features when they categorize objects. Participants saw a target triad (e.g., a metal nail) and two alternate triads with the same material (a scrap of metal) or the same shape (a wooden pencil) compared to the target respectively. Lucy and colleagues found that while English speakers who have grammatical number in their language preferred to categorize objects by shape while Yucatec speakers whose language lacks grammatical number preferred to categorize objects by material. This finding was taken as evidence for the *linguistic relativity* hypothesis that language influences our cognition. This chapter aims to test the *linguistic relativity* hypothesis in the domain of negation.

English and Chinese speakers may use language-specific routes when they process negation in a nonverbal context. What was found in previous Expt. 1 & 2 suggest that the processing of negation in negative questions in Chinese and English systematically varies. Chinese speakers process negative questions (*Doesn't she like cats?*) by first processing the corresponding positive statement 'she likes cats' and then they process the negative statement 'she doesn't like cats'. In contrast, the performance of English speakers process *Doesn't she like cats?* in one step. *Linguistic relativity* predicts that English and Chinese speakers follow language-entrained routines to process negative questions irrespective of whether the context is verbal or nonverbal. That is, Chinese speakers who habitually process negative questions in two steps would also follow the same route when they process negation in a nonverbal context. Processing negation in two steps is well-documented (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983; Kaup et al, 2006, 2007; Lüdtke et al., 2008). Unlike Chinese speakers, English speakers who habitually process negative questions in one step may also use one step when they process negation in a nonverbal context. Supporting the one-step model, there is growing empirical evidence indicating that negative statements can be processed directly in one step without a detour via the corresponding positive statements (Nieuwland & Kuperberg, 2008; Orenes et al., 2014; Tettamanti et al., 2008; Tian et al., 2010).

The processing of negation and the verification of negation should be teased apart. A verification task is widely used in the research on the processing of negation (Akiyama et al., 1979; Carpenter & Just, 1975; Clark & Chase, 1972; Dale & Duran, 2011; Fischler et al., 1983; Sherman, 1973, 1976; Wason & Jones, 1963). For example, to investigate the processing of negation, Fischler et al. (1983) instructed English speakers to verify whether *A robin is not a bird* is true or not. The problem with this design is that the verification of negation and the processing of negation are mixed together. To focus on the processing instead of the verification of negation, many researchers (Giora et al., 2004; Kaup et al., 2006; Kaup et al. 2007; Orenes et al., 2014; Tettamanti et al., 2008; Tian et al., 2010; Tian et al. 2016) designed experimental paradigms that did not involve sentence verification. For example, in Kaup et al. (2007), English speakers saw a sentence (e.g., *There was no eagle in the sky*) which was followed by a picture (an eagle with folded/outstretched wings). They were instructed to recognize whether the object in the picture was mentioned in the proceeding sentence or not. In order to separate negation processing from negation verification, two nonverbal tasks were designed in this chapter with and without the involvement of verification.

Despite growing evidence for the *linguistic relativity* hypothesis, to the best of the author's knowledge, it has not yet been examined in the domain of negation. The research gap this chapter aims to fill is to show in what ways and to what extent language can influence the processing of negation in a nonverbal context. If Chinese and English speakers do not process negation in the same way, different routes are expected to manifest themselves as a variation in processing speed. If Chinese speakers take two steps to process negation in a nonverbal context while English speakers use one step, slower response speed is expected in the former compared to the latter when they process negative stimuli. This prediction was built on the view that an additional processing step gives rise to the greater difficulty in the processing of negative sentences than positive sentences (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983; Kaup et al, 2006, 2007; Lüdtke et al., 2008). Also, on the within-group level, if Chinese speakers take two steps to process negation in a nonverbal context, it would take them longer to *agree* than *disagree* with negative stimuli. This pattern was not expected from English speakers who were predicted to take one step to process negation. These predictions were made considering the interaction between positive/negative sentences and true/false value that has been consistently reported in previous studies (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983; Lüdtke et al., 2008). According to Clark & Chase (1972), this interaction suggests that to verify a negative sentence when it is true is to perform two negations and thus takes longer. These predictions were also built on the finding from the verbal Expt. 2 that it only took Chinese speakers longer to answer *yes* than *no* to negative questions.

In light of the *linguistic relativity* hypothesis, two alternative hypotheses are proposed regarding the strength with which language mediates the processing of negation in English and Chinese speakers.

a) *Language-independent processing of negation in a nonverbal context.* The first hypothesis is that English and Chinese speakers use the same number of steps when they process negation in a nonverbal context. If this hypothesis holds true, speakers of both languages would show similar patterns. If both language groups use two steps to process negation, then it would take them longer to process negative stimuli compared to positive stimuli. Also, on the within-group level, it is expected to take both groups longer to *agree* than *disagree* with a negative stimulus. This is built on the view that verifying a negative sentence as true is to perform two negations and therefore takes longer compared to verifying a negative sentence as false (Clark & Chase, 1972). If both language groups use one step to process negation, then it would take them a similar amount of time to process negative stimuli compared to positive stimuli. On the within-group level, it would take neither group longer to *agree* than *disagree* with a negative stimulus.

b) *Language-specific processing of negation extending from a verbal to a nonverbal context.* The second hypothesis is that Chinese speakers tend to use an additional step compared to English speakers in a nonverbal context. If this hypothesis holds true, then in comparison to English speakers, one would expect Chinese speakers to be slowed down more when processing negative stimuli compared to positive stimuli. On the within-language level, if English speakers use one step to process negation, it would not take them longer to *agree* than *disagree* with negative stimuli. If Chinese speakers typically use two steps to process negation, it would take them longer *agree* than *disagree* with negative stimuli.

To test the validity of hypotheses a) and b), a nonverbal agree-disagree experiment (Expt. 3) was designed. Expt. 3 tested the response speed of English and Chinese speakers when they process the critical '≠' and control '=' symbols during equation verification e.g., 'triangle-unequal-tringle'.

To separate the processing of negation from the verification of negation in a nonverbal context, Expt. 4 was designed on the basis of Expt. 3. Expt. 4 tested the response speed of English and Chinese speakers when they process shape (in)congruence with the presence of the '≠' symbol (critical condition), the '=' symbol (control condition) and without any symbols (control condition). To illustrate, English and Chinese speakers were instructed to judge whether the two shapes are the same or not in 'triangle-unequal-tringle'/'triangle-equal-tringle'/'triangle-no-symbol-tringle'. Unlike Expt. 3 in which participants were instructed to verify the equations, Expt. 4 tested the way in which participants process the critical '≠' symbol in equations without verification. If English speakers tend to process negation immediately in one step in a nonverbal context, when judging that two shapes are the same, they would be slowed down more with the presence of the '≠' symbol compared to the symbol-free trials. Analogously, when judging that two shapes are different, they would be slowed down less with the presence of the '≠' symbol compared to the symbol-free trials. In contrast, if Chinese speakers tend to process the corresponding positive statement first when they process negation in a nonverbal context, the presence of the '≠' symbol would not interfere with their responses when they judge 'triangle is the same as triangle'. Neither would the presence of the '≠' symbol prime faster responses in Chinese speakers when they judge 'triangle is different from square'. Unlike the critical condition with the '≠' symbol, English and Chinese speakers would not differ in the control conditions i.e., trials with the '=' symbol and the symbol-free trials. The null hypothesis is that English and Chinese speakers process negation in the same way in a nonverbal context. If this is the case, no between-group difference was expected when they process the '≠' symbol during shape congruence judgment.

6.2 Experiment 3. English versus Chinese monolinguals' processing of negation in a nonverbal agree-disagree experiment

6.2.1 Participants

20 randomly selected English participants and 20 randomly selected Chinese participants from Expt. 1 also took part in Expt. 3. They were tested with the nonverbal Expt. 3 first. Immediately after Expt. 3, they were tested with the verbal Expt. 1.

6.2.2 Materials

13 blue-coloured shapes and 2 symbols (i.e., the equal symbol '=' and the unequal symbol '≠') were used to form 24 distinct equations (see example stimuli in Figure 6.1). The lengths of the two symbols '=' and '≠' on the screen are 3.2 cm. The height of each equal symbols '=' was 0.9 cm and that of the unequal symbol '≠' was 2.6 cm. The heights of the shapes raged from 4.4 cm (the trapeziums) to 6.2 cm (the annuluses). The distance between the centres of the two shapes that appeared simultaneously in each trial is 16.5 cm. The resolution ratio of the screen was 1366×768 pixels. The shapes and the symbols appeared centred on the screen. The combinations of shapes and symbols were divided into four conditions based on the polarity of the equation symbol (positive/negative) and the state of affairs (triangle is triangle = true; triangle is square = false) (i.e., positive-true, positive-false, negative-true and negative-false respectively) which are shown in Figure 6.1 with the corresponding correct responses. These four combinations of shapes and symbols were comparable with the four conditions in Experiment 2 (i.e., positive-true, positive-false, negative-true and negative-false respectively).

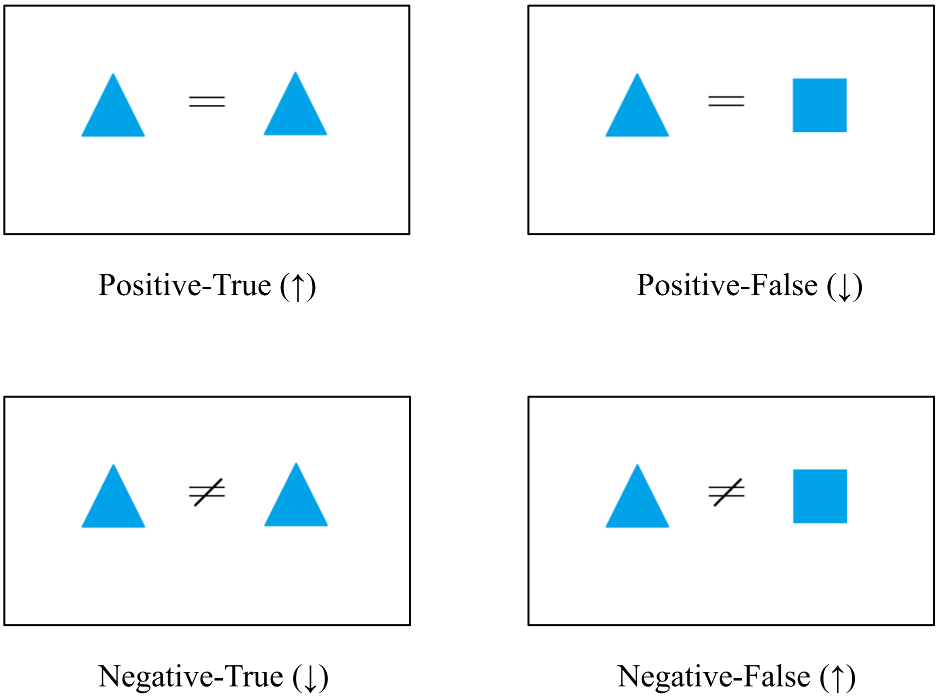


Figure 6. 1 Example stimuli in the nonverbal task, Experiment 3, showing each of the four conditions and the corresponding correct responses in the brackets.

6.2.3 *Procedure*

The participants were tested individually. First, they were provided with a consent form containing the information they need to know about the experiment, i.e., anonymity, confidentiality, data collection etc. Then, they were asked to carefully read the instructions displayed on a computer screen at the beginning of the test. They were informed that they would see “some equation represented by shapes and symbols.” Their task was to “agree or disagree with these equations as quickly and accurately as possible”. Participants were asked to press ‘↑’on the keyboard when they agree with an equation and to press ‘↓’ when they disagree with it. The test started with a brief training session including 4 trials (i.e., 2 same/different shapes × 2 types of symbols) before the experimental session. Participants were informed that if they make a mistake during the trials, they should not stop but continue with the following equation.

During the experimental session, the participants saw two blue shapes and an equation symbol (either the equal symbol ‘=’ or the unequal symbol ‘≠’) on a white background in each trial. When a key ‘↑’or ‘↓’ was pressed by the participant, the computerized task would automatically display a blank screen (1000 ms) before showing the next trial. The task was set up using E-Prime 2.0. The order of the trials was semi-randomized to ensure that the same condition would not appear more than twice consecutively. Each response and reaction time was recorded. Whenever a sustained pause as a result of a participant’s mistake was observed, this was noted down and the data for that trial was eliminated from subsequent analyses (i.e., 1 English (0.2% of total) and 3 Chinese (0.6% of total) data entries).

6.2.4 *Results*

6.2.4.1 *Inclusion criteria for reaction times*

Response accuracy was checked first and then the RTs were analysed. The response accuracy of English participants was 96.04% and that of Chinese participants was 90.83%. Only RTs of correct responses were included in the analyses. To eliminate outliers, 13 English (2.7% of total) and 12 Chinese (2.5% of total) data entries were more than 2.5 standard deviations away from the group mean in each condition and they were replaced by the cut-offs (group mean +/- 2.5 SDs) following Keating and Jegerski (2015) and Norris (2015).

6.2.4.2 Reaction times of English and Chinese speakers in the agree-disagree task

RT results of Experiment 3 are shown in Figure 6.2. A mixed-effects regression model was built with *Language Group* (English/Chinese), *Equation symbol* (equal/unequal) and *Truth* (true/false) as fixed effect factors, *Participant* and *Item* as random effect factors. Interactions between the fixed effects factors were also tested lmer (RT ~ equationsymbol * truth + equationsymbol * group + (1|participant) + (1|item)). The results are shown in Table 6.1.

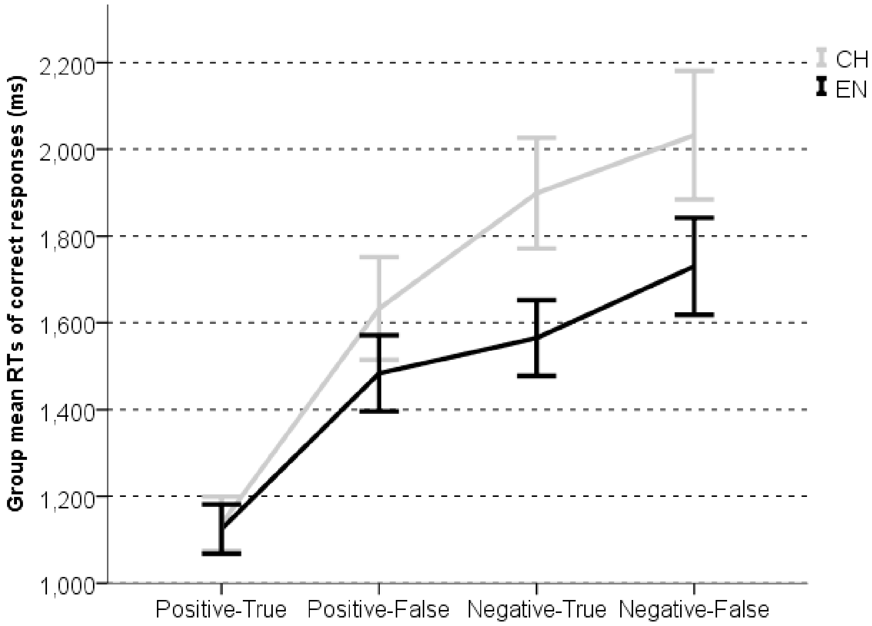


Figure 6. 2 Group mean RTs of correct responses given by English and Chinese speakers in the nonverbal task, Experiment 3 (error bars = 95% confidence interval).

Table 6. 1 Coefficients of a mixed effects model fitted to the RTs of English and Chinese speakers, Experiment 3

Fixed effects	Estimate	SE	t value	*p*
Intercept	1603.20	77.65	20.65	< .001**
Equation symbol(equal/unequal)	432.95	68.95	6.28	< .001**
Truth (true/false)	-430.41	59.76	-7.20	< .001**
Group (EN/CH)	-83.78	96.39	-0.87	.389
Equation symbol × truth	281.58	85.76	3.28	.004*
Equation symbol × group	-226.63	62.59	-3.62	< .001**
Random effects	Variance		SD	
Participants (intercept)	74446		272.85	
Item (intercept)	5175		71.94	

Note: A single asterisk * indicates p < .05 and double asterisks ** indicate p < .001

The intercept refers to the estimated mean RT of Chinese speakers processing equal equations when they were false. The model returned a simple effect of *Equation symbol*, which demonstrated that the mean RTs in the two critical unequal conditions were significantly longer than those in the control equal conditions. Specifically, the mean RT of English speakers verifying negative equations was 1647 ms (SD = 535) and that of Chinese speakers was 1967 ms (SD = 706). The mean RT of English speakers verifying positive equations was 1304 ms (SD = 446) and that of Chinese speakers was 1376 ms (SD = 559). Critically, a significant interaction was found between *Equation symbol* and *Group*, which suggests that the processing of negative equations was relatively more demanding for Chinese speakers than it was for English speakers as predicted, even though both groups found negative equations significantly more difficult than positive equations. There was also a significant simple effect of *Truth* and a significant interaction of *Equation symbol* and *Truth*. These results showed that it took English and Chinese speakers longer to verify a positive equation when the state of affairs was false (e.g., ‘triangle-equal-square’) than when it was true (e.g., ‘triangle-equal-triangle’). Analogously, it also took English and Chinese speakers longer to verify a negative equation when the state of affairs was false (e.g., ‘triangle-unequal-square’) than when it was true (e.g., ‘triangle-unequal-triangle’). These results showed that it took English and Chinese speakers shorter to *agree* than *disagree* with a positive equation. In contrast, it took them longer to *agree* than *disagree* with a negative equation.

6.2.5 Discussion

This experiment set out to investigate whether English and Chinese speakers process negative equations in language-specific ways. Crosslinguistic differences in reaction times suggest that it is indeed the case. Chinese speakers, in comparison to English speakers, were slowed down more by negative equations compared with positive equations. Based on the relatively greater slowdown, the argument here is that Chinese speakers have a stronger tendency than English speakers to take two steps when they process negative equations. For an illustration, when Chinese speakers process the stimulus ‘triangle-unequal-square’, their longer reaction times suggest that they process negative equations less directly, i.e., via the positive equation ‘triangle-equal-square’ in the first step, and subsequently reversing the truth value of the positive equation to process ‘triangle-unequal-square’ in the second step. The explanation is that Chinese speakers habitually use two steps when they process negation in negative questions, and this extends from a verbal to a nonverbal context. Unlike Chinese speakers, English speakers have a stronger tendency to process negative equations in a single step ‘triangle-unequal-square’. This claim builds on empirical evidence suggesting that, in the polarity-based system, a negative statement can be processed either in a single step (Nieuwland & Kuperberg, 2008; Orenes et al., 2014; Tettamanti et al., 2008; Tian et al., 2010, 2016) or in two steps (Clark & Chase, 1972; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al., 2007; Orenes et al., 2014). English speakers’ habitual use of one step when they process negative questions can explain their relatively faster processing of negative equations. In sum, crosslinguistic reaction time differences can be ascribed to varied routines in the processing of negation.

There is an alternative account. It is possible that speakers silently verbalise the unequal symbol when they solve the equation verification task. The '≠' symbol can be verbally expressed as *unequal* and *not equal* in English; however, it can only be expressed as *bu deng yu* 'not equal' in Chinese. Lexical negation (e.g., *unequal*) has been reported to be processed faster than negative particles (e.g., *not equal*) (Sherman, 1973, 1976; Giora et al. 2004; Kaup et al. 2006). If verbal labelling was used in silence to solve the task of equation verification, then it cannot be ruled out that in the nonverbal task participants used "language as a strategy" (Kousta et al., 2008).

One may argue that an alternative way of explaining the results would be that the Chinese vs. English samples could differ with respect to cognitive resources. Given that the Chinese participants were recruited from a vocational college of preschool education while English participants from a university, the socio-demographics of the samples might be different, possibly associated with differences in IQ, verbal skills, memory and cognitive processing in general. Also, it may be the case that the English sample is more likely composed of participants who are familiar with psychological experiments. However, the explanation of the results due to robust differences in cognitive resource is unlikely. If the Chinese group was less task-wise, or if they had overall lower cognitive abilities, they would have shown longer reaction times compared to English speakers across all conditions. However, this was not the case. It is observed that they showed similar mean reaction times compared to English speakers in the control condition (positive equations).

To further explain the nuances in the results for English speakers, it is important to highlight that one-step vs. two-step processing of negation is more likely to be a tendency rather than a strict rule. It took English speakers longer to process negative equations than positive equations, which is interpreted as an instance of within-group variation in two-step vs. one-step negative equation processing respectively. In other words, longer response time in English speakers suggests that they used an additional step when they processed negative equations compared with when they processed positive equations. If English speakers had processed negative equations exclusively in a single step, there would have been no reaction time difference between the processing of positive and negative equations. For the same reason of flexibility in processing, the reaction time difference between the two types of positive and two types of negative equations are asymmetric for English speakers. It took them longer to respond *agree* than *disagree* to a negative equation but it took them shorter to respond *agree* than *disagree* to a positive equation, which is in line with earlier studies (e.g., Clark and Chase, 1972).

Still, Expt. 3 cannot provide answers to the following questions. First, like previous studies that used a verification task to investigate the processing of negation (Akiyama et al., 1979; Carpenter & Just, 1975; Clark & Chase, 1972; Dale & Duran, 2011; Fischler et al., 1983; Sherman, 1973, 1976; Wason & Jones, 1963), Expt. 3 alone cannot separate the verification of negation and the comprehension of negation. English and Chinese speakers may differ in the processing part and/or in the answering part when they verified negative equations. Second, we cannot rule out the possibility that the two alternative ways to express the unequal symbol (i.e., *unequal* and *not equal*) helped English speakers processed negative equations faster. To address the first limitation, Expt. 4 was designed on the basis on Expt. 3.

6.3 Experiment 4. English versus Chinese monolinguals' processing of negation in a nonverbal facilitation experiment

In previous Expt. 3, language-specific patterns were found in English and Chinese speakers when they verified negative equations (e.g., 'triangle-unequal-triangle'). On the basis of this finding, Expt. 4 was designed to further investigate whether English and Chinese speakers process the '≠' symbol put in an equation differently without the involvement of equation verification. In this experiment, English and Chinese still saw positive/negative equations with the '≠'/ '=' symbols. Critically, unlike previous Expt. 3, the task was to judge whether the two shapes put in an equation was the same or not. The '≠'/ '=' symbols put in an equation were expected to serve as an facilitator/inhibitor in the sense that their presence can accelerate/decelerate the response speed of shape congruence judgement. Symbol-free trials (e.g., 'triangle-no-symbol-triangle') were included to serve as a baseline for testing the effect of the '≠'/ '=' symbols on shape congruence judgement. Although the '≠'/ '=' symbols were irrelevant information for the given task (i.e., judging whether the two shapes are the same or not), they were expected to be processed by participants automatically. This prediction was built on previous experimental studies (Bylund & Athanasopoulos, 2017; Casasanto, 2016; Casasanto et al. 2004) in which the length and volume of the stimuli that were irrelevant for the target estimation of duration were found to be processed by participants. Also, the '≠'/ '=' symbols were put between the two shapes so that it was difficult for participant to ignore them.

If the processing of negation in a nonverbal context is language-specific, the effect of the '≠' symbol on shape congruence judgement was predicted to be different for English and Chinese speakers. Specifically, if English speakers tend to process negation immediately in one step in the nonverbal context, the presence of the '≠' symbol would slow them down more compared to the symbol-free trials when they judge that two shapes are the same. To illustrate, it would take English speakers longer when they judge the two shapes in 'triangle-unequal-triangle' are the same compared to when they see 'triangle-no-symbol-triangle'. Analogously, the presence of the '≠' symbol would prime their faster responses compared to the symbol-free trials when they judge that the two shapes are different. To illustrate, it would take English speakers shorter when they judge the two shapes in 'triangle-unequal-square' are different compared to when they see 'triangle-no-symbol-square'. In contrast, Chinese speakers were not expected to process negation in a nonverbal context in one step. Rather, they were expected to process the corresponding positive equation in the first step when they see a negative equation. If this prediction holds true, the presence of the '≠' symbol would not decelerate the response speed of Chinese speakers when they judge that the two shapes are the same in 'triangle-unequal-triangle' compared to 'triangle-no-symbol-triangle'. Neither would the presence of the '≠' symbol accelerate their responses speed when they judge that the two shapes are different in 'triangle-unequal-square' compared to 'triangle-no-symbol-square'. Alternatively, if English and Chinese speakers process negative equations in the same way, the effect of the '≠' symbol on shape congruence judgement would be the same for the two groups. For the control positive equations and in the control symbol-free condition, English and Chinese speakers were expected to show the same pattern.

6.3.1 Participants

20 English (18 females) and 20 Chinese (20 females) monolingual speakers took part in this experiment. The English participants were recruited from a university in the UK (mean age 20.30, range 5 years) and the Chinese participants were recruited from a vocational college of preschool education in China (mean age 21.00, range 3 years). All participants were right-handed and reported no fluency in any language other than their L1.

6.3.2 Materials

The materials for Experiment 4 were similar to that for Experiment 3. 8 blue-coloured shapes randomly selected from the 13 shapes used for Experiment 3 and two symbols (i.e., the equal symbol '=' and the unequal symbol '≠') were used to form 24 distinct equations and 12 pairs of shapes without symbols (stimuli). The combinations of shapes and symbols constituted six types of conditions (i.e., same-no-symbol, different-no-symbol, same-equal, different-equal, same-unequal and different-unequal). They are shown in Fig. 6.3 with the corresponding correct responses.

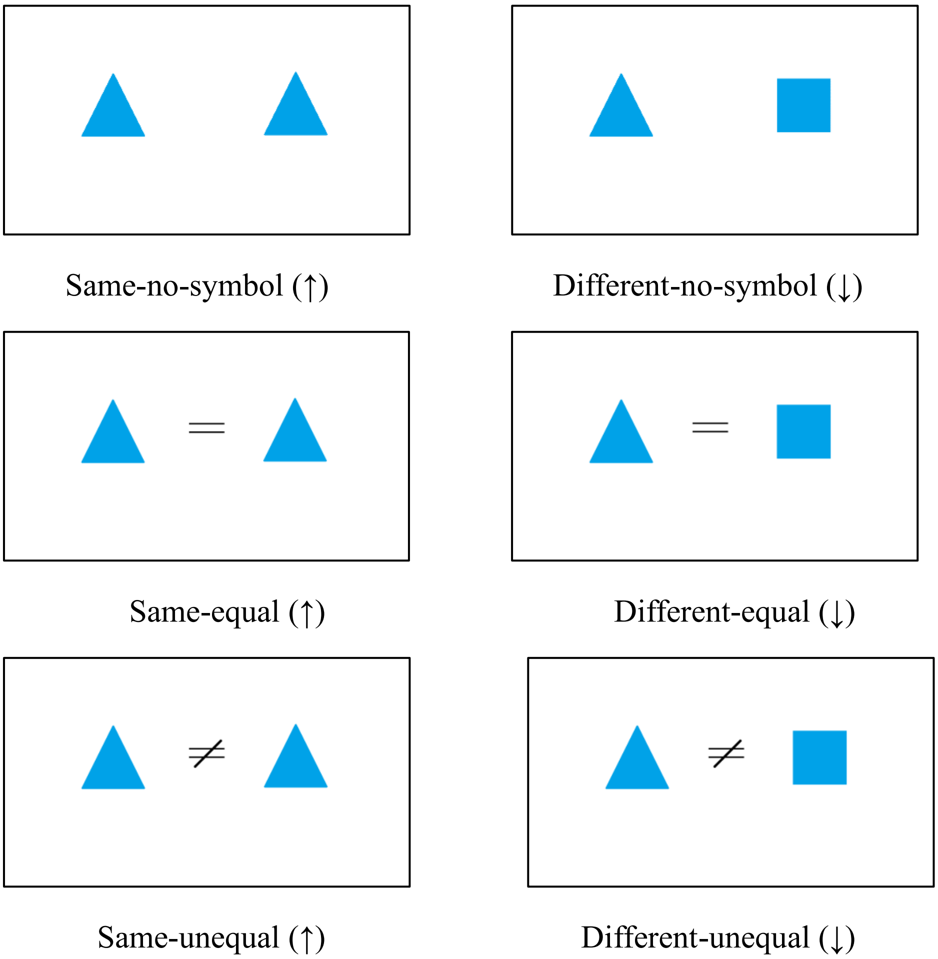


Figure 6. 3 Stimuli for nonverbal Experiment 4 in each condition with correct responses in the brackets.

6.3.3 Procedure

Participants were tested individually. They were asked to read the instructions carefully on a computer screen at the beginning of the test. They were informed that they would see two blue-coloured shapes on a white background in each trial. Their task was to judge whether the two shapes "are the same or not the same." Participants were asked to press '↑' on the keyboard when the two shapes were the same, and to press ‘↓’ when they were not the same, and to “react accurately and as quickly as possible”. The test started with a training session including six trials (i.e., same-no-symbol, different-no-symbol, same-equal, different-equal, same-unequal and different-unequal) before the experimental session with feedback on the correctness on their responses to ensure that they understand the requirement and the procedures of the task. They were informed that if they make a mistake during the trials, they should not stop but continue with the following step. The requirement of the task (i.e., to judge whether the two shapes are the same or not the same) was reiterated orally if they asked about the symbols ‘=’ and ‘≠’.

During the training and the experimental sessions, participants saw two blue shapes with (either the equal symbol ‘=’ or the unequal symbol ‘≠’) or without a symbol displayed simultaneously on a white background in each trial. Once a key ‘↑’or ‘↓’ was pressed by a participant, the computerized task would automatically present a blank screen (1000 ms, no fixation cross) before displaying the next trial. The computerized task was set up using E-Prime 2.0. The order of the trials was semi-randomized to ensure that the same condition would not appear more than twice consecutively. Participants’ responses and RTs were collected. Whenever the researcher observed any sustained pause because a participant made a mistake, this would be noted down and data for the trial during which the pause happened would be eliminated from subsequent analyses (i.e., 2 English (0.3% of total) data entries were eliminated from analysis).

6.3.4 Results

6.3.4.1 Inclusion criteria for reaction times

Response accuracy was checked first and then the RTs were analysed. The response accuracy of English participants was 97. 08% and that of Chinese participants was 97.64%. Only RTs of correct responses were included in the analyses. 16 English (2.22% of total correct responses) and 12 Chinese (1.67% of total correct responses) RTs were more than 2.5 standard deviations from the mean of the group in each condition and they were replaced by the cutoffs.

6.3.4.2 RTs of English and Chines speakers in the facilitation task

Results of Expt. 4 are shown in Fig 6.4. A mixed-effects regression model was built with *Language Group* (English/Chinese), *Equation symbol* (no-symbol/equal/unequal) and *Sameness* (same/different) as fixed effect factors, *Participant* and *Item* as random effect factors. Interactions between the fixed effect factors were also tested lmer (RT ~ equationsymbol * sameness + sameness * group + (1|participant) + (1|item)). The results are shown in Table 6.2.

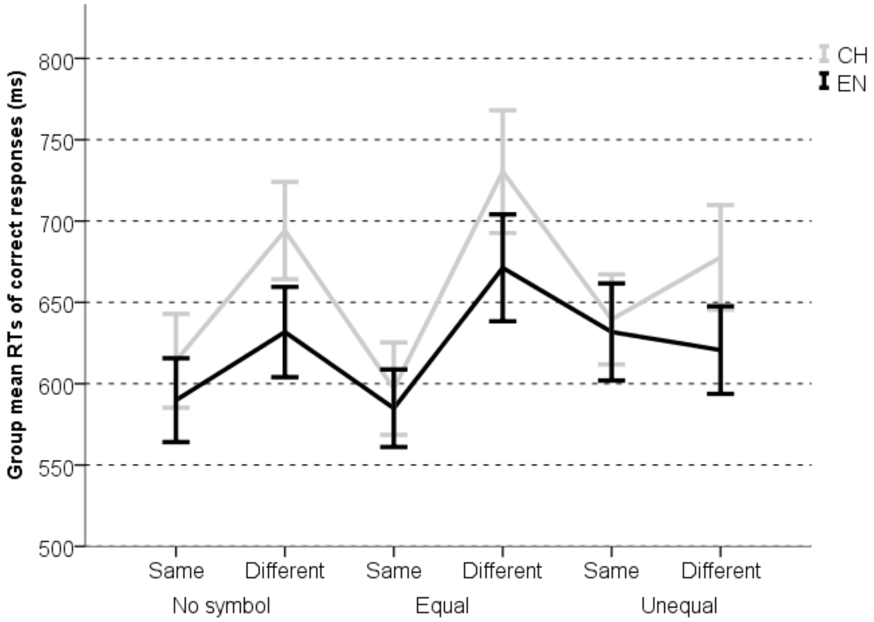


Figure 6. 4 Group mean RTs of correct responses given by English and Chinese speakers in Experiment 4 (Error bars indicate the 95% confidence interval of a mean).

Table 6. 2 Coefficients of a mixed effects model fitted to the RTs of English and Chinese speakers in the nonverbal Experiment 4

Fixed effects	Estimate	SE	t value	*p*
Intercept	729.27	26.07	27.97	< .001**
Equation symbol (no-symbol)	-37.07	11.48	-3.23	.001*

Equation symbol (unequal)	-51.59	11.48	-4.49	< .001**
Sameness (same/different)	-130.34	13.29	-9.81	< .001**
Group (EN/CH)	-59.62	33.71	-1.77	.084
Equation symbol (no-symbol) × sameness	48.12	16.24	2.96	.003*
Equation symbol (unequal) × sameness	95.61	16.31	5.86	< .001**
Sameness × group	42.82	13.28	3.23	.001*
Random effects	Variance	SD		
Participants (intercept)	10484	102.39		
Item (intercept)	407	20.16		

Note: A single asterisk * indicates p < .05 and double asterisks ** indicate p < .001

The intercept refers to the estimated mean RT of Chinese speakers processing two different shapes with the equal symbol. The model returned a simple effect of *Equation symbol*, which demonstrated that the presence of an equation symbol slowed down English and Chinese speakers compared to when there was no equation symbol. Specifically, the mean RT of English and Chinese participants when there was no symbol was 632 ms (SD = 159). The mean RT of English and Chinese participants in the same-equal and the different-equal conditions was 646 ms (SD = 179), and that in the same-unequal and the different-unequal conditions was 642 ms (SD = 160). There was also a simple effect of *Sameness*, indicating that it took English and Chinese speakers longer to process two different shapes (e.g., ‘triangle is different from square’) than two same shapes (e.g., ‘triangle is the same as triangle’). Specifically, it took English and Chinese participants 609 ms on average (SD = 150) to judge that two shapes are the same and 671 ms on average (SD = 175) to judge that two shapes are different. A significant interaction was found between *Sameness* and *Group*, which suggested that the processing of different shapes was relatively more demanding for Chinese speakers than it was for English speakers, even though both groups found different shapes more difficult than the same shapes. The mean RT of English speakers judging two different shapes was 641 ms (SD = 161) and that of

Chinese speakers was 701 ms (SD = 183). The mean RT of English speakers judging two same shapes was 602 ms (SD = 145) and that of Chinese speakers was 617 ms (SD = 156). There was no significant effect of *Group*, suggesting that the mean RT of Chinese speakers was similar to that of English speakers.

6.3.4.3 Exploratory analyses

Although the model did not describe an interaction among the three independent variables, Fig 6.4 showed that the longer slowdowns in Chinese speakers than English speakers when processing two different shapes compared to two same shapes may be accounted for by the different patterns in the unequal conditions. As exploratory, a mixed-effects regression model was built with *Sameness* and *Group* as fixed effect factors, *Participant* and *Item* as random effect factors and. The model lmer (RT ~ sameness * group + (1|participant) + (1|item)) confirmed that the patterns of English and Chinese speakers were significantly different (sameness * group: Estimate = 45.86, *SE* = 22.01, *t* value = 2.08, $p = .038$) in the unequal conditions. The results might be suggestive that, with the presence of the '≠' symbol, it took English speakers shorter to judge that two shapes are different compared to judging that two shapes are the same; however, it took Chinese speakers longer to judge that two shapes are different compared to judging two that shapes are the same. Importantly, these tentative results need further replication. The same model was also used to compare the patterns of English and Chinese speakers in the control conditions. In the symbol-free condition, English speakers did not significantly differ from Chinese speakers (sameness * group: Estimate = 37.22, *SE* = 20.75, *t* value = 1.79, $p = .074$). Also, with the presence of the '=' symbol, the patterns of the two groups were not significantly different (sameness * group: Estimate = 47.14, *SE* = 25.42, *t* value = 1.86, $p = .064$).

As shown in table 6.4, there was a significant interaction between *Equation symbol* and *Sameness*. To further analyse this interaction, a mixed-effects regression model was built with *Equation symbol* as the fixed effect factor and *Participant* and

Item as random effect factors. The model lmer (RT ~ equationsymbol + (1|participant) + (1|item)) confirmed that, compared to the symbol-free trials, the presence of the '≠' symbol significantly slowed down the judgement of two same shapes (Estimate = 33.12, *SE* = 10.35, *t* value = 3.20, *p* = .001) but did not significantly accelerate the judgement of two different shapes (Estimate = -14.21, *SE* = 10.77, *t* value = -1.32, *p* = .188). The same model also confirmed that, compared to the symbol-free trials, the presence of the '=' symbol significantly slowed down the judgement of two different shapes (Estimate = -37.42, *SE* = 11.97, *t* value = -3.13, *p* = .002) but did not significantly accelerate the judgement of two same shapes (Estimate = 9.94, *SE* = 9.33, *t* value = 1.07, *p* = .287). The RT pattern shared by English and Chinese speakers indicated that the incongruence of *Sameness* and *Equation symbol* (e.g., 'triangle-unequal-triangle'/ 'triangle-equal-square') interfered with the formulation of responses for both monolingual groups. In contrast, the congruence of *Sameness* and *Equation symbol* ('triangle-equal-triangle'/ 'triangle-unequal-square') did not prime faster responses for either language group.

6.3.5 Discussion

6.3.5.1 Language-specific patterns found in shape congruence judgement

The language-specific effect of the '≠' symbol on shape congruence judgement found in this experiment suggests that English speakers are more likely to process negation in one step compared to Chinese speakers. The most important finding of Expt. 4 was that the effect of the '≠' symbol was stronger for English speakers compared to that for Chinese speakers. Specifically, with the presence of the '≠' symbol, it took English speakers longer to judge that two shapes are the same ('triangle-unequal-triangle') compared to judging that two shapes are different ('triangle-unequal-square'). In contrast, it took Chinese speakers shorter to process 'triangle-unequal-triangle' compared to 'triangle-unequal-square'. To explain the pattern of English speakers, the presence of the '≠' in an equation significantly decelerated their response speed when they judged that two shapes are the same. In other words, it took English speakers longer when they judged the two shapes in 'triangle-unequal-triangle' are the same compared to when they saw 'triangle-no-symbol-triangle'. The interference from the '≠' symbol on shape congruence judgement suggests that English speakers processed the '≠' symbol put in an equation in one step. This one-step route is in line with Nieuwland and Kuperberg, (2008), Orenes et al. (2014), Tettamanti et al. (2008), and Tian et al. (2010, 2016) who argued that negation can be processed in one step. For Chinese speakers, if they also tend to process the '≠' symbol in an equation in one step, they would have processed 'triangle-unequal-triangle' more slowly compared to 'triangle-unequal-square' like English speakers. However, this was not the finding here. Instead, Chinese speakers were not interfered by the '≠' symbol so much that it still took them shorter to process 'triangle-unequal-triangle' compared to 'triangle-unequal-square'. The explanation is that Chinese speakers were less likely to process the '≠' symbol in an equation in one step compared to English speakers. Unlike English speakers, Chinese speakers first process the positive statement of negation and then process the negative statement. This argument is built on the view that the processing of a negative sentence incurs an additional step via its positive counterpart (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983; Kaup et al, 2006, 2007; Lüdtke et al., 2008). To illustrate the two-step route in Chinese speakers, when processing a negative equation such as 'triangle-unequal-triangle', Chinese speakers tend to first process its positive counterpart 'triangle-equal-triangle' before they process 'triangle-unequal-triangle'.

One may argue that the longer response speed of English speakers in 'triangle-unequal-triangle' compared to 'triangle-no-symbol-triangle' is because there is more information in the former. Then the interaction between *Equation symbol* and *Sameness* does not suggest that English speakers processed the '≠' symbol in one step which interfered with their judgment of two same shapes. Challenging this explanation, we found that it took English speakers similar amount of time to process ‘triangle-unequal-square’ compared to ‘triangle-no-symbol-square’ even though the former has more information. One may further argue that the presence of the ‘≠’ symbol can prime faster responses for judging the different shapes in ‘triangle-unequal-square’, which compensates the longer slowdowns caused by processing additional information in ‘triangle-unequal-square’ compared to ‘triangle-no-symbol-square’. However, if the ‘≠’ symbol can prime faster responses in ‘triangle-unequal-square’ compared to ‘triangle-no-symbol-square’, it still suggests that English speakers processed the ‘≠’ symbol in an equation during shape congruence judgement in one step. In sum, it is unlikely to explain the interaction between *Equation symbol* and *sameness* by varied cognitive load of information alone.

6.3.5.2 Explanations for the language-specific patterns

One explanation for the language-specific results is that habitual processing of negation extending form verbal to nonverbal contexts. In previous verbal Expt. 2, Chinese speakers were found to answer *yes* slower compared to *no* to negative questions. Also, it took Chinese speakers longer to answer negative questions compared to positive questions than English speakers. These findings were interpreted as evidence that when processing negative questions such as *Doesn't she like cats?*, Chinese speakers first process the corresponding positive statement ‘she likes cats’ before they process the target negative statement ‘she does not likes cats’. Analogously in a nonverbal context, the initial processing of positive statements can be transferred here when Chinese speakers process the ‘≠’ symbol in an equation during shape congruence judgment. That is, when they process ‘triangle-unequal-triangle’, they first process ‘triangle-equal-triangle’. As for English speakers, they were found to process negation in negative questions in one step. The one-step route is also transferred here as English speakers processed ‘triangle-unequal-triangle’ immediately. Many empirical studies (Athanasopoulos & Bylund, 2013;

Athanasopoulos et al., 2011; Casasanto et al., 2004; Fuhrman et al., 2011; Levinson, 1996; Lucy, 1992; Lucy & Gaskins, 2001, 2003; Sera et al., 1994) revealed that language-entrained routines are used irrespective of whether the context is verbal or nonverbal. Here, it is also possible that processing negation via its positive counterpart is routinised in Chinese speakers and thus extends from a verbal context to a nonverbal context. Following their processing routine, Chinese speakers used two steps to process negative equations during shape congruence judgment.

The varied processing of the '≠' symbol in an equation during shape congruence judgment between English and Chinese speakers gives new empirical evidence to the *linguistic relativity* hypothesis (Whorf, 1956). Evidence for relativistic effects is growing fast in domains such as grammatical number (Lucy, 1992; Lucy & Gaskins, 2001, 2003), motion events (Athanasopoulos & Bylund, 2013), time (Casasanto et al., 2004; Fuhrman et al., 2011), grammatical gender (Sera, Berge, and Pintado, 1994), colour (Davidoff et al., 1999) and space (Brown & Levinson, 1993; Levinson, 1996) and quantity (Gordon, 2004). For example, English speakers who distinguish countable and mass nouns were more likely to categorize stable objects (e.g., nails) by shape than Yucatec speakers whose language lacks the grammatical number (Lucy, 1992; Lucy & Gaskins, 2001, 2003). However, to the best of the author's knowledge, relativistic effects have never been attested in the domain of negation. This experiment shows that, the habitual processing of negation diverges in Chinese speakers (two processing steps) and in English speakers (a single step) when they processed the '≠' symbol in an equation during shape congruence judgment. This finding is in line with the idea that "cognition varies in accordance with people's language" (Everett, 2013, p.1), and thus contributes to the existing evidence supporting the relativity hypothesis. Notably, besides the linguistic relativity hypothesis, Slobin's (2003) view that language influences thinking for speaking can also apply here. According to Slobin (2003), thinking for speaking includes "a range of mental processes (understanding, imaging, remembering, etc.)." (p. 160). The discussion rests on the linguistic relativity hypothesis because thinking for speaking is primarily concerned with the impact of linguistic categories on cognitive processes that directly relate to the conversion of thought to speech, while linguistic relativity is a broader hypothesis that also encompasses more automatic (less conscious) nonverbal processes.

Another alternative explanation for the varied processing of negative equations during shape congruence judgment in English and Chinese speakers is associated with language-specific verbal labelling. As mentioned in previous Expt. 3, while the '≠' symbol can be verbally expressed in English by the use of the lexical negation *unequal* and the negative particle *not equal,* there is no direct one-to-one translation equivalent to *unequal* in Chinese. To express *unequal*, Chinese speakers need to use the negative particle *bu deng yu* 'not equal'. Given that lexical negation (e.g., *unequal*) is processed faster compared with a negative particle (e.g., *not equal*) (Giora et al., 2004; Kaup et al., 2006; Sherman, 1973, 1976), the more efficient processing of the '≠' symbol during shape congruence judgement in English speakers may arise because they silently verbalized the lexical negation *unequal* while Chinese speakers silently verbalized *bu deng yu* 'not equal'.

6.3.5.3 Processing routes are tendencies

The one-step vs. two-step routes are tendencies rather than strict rules. One piece of evidence for this argument is that the judgement of two same shapes in 'triangle-unequal-triangle' was interfered by the presence of the '≠' symbol in Chinese speakers, even though the interface of the '≠' symbol was weaker in Chinese speakers compared to that in English speakers. Specifically, it took Chinese speakers longer to judge that the two shapes are the same when they saw 'triangle-unequal-triangle' compared to when they saw 'triangle-no-symbol-triangle'. This finding suggests that Chinese speakers can also process the '≠' symbol in an equation in one step, which interferes with their formulation of the response (i.e., triangle is same as triangle).

Considering the two-step route argued by many researchers (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983; Kaup et al, 2006, 2007; Lüdtke et al., 2008), if Chinese speakers had processed the '≠' symbol in an equation ('triangle-unequal-triangle') exclusively in two steps via the corresponding positive counterpart ('triangle-equal-triangle'), they would not have been slowed down more by 'triangle-unequal-triangle' compared to 'triangle-no-symbol-triangle'. Another piece of evidence is that, despite a comparatively greater tendency to process negation in one step, English speakers still find the processing of different shapes more difficult than the processing of the same shapes. One explanation is that English speakers did not use one step exclusively to process negation. If English speakers had processed different shapes exclusively in one step, there should have been no extra difficulty in the processing of negative statements compared to the processing of positive statements as reported by Nieuwland and Kuperberg (2008) and Tettamanti et al. (2008). Another possible explanation is that English speakers processed 'triangle is different from square' exclusively in one step, and this one step for processing negation is more difficult compared to the one step for processing the positive statement 'triangle is the same as triangle'. This explanation rests on the idea that it is more difficult to process a positive sentence when it is false than when it is true even though both are carried out in one step according to Dale and Duran (2011).

6.3.5.4 limitations

There are many questions left. First, this experiment does not provide conclusive evidence for the *linguistic relativity* hypothesis. English and Chinese speakers are likely to use different routes to process the '≠' symbol during shape congruence judgement. Although this can suggest language-specific routines extend from a verbal to a nonverbal context, it is also possible that English and Chinese speakers may have silently verbalized the lexical negation *unequal* and *bu deng yu* 'not equal' respectively. To rule out the silent verbalization of language-specific verbal expressions, further studies would benefit from employing nonverbal negation-denoting stimuli with direct one-to-one translation equivalents in English and Chinese (e.g., *wrong/cuo* 'wrong'). Alternatively, future designs may be suitably extended by adding a concurrent language interference task (e.g., repeating simple digits) while English and Chinese speakers judge shape congruence with and without the '='/'≠' symbol. Second, it remains to be investigated whether English speakers process two different shapes (triangle is different from square) exclusively in one step or not. Future studies will benefit from testing the eye-movements of English speakers when they process 'triangle is different from square' to check whether there is extended gaze at 'triangle is the same as square'.

Chapter 7. Conceptual changes in bilinguals

7.1. Introduction

Bilinguals have often been found to differ from L1 speakers in their language use. Previous empirical evidence indicated that bilinguals can resemble native speakers of their L1 when they use their target L2 (Alonso, 2016; Bassetti, Clarke, & Trenkic, 2018; Hohenstein et al., 2006; Pavlenko & Jarvis, 2002; Vanek & Selinker, 2017; von Stutterheim, 2003). For example, Pavlenko and Jarvis (2002) reported that Russian-English bilinguals preferred to describe emotions as possessive in English (e.g., *She had some personal emotions*), which is typical of Russian speakers but not typical of English speakers. Nonetheless, bilinguals can diverge from native speakers of their L1 while resembling native speakers of their L2 when they use their mother tongue (Akiyama, 1979; Bylund & Jarvis, 2011; Choi, 2014; Hohenstein et al., 2006; Pavlenko & Jarvis, 2002; Pavlenko & Malt, 2011; von Stutterheim, 2003). For example, Akiyama (1979) found that Japanese-English bilingual children typically answered *iie* ‘no’ when they responded to *Can’t you eat a block?* in Japanese whereas Japanese children typically answered *hai* ‘yes’. These digressions from target patterns in bilinguals have been accounted for by the interactions between their two language systems. These interactions are known as *crosslinguistic influence* (Cook, 2016; Odlin, 1989). Crosslinguistic influence between bilinguals’ L1 and L2 is well-documented in many domains such as motion events (Bylund & Jarvis, 2011; Hohenstein et al., 2006; von Stutterheim, 2003; Vanek & Selinker, 2017). However, little is known in the way Chinese learners of English answer negative questions in Chinese and English. The present study aims to fill this research gap.

Some scholars argue that differences between bilinguals’ linguistic patterns and those of monolingual speakers could indicate changes at the conceptual level, which is known as *conceptual transfer* (Jarvis, 2011; Odlin, 2005). By definition, crosslinguistic influence and conceptual transfer diverge on an important point, which is the extent to which L2 acquisition can change thinking. Crosslinguistic influence only concerns bilinguals’ thinking for overt language use. Under this view, we can predict that Chinese-English bilinguals may differ from English and even Chinese monolingual speakers when they answer negative questions. In contrast, conceptual transfer suggests that acquisition of L2-specific linguistic patterns can change bilinguals’ thinking in general (Odlin, 2005). As a result, differences between bilinguals and L1 speakers found in a verbal context can persist in a comparable nonverbal context. Empirical evidence supporting this idea from studies using a nonverbal context is growing fast (Athanasopoulos, 2009; Athanasopoulos & Kasai , 2008; Athanasopoulous et al., 2011; Brown & Gullberg, 2008; Athanasopoulos et al., 2015; Bylund & Athanasopoulos, 2017; Cook et al., 2006; Kersten et al., 2010; Park & Ziegler, 2014; Vanek & Selinker, 2017). For example, Park and Ziegler (2014) designed a nonverbal triads-matching task on the basis of a crosslinguistic difference between English and Korean in describing ‘put on’ and ‘put in’ events (e.g., *put gloves on* versus *put a bookmark in a book*). While English speakers used *put on*/*put* *in* according to containment, Korean speakers relied on tight vs. loose fitting, e.g., both *put gloves on* and *put a bookmark in a book* are considered tight-fitting in Korean. The researchers found that Korean-English bilinguals differed from Korean speakers and English speakers when the three groups categorized pictures of ‘put on’ and ‘put in’ events. Then regarding current exploration of negation, if Chinese-English bilinguals differ from English and Chinese monolingual speakers when they answer negative questions, conceptual transfer predicts that bilinguals may differ from L1 speakers when they process negation in a comparable nonverbal context. Notably, in some cases (Ameel et al., 2005; Bylund & Jarvis, 2011; von Stutterheim, 2003), conceptual transfer can be manifested in a verbal context. For example, von Stutterheim (2003) investigated the processing of motion events in German-English bilinguals by testing how long it took them to start describing a motion event (e.g., two people walking along the road towards a house). The result was that German learners significantly differed from German native speakers, which was interpreted as evidence for conceptual changes in the bilinguals.

With the aim to explore the cognitive consequences of using two seemingly competing answering systems for Chinese-English bilinguals, in this chapter, empirical studies suggesting crosslinguistic influence in the processing of negative questions as well as in other comparable domains will be reviewed first. Then this chapter will proceed to discuss conceptual changes observed in grammatical number (Athanasopoulos & Kasai , 2008; Cook et al., 2006), time (Bassetti et al., 2018; Bylund & Athanasopoulos, 2017), motion events (Athanasopoulos et al., 2015; Brown & Gullberg, 2008; Kersten et al., 2010; Vanek & Selinker, 2017), colour (Athanasopoulos, 2009; Athanasopoulous et al., 2011) and space (Park & Ziegler, 2014). The discussion of conceptual changes in this chapter is built on Athanasopoulos (2015) and Pavlenko (2011), according to whom the possible cognitive consequences of L2 acquisition include (1) *coexistence of L1 and L2 concepts*, (2) *transfer of L1 concepts*, (3) *internalization of L2 concepts*, (4) *convergence of L1 and L2 concepts*, (5) *restructuring of L1 concepts*, (6) *transfer of L2 concepts*, and (7) *attrition of L1 concepts*. Among the seven outcomes of conceptual transfer, (3) and (7) are unlikely to apply to the Chinese-English bilinguals in this study with the focus here being the processing of negation. The internalization of L2 concepts is often associated with the acquisition of novel conceptual categories (e.g., borrowing words) (Pavlenko, 2011, p. 247). Apparently, this is not the case in this study since negation is not a new conceptual category to Chinese learners. As for the attrition of L1 concepts, it often occurs when bilinguals have been living in L2-speaking countries for decades (Pavlenko, 2011). However, the Chinese-English bilinguals in this study have been living in the UK for less than a year. The key notions for this study are listed here with their definitions adapted from Athanasopoulos (2015) and Pavlenko (2011):

a) *Coexistence of L1 and L2 concepts.* Bilinguals can develop independent L1-specific and L2-specific conceptual representations for the same conceptual category. For example, Kersten et al. (2010) showed that Spanish-English bilinguals, when tested in English context, attended to manner information quickly like English speakers; however, when tested in Spanish context, they attended to manner information slowly like Spanish speakers. If this outcome of conceptual transfer holds true for Chinese-English bilinguals when they process negation, one would expect them to use one step like English speakers in English context while bilinguals would use two steps like Chinese speakers in Chinese context.

b) *Transfer of L1 concepts.* Bilinguals rely on L1-specific conceptual representations for a conceptual category. For example, Vanek and Selinker (2017) found that Chinese-English bilinguals tended to view resultative events (e.g., *a man hanging a hat on a hook*) as complete rather than on-going in their description and categorization, resembling

Chinese speakers but diverging from English speakers. If this outcome of conceptual transfer holds true, Chinese-English bilinguals would use two steps to process negation resembling Chinese speakers regardless of the language context.

c) *Convergence of L1 and L2 concepts.* Bilinguals develop L1-L2 converged conceptual representations for a conceptual category. Ameel et al. (2005) gave support to this outcome of conceptual convergence. The researchers discovered that the gap between Dutch-French bilinguals' naming pattern of common objects (e.g., 'bottle') in L1 Dutch and that in L2 French was very small, and it was less prominent in comparison to the differences between the naming patterns of Dutch and French speakers. If this is the cognitive consequence of using two answering systems for Chinese-English bilinguals, they are expected to take a unique route to process negation, neither in one step nor in two steps, in both Chinese and English context.

d) *Restructuring of L1 concepts.* Bilinguals' L1-specific conceptual representations are changing towards the L2-specific conceptual representations. One piece of empirical evidence comes from Athanasopoulous et al. (2011) who found that Japanese-English bilinguals became less sensitive to the distinction between light-blue shade in the category *mizuiro* and dark-blue shade in the category *ao,* shifting towards English-like performance. This outcome of conceptual transfer predicts that Chinese-English bilinguals would shift from taking two steps to process negation towards one step typical of English speakers in both English and Chinese context.

e) *Transfer of L2 concepts.* Bilinguals rely on L2-specific conceptual representations, which replaced their L1-specific conceptual representations for a conceptual category. For example, Brown and

Gullberg (2008) found that Japanese-English bilinguals did not gesture manner during their description of motion events. This pattern resembled English speakers while it differed from Japanese speakers. If this outcome of conceptual transfer holds true for Chinese-English bilinguals when they process negation, between-group contrasts are only expected from the comparison of bilinguals and Chinese speakers but not from the comparison of bilinguals and English speakers.

Alongside the discussion of conceptual transfer, this chapter will also examine empirical evidence indicating the correlation between bilinguals' conceptual transfer and common predictors including L2 proficiency (e.g., Athanasopoulos & Kasai, 2008), age of L2 acquisition (e.g., Pavlenko & Malt, 2011), length of stay in L2-speaking countries (e.g., Cook et al., 2006), frequency of L2 use (e.g., Athanasopoulos et al., 2011) and the language of instruction (e.g., Bylund & Athanasopoulos, 2017).

7.2. Crosslinguistic influence in bilinguals

7.2.1. Crosslinguistic influence in the processing of negation

Akiyama (1979) investigated the way in which Japanese-English children answer negative questions. Similarly to Chinese speakers, Japanese speakers typically use the truth-based system (e.g., *-Doesn't she like cats? -No, she does/Yes, she doesn't*) when they answer negative questions (Akiyama, 1979, 1992; Holmberg, 2015). In contrast, English speakers typically use the polarity-based system (e.g., -*Yes, she does/No, she doesn't*) when they answer negative questions. Akiyama (1979) asked Japanese-English children (3-6 years old) and Japanese and English monolingual children of the same age to answer negative questions (e.g., *Can't you eat a block?*). Results first confirmed the crosslinguistic contrast as Japanese and English children showed language-specific responses to negative questions as predicted. Critically, bilingual children's responses to Japanese negative questions significantly differed from those from Japanese children (see examples 66-67). In contrast, bilingual children's responses to English negative questions resembled those from English children (e.g., -*Can't you eat a block? -No.)*. Akiyama interpreted the English-like responses in bilinguals when they answered Japanese negative questions as evidence for crosslinguistic influence from English to Japanese. Given the crosslinguistic influence from the polarity-based system to the truth-based system found in Japanese-English bilinguals by Akiyama (1979), it is expected that Chinese-English bilinguals use the polarity-based system typical of English speakers when they answer Chinese negative questions.

An example from a Japanese monolingual child:

66) Q: Kimi-wa tsumiki-o taberare-naino?
'Can't you eat a block?'

A: - hai.
yes
'No'

An example from a Japanese-English bilingual child:

67) Q: Kimi-wa tsumiki-o taberare-naino?
'Can't you eat a block?'

A: - iie.
no
'No'

Empirical evidence supporting crosslinguistic influence between the two answering systems was also found in Korean-English bilingual children. Like Chinese and Japanese speakers, Korean speakers also use the truth-based system when they answer negative questions (Choi, 2014; Holmberg, 2015). To examine the way Korean-English bilingual children answer negative questions, Choi (2014) instructed one group of Korean monolingual children (mean age 4;9) and one group of Korean-English bilingual children of the same age to first listen to stories and then answer negative questions (e.g., *Didn't the second pig build his house out of mud?*). Choi found that bilingual children made significantly more errors when they answered Korean negative questions compared to Korean children. To illustrate the errors, if the second pig didn't build his house out of mud, it was incorrect when bilingual children answered *niyo* 'no' since *ye* 'yes' was the correct answer following the truth-based system. Also, bilingual children made significantly more errors when they answered Korean negative questions in comparison with when they answered English negative questions. The researcher interpreted these results as evidence for crosslinguistic influence from the English system to the Korean system in Korean-English bilinguals. What was found in Choi (2014) supports the assumption that Chinese-English bilinguals can differ from Chinese speakers when they answer Chinese negative questions.

There are still many questions to be answered regarding the answering systems in bilinguals. Both Akiyama (1992) and Choi (2014) revealed that there is crosslinguistic influence from the polarity-based system to the truth-based system when bilinguals answer negative questions. However, the two studies diverge on the strength of this crosslinguistic influence. While Akiyama (1979) observed that Japanese-English bilinguals used English-typical answers when they responded to Japanese negative questions, Korean-English bilinguals in Choi (2013) predominantly used Korean-typical answers when they responded to Korean negative questions. It remains to be explored what predictors of conceptual changes are associated with the preference for using English-based answers by bilinguals. Also, neither Akiyama (1979) nor Choi (2014) explained the mechanism of the crosslinguistic influence reported. Variations in production observed in the two studies can suggest that bilinguals tend to process negative questions in the L2-specific manner or that bilinguals relied on the semantic meanings of *yes/no* in English when they answered Japanese/Korean negative questions (see the later discussion of Alonso (2016) in this chapter). In order to disentangle this complication, this study will test Chinese-English bilinguals' responses as well as measure their response speed when they answer negative questions.

Recently, there has been one study suggesting that bilinguals can differ from monolingual speakers when they process negative sentences. To investigate whether L1 and L2 English speakers process negation in the same way, Manning, Sabourin and Farshchi (2018) measured event related brain potentials (ERPs) of French learners of English and simultaneous French-English bilinguals when they process true/false positive/negative sentences (e.g., *The jury found him innocent/guilty because the fire was recognized as intentional/not intentional in court*). The two groups of bilinguals read the sentences in a word-by-word fashion while their EEG was measured. The researchers observed that, in the group of L2 learners, around 400 ms after the offset of the stimuli the brain potentials were significantly more negative for negative-true sentences (*...innocent…not intentional…*) than positive-true sentences (*...guilty…intentional…*). Also, L2 learners' brain potentials were significantly different for negative-false and negative-true sentences. However, these patterns were not found in the group of simultaneous bilinguals. The researchers concluded that there is additional processing cost for L2 learners but not for L1 speakers when they process negative statements. For L2 learners, they take two steps to process a negative statement (e.g., *not intentional*) via its positive counterpart (*intentional*). Since Manning and colleagues did not test L1 French and L1 English speakers, one cannot tell whether their EEG results suggest crosslinguistic influence or not. What their study indicates is that L2 learners can differ from L1 speakers when they process negation. It gives support to the view that the processing differences between bilinguals and monolingual speakers give rise to their varied responses found in Akiyama (1979) and Choi (2014). It also leads to the prediction that Chinese-English bilinguals can differ from English and Chinese monolingual speakers when they process negation in negative questions.

Unlike Manning et al. (2018), Ćoso and Bogunović (2019) reported that bilinguals do not have increased difficulty when processing negation in L2. To test whether Croatian learners of English process negation in their L1 and L2 in the same way or not, the researchers instructed Croatian learners to see sentence-picture pairs and verify whether a picture (e.g., a heart symbol placed above an arrow symbol) (mis)matches the previous positive/negative sentence. The researchers designed three types of negative sentences, namely *negated subject* (e.g., *No heart is above an arrow*), *sentential negation* (e.g., *Hearts are not above arrows*) and *constituent negation* (e.g., *Not every heart is above an arrow*). Notably, the Croatian counterpart for *No heart is above an arrow* was *Nijedno srce nije iznad strelice* 'No heart is not above an arrow' with both the quantifier and the verb being negated. Croatian learners showed similar response speed and accuracy rate when they processed positive and negative sentences in English and Croatian. On the within-language level, it took Croatian learners longer to process negative sentences compared to positive sentences in both English and Croatian. Moreover, for constituent negation, it took the participants longer to respond when a picture matched a sentence (a heart symbol placed below an arrow symbol for *Not every heart is above an arrow*) compared with when they mismatched (a heart symbol placed above an arrow symbol). Also, lower accuracy rates were observed when negative sentences with sentential negation and constituent negation were paired with matching pictures than mismatching pictures. The researchers concluded that Croatian learners processed negation in English and Croatian in the same way in two steps. If Croatian learners did not process the positive statement of a negative sentence in the first step, they would not be slowed down more by negative sentences compared to positive sentences in both English and in Croatian. Neither would they perform comparatively worse when the pictures matched the sentences than when they mismatched. However, the researchers did not explain why faster response speed for processing mismatching sentence-pictures pairs was not observed for negative sentences with negated subject or sentential negation. It is possible that Croatian learners do not have the same tendency in using two steps to process different forms of negation. In light of the findings in Ćoso and Bogunović (2019), Chinese-English bilinguals in this study may show similar patterns when they process negation in English and Chinese negative questions.

7.2.2. Crosslinguistic influence in other domains

Given that the number of empirical studies on the processing of negation in bilinguals is quite limited, empirical evidence suggesting crosslinguistic influence from other domains is discussed. To examine crosslinguistic influence between bilinguals' two language systems, Alonso (2016) tested the use of prepositions by Danish and Spanish learners of English and three monolingual control groups. While there are three prepositions in Danish (*PÅ* 'on', *I* 'in' and *VED* 'at') which are similar to *in/on/at* in English, Spanish has only one preposition (*EN*) that covers the three spatial relations. In the experiment, participants first saw pictures indicating spatial relations (e.g., a notice on a door), and then they were instructed to answer questions about the locations of the objects in the pictures (e.g., *where is the notice*/*there is a notice _ the door*). Results showed that Danish learners basically resembled English speakers in the way they used prepositions (e.g., *there is a notice on the door*) with between-group difference only found in one item out of 23. However, Spanish learners significantly differed from English speakers in 9 out of 23 items (e.g., *there is a notice at the door*). Moreover, Danish and Spanish learners diverged from English speakers in the same items where Danish and Spanish L1 speakers differed from English speakers. Alonso interpreted the patterns of bilinguals as evidence for L1 influence on the use of L2 prepositions. Importantly, Alonso acknowledged that she can hardly explain the crosslinguistic influence with this experimental design. The crosslinguistic influence can be attributed to conceptual transfer, meaning the spatial reference in L2 learners was mediated by their L1. Alternatively, the crosslinguistic influence can suggest semantic transfer that L2 learners used L1-based form-meaning mappings for L2 expressions. The argument for conceptual transfer is later supported by Park and Ziegler (2014) with the help of a nonverbal context (see later discussion in this chapter). Considering the crosslinguistic influence from L1 to L2 found in Alonso (2016), it is possible that Chinese-English bilinguals use the truth-based system like Chinese speakers even when they answer English negative questions.

Crosslinguistic influence from L1 to L2 in bilinguals has also been reported from word recognition. Akamatsu (2003) investigated if there is a link between the orthography of bilinguals' L1 and the way they process words in L2. With regards to orthography, while Japanese and Chinese are not alphabetic languages, Persian is an alphabetic language like English. The researcher instructed Japanese, Chinese and Persian learners of English to read short texts followed by comprehension questions. Critically, half of the texts were printed in alternated case (e.g., aLtErNaTd cAsE) and the other half in normal case. If bilinguals process English words in L1-based manner, it would take Japanese and Chinese learners longer to process case alternation compared to Persian speakers because weaker sensitivity to intraword information was reported in users of nonalphabetic languages than those of alphabetic languages. The results confirmed this prediction, showing that both Japanese and Chinese learners were slowed down significantly more when they read the texts in alternated case compared to texts in normal case than Persian speakers. The researcher concluded that the L1-based word recognition skills were transferred into processing word in L2 otherwise there would be no between-group difference. In light of this argument, Chinese-English bilinguals in this study may also transfer their L1-based processing of negation in negative questions to the L2 context.

Bilinguals' L1 is also susceptible to L2 influence. To explore the reversed crosslinguistic influence from L2 to L1, Pavlenko and Malt (2011) examined the way in which Russian-English bilinguals (early, childhood and late bilinguals) name common kitchen vessels (e.g., cups) in their L1 Russian. The crosslinguistic contrast in focus was that a same drinking vessel can vary in its English name and its Russian name. For example, a container which is likely to be referred to as *cup* in English can be typically expressed as *stakan* 'glass' in Russian. In the experiment, Russian-English bilinguals and Russian and English monolinguals speakers were instructed to name pictures of drinking containers which are typically called *cup*, *mug* or *glass* in English and *chashka* 'cup', *kruzhka* 'mug' and *stakan* 'glass' in Russian. Results first confirmed that there is crosslinguistic contrasts between English and Russian in naming the drinking vessels. For example, English speakers exclusively used *cup*, *mug* or *glass* to name the stimuli which were expressed in ten ways by Russian speakers. Also, discrepancies were found between bilinguals and Russian speakers in naming the kitchen vessels. For example, bilinguals preferred naming a glass for drinking beer as *stakan* ‘glass’, which resembled English speakers who also typically named the same vessel *glass*, while Russian speakers predominately named this glass vessel for drinking beer as *bokal* which is the Russian expression for tall contains for liquors. Among the three groups of bilinguals, the researchers found that late bilinguals resembled Russian speakers most, and then followed by childhood bilinguals, with the least similarity found in early bilinguals. These results indicate that L2 acquisition can change bilinguals’ use of their L1 words. Given the L2 influence on L1 use reported, acquisition of the L2 polarity-based system may affect the way in which Chinese-English bilinguals answer Chinese negative questions in the current study. However, instead of crosslinguistic influence from L2 to L1, the findings in Pavlenko and Malt (2011) may also be accounted for by a comparatively smaller vocabulary size in bilinguals (i.e., bilinguals can lose words in their L1 due to L2 acquisition).

Many studies showed that crosslinguistic influence is bidirectional interaction, both from L1 to L2 and from L2 to L1. Pavlenko and Jarvis (2002) investigated the expressions of emotions in Russian learners of English. The researchers instructed participants to watch short films first (e.g., a person reading someone else's letter without authorization) and then to retell the story in English and Russian. Results demonstrated that there was bidirectional crosslinguistic influence in bilinguals' grammatical constructions. For example, bilingual participants used the VERB+NOUN construction (e.g., *She had some personal emotions*) when they described the films in L2 English. This frame is typical of Russian speakers but not typical of English speakers who use the COPULA+ADJECTIVE construction (e.g., *She was upset*). In contrast, when bilingual participants recalled the films in their L1 Russian, they were found to use the COPULA+ADJECTIVE construction typical of English speakers. The researchers concluded that crosslinguistic influence is bidirectional in the sense that while L1 Russian influences bilinguals' oral production in L2 English, L2 English also affects their description in L1 Russian. Based on the findings in Pavlenko and Jarvis (2002), it can be predicted that there may be bidirectional crosslinguistic influence (e.g., answering *yes, she doesn't* to English negative questions and *yes, she does* to Chinese negative questions) between L1 and L2 answering systems in Chinese-English bilinguals. The story retelling paradigm in Pavlenko and Jarvis (2002) was designed to test crosslinguistic influence between bilinguals' L1 and L2. However, it cannot shed light on the sources of the crosslinguistic influence. It is possible that conceptual changes gave rise to the crosslinguistic influence (e.g., Bilinguals may be less likely to think of emotions as possessions compared to Russian native speakers). Alternatively, the crosslinguistic influence may also indicate that it is difficult to supress the syntax of one language while the other is in use by bilinguals.

More empirical evidence supporting bidirectional crosslinguistic influence comes from Hohenstein, Eisenberg, and Naigles (2006). To explore whether crosslinguistic influence functions both from L1 to L2 and from L2 to L1, Hohenstein and colleagues examined the way late Spanish-English bilinguals (i.e., bilinguals who learnt L2 English after the age of 12) expressed path and manner when they described motion events. English and Spanish differ in the information encoded in the main verb when they describe motion events. According to Talmy's (1985), languages can be categorized into different systems in terms of the way they encode manner and path of motion events. As mentioned in the previous chapter, one system is known as the satellite-framed system such as English, which encodes manner of motion events in main verbs (e.g., *She is RUNNING out of the house*). The other is known as the verb-framed system (such as Spanish), which encodes path of motion events in main verbs while leaving manner outside of main verbs (e.g., *Ella est´a saliendo de la casa* 'She is exiting the house'). In Hohenstein et al. (2006), bilingual participants watched one video clip of motion events (e.g., Man walking across sidewalk) first in each trial. Immediately after watching the video clip, bilinguals were instructed to retell what was happening. Results showed that bilinguals used fewer path verbs in Spanish compared to Spanish speakers, suggesting L2 influence on L1 production. However, bilinguals used significantly more path verbs in English compared to English speakers, and they mentioned manner information significantly more frequently compared to Spanish speakers but less frequently than English speakers. These results suggested crosslinguistic influence from L1 to L2 production. The researchers concluded that there was bidirectional crosslinguistic in Spanish-English bilinguals when they described motion events. Both Pavlenko and Jarvis (2002), and Hohenstein et al. (2006) demonstrated that crosslinguistic influence can be a two-way interplay between bilinguals' L1 and L2. In light of this view, Chinese-English bilinguals can answer negative questions in a way that is in-between English and Chinese speakers.

7.3. Conceptual transfer in bilinguals

7.3.1. Coexistence of L1 and L2 concepts

Kousta, Vinson, and Vigliocco (2008) examined the influence of using grammatical gender on thinking. In Italian, it is obligatory to mark nouns as masculine or feminine; In contrast, English lacks grammatical gender. The researchers asked Italian-English bilinguals and two control groups to name pictures of common land animals which were presented one by one as quickly as possible. In theory, Italian speakers would make more semantic substitution errors in production (i.e., using another semantically related word such as *eye* instead of the target word *ear* during word selection) because nouns with the same grammatical gender in Italian would have greater semantic similarity in comparison to their translation equivalents in English where grammatical gender is absent. As the researchers predicted, they found that the presence of grammatical gender affected the number of substitution errors made by Italian speakers relative to English speakers. Critically, bilinguals' error rates resembled those of the Italian native speakers in the Italian context while they resembled those of the English native speakers in the English context. Kousta and colleagues argued that L2 acquisition affects bilinguals' semantic representations. However, they further argued that linguistic influence does not extend to thinking beyond language use, otherwise bilinguals should have shown comparable performance regardless of language context. Despite this claim, Kousta et al. (2008) may suggest that bilinguals can develop different conceptual representations separately according to the view of Kersten et al. (2010) which will be reviewed next.

Kersten and colleagues (2010) investigated the influence of language on cognition focusing on the crosslinguistic difference between English and Spanish in expressing manner of motion events. They compared the categorization of motion events by Spanish-English bilinguals who began to learn English after the age of 5, Spanish speakers and English speakers. As mentioned earlier, while English speakers encode manner information in main verbs when they describe motion events, this information is typically omitted by Spanish speakers. The researchers designed a nonverbal categorization-learning task. In each trial, participants would see an animated motion event (e.g., A bug-like creature rotating directly towards the other bug-like creature). After the offset of each event, four buttons which were labelled *Species 1-4* respectively indicating four different categories of manner (e.g., *rotate*) would appear on the screen. Participants were instructed to assign a category by choosing one of the four buttons for the moving bug-like creature based on its traits (Experiment 2 & 3). They were given the correct categorization (e.g., Species 1 for a rotating bug) after each trial. Results demonstrated that the accuracy of English speakers was significantly higher compared to that of Spanish speakers, suggesting that English speakers learned to attend to manner information faster than Spanish speakers. The researchers attributed the faster learning of English speakers to their habitual attention to manner in their language production. Results also showed that, comparable to English speakers, bilinguals attended to manner information quickly when they were tested in English; however, bilingual participants attended to manner information more slowly compared to English speakers when they were tested in Spanish. Kersten and colleagues argued that bilinguals have distinct patterns when they conceptualize motion events in L1 and L2 context. If acquisition of L2-specific verbal expressions can change bilinguals' mental structure as suggested by Kersten et al. (2010), then we might also expect that using the L2 answering system would give rise to conceptual transfer in Chinese-English bilinguals which would show as divergence from Chinese speakers in a nonverbal context.

Bylund and Athanasopoulos (2017) investigated the way in which Swedish-Spanish bilinguals process durations. Swedish speakers describe time as length (*long/short)* like English speakers while Spanish speakers use *big/small* like Greek speakers (see chapter 3). In the experiment, participants first saw a prompt of an hourglass symbol which indicated that the task was to estimate the duration of the following stimuli (e.g., an increasing line or a gradually filled container) displayed on the screen. Critically, this hourglass symbol could be displayed with or without a verbal label *duration* in Swedish or in Spanish. Then participants proceeded to see the stimuli and they were instructed to reproduce the durations of the stimuli by clicking their computer mouse twice with an appropriate interval to indicate the start and the end. The researchers found that when the hourglass symbol had verbal labels, Swedish speakers were interfered by the length of linear stimuli (i.e., longer durations for longer lines) while Spanish speakers were interfered by the volume of container stimuli (i.e., longer durations for fuller containers). In terms of bilinguals, their estimations of durations were interfered by the linear distractors resembling that of Swedish speakers when verbal labels were in Swedish. In contrast, their estimations were interfered by the volume distractors resembling that of Spanish speakers when verbal label were in Spanish. These results confirmed Casasanto's argument (Casasanto, 2016; Casasanto et al., 2004) that language-specific spatiotemporal metaphors mediates the conceptual representations of time. Furthermore, Bylund and Athanasopoulos (2017) demonstrated that a bilingual mind is highly flexible in the sense that they can shift between L1-specific and L2-specific conceptual representations. Bylund and Athanasopoulos (2017) provides empirical support for the idea that L2 acquisition is closely linked to bilinguals' conceptual transfer.

7.3.2. Transfer of L1 concepts

Bilinguals have been widely reported to show L1-based patterns. Von Stutterheim (2003) investigated the processing of motion events in English-German bilinguals. As discussed in Chapter 3, von Stutterheim (2003) found that German speakers attended more to endpoints of motion events than English speakers who were more progressiveness-driven. She further tested advanced English learners of German using the same description task. Bilinguals were instructed to watch video clips that showed motion events with a potential endpoint in the background (e.g., two people walking along the road towards a house), and to describe what was happening. Results showed that English learners of German differed from German speakers by verbalizing significantly fewer endpoints (e.g., *two people walked*) while they resembled the pattern of English speakers. Furthermore, it took English learners and English speakers similar amount of time to speak after the onset of a stimulus. These results suggested that English learners did not attend to the completeness of motion events like German speakers. Their processing of motion events was still L1-based even in the L2 context. Von Stutterheim (2003) found empirical evidence for conceptual transfer by examining production as well as measuring reaction times. Then if Chinese-English bilinguals process L2 English negative questions in the same way they process L1 Chinese negative questions, they would show L1-based responses and response speed in the L2 context.

Vanek and Selinker (2017) designed a verbal and a nonverbal context to investigate how strongly the use of grammatical aspects in verbal expression can influence the processing of motion events. The researchers focused on the crosslinguistic difference that resultative events can be marked as on-going in English (e.g., *a man is hanging a hat on a hook*) while this type of events in Chinese is typically marked as completed rather than progressive (e.g., *a man hung a hat on a hook*). In the verbal experiment, the researchers asked Chinese-English bilinguals and monolingual speakers of English and Chinese to watch video clips of complete resultative events (e.g., a man jumping towards a hook, hanging a hat on the hook and moving away) and describe the events they saw. In the nonverbal experiment, the researchers cut the complete resultative events into three phases, namely the source-phase (e.g., a man jumping towards a hook), the middle-phase (e.g., the man hanging a hat on the hook) and the target-phase (e.g., the man moving away). Participants were instructed to watch three individual video clips showing each phase and decide whether the source-phase or the target-phase is more similar to the middle-phase. Results showed that bilinguals used significantly fewer progressive expressions compared to English speakers when they described the critical middle-phase of the events (e.g., *a man hung a hat on a hook*), and this pattern resembled Chinese speakers. Regarding the nonverbal context, bilinguals chose the video clips showing the target-phase as more similar to the middle phase more frequently than English speakers in their categorization. This categorization preference of bilinguals also resembled that of Chinese speakers. The researchers argued that there was crosslinguistic influence from bilinguals' L1 grammatical aspects as they tend to mark resultative events as completed in L2 production. Importantly, marking resultative events as completed is routinised in the mind of bilinguals, which was evidenced by their inclination for choosing the target-phase in categorization without overt language use. Moreover, the more frequently bilinguals used combined expressions (e.g., *a man is jumping and hung a hat on the hook*) in their descriptions, the less they preferred to choose the target-phase alternates. These results aligned with transfer of L1 concepts in both verbal and nonverbal contexts. In light of the findings in Vanek and Selinker (2017), Chinese-English bilinguals may show a L1-based pattern when they process English negative questions.

Bassetti, Clarke, and Trenkic (2018) explored calendar calculations (e.g., Which month is seven months after January?) in Chinese learners of English. Chinese and English differ in the transparency of the expressions of month. While the calendar expressions in English (e.g., *January*) are opaque with 12 varied names, those in Chinese are transparent following a numeric structure i.e., 'numeral+month'. For example, in Chinese*, January* is expressed as *yi yue* 'one month' and February is *er yue* 'two month' and so on. The researchers tested the response speed of Chinese learners and English monolingual speakers when they calculate months in English context. Participants were first told that it takes seven months for one kind of flower to blossom. Then they were given the month when the flower was planted and were asked to calculate in what month would it blossom (i.e., forward condition). Alternatively, participants were told the month the flower blossomed and were asked to calculate in what month was it planted (i.e., backward condition). For example, participants may be told that the flower was planted in January, and they were expected to calculate that it would blossom seven months later in August. Results showed that Chinese learners were equally fast compared to English speakers in month calculations in the forward condition; more surprisingly, Chinese learners outperformed native speakers in the backward condition. Based on these results, the researchers argued that even though Chinese learners were tested in their L2 English, they relied on the Chinese-based numerical system because it is more transparent and thus easier to calculate months for solving the given task. In light of Bassetti et al. (2018), Chinese-English bilinguals in this study may perform like English speakers given that processing negation in one step (English-like) is easier than in two steps (Chinese-like).

7.3.3. Convergence of L1 and L2 concepts

Some studies revealed that bilinguals can develop L1-L2 converged representations for a conceptual category. To test whether bilinguals have the same word mappings compared to L1 speakers, Ameel and colleagues (2005) examined the way Dutch-French bilinguals and monolingual speakers of Dutch and French name common kitchen objects such as plates. To include a wide range of objects, the researchers designed two sets of pictorial stimuli, one of which showed containers typically called *bottle* or *jar* in English and the other of which showed objects likely to be called *dish*, *plate* and *bowl.* Although there are translation equivalents for these English names of objects in Dutch and in French, they may not refer to the same kind of object as discussed earlier in Pavlenko and Malt (2011) (e.g., A bottle can be typically called *fles* 'bottle' in Dutch while typically expressed as *flacon* 'flacon' in French instead of *bouteille* 'bottle'). Using these two sets of stimuli, Ameel and colleagues instructed participants to name the objects in the pictures in Dutch and French. The researchers found that, on the group level, the gap between bilinguals' naming pattern in Dutch and that in French was very small, and it was smaller in comparison to the gap between the naming patterns of Dutch and French speakers. On the individual level, Dutch and French monolingual speakers agreed much better on naming objects within a language than between languages and so did bilinguals. However, the effect of language was significantly weaker for bilinguals than for

Dutch and French monolingual speakers. Based on these results, the researchers concluded that bilinguals' L1-specific and L2-specific conceptual categories are converging into one shared system, which differs from either L1 group. Ameel et al. (2005) gives further empirical support to the view that L2 acquisition can change a bilingual mind. If L1 and L2 conceptual routines converge in the mind of Chinese-English bilinguals in this study, they would show a unique pattern (i.e., The proposition of *yes/no* answers in bilinguals would be in-between that of English and Chinese speakers) to answer both L1 and L2 negative questions.

Empirical evidence suggesting conceptual convergence has also been reported by Park and Ziegler (2014). While English speakers distinguish *put on* and *put in* events (e.g., *put gloves on* versus *put a paper cup in a trash can*) by relying on the concept of containment, these events are divided by Korean speakers by relying the concept of tight vs. loose fitting (e.g., *kkita* for tight-fitting and varied verbs such as *nehta* for losse-fitting). To investigate whether the acquisition of *put on*/*put in* is associated with changes in the conceptual representation of spatial relations, Park and Ziegler (2014) compared the categorization preference of Korean-English bilinguals and monolingual control groups. In the experiment, participants were presented with three pictures in each trial, and their task was to choose one picture that indicated different spatial relations from the other two. The spatial relations indicated by the three pictures were expected to be categorized differently when participants relied on containment and when they relied on tight vs.loose fitting. For instance, one set of three pictures were 'put a bookmark in a book' (tight-fitting), 'put gloves on' (tight-fitting) and 'put a paper cup in a trash can' (loose-fitting). The odd picture should be 'put gloves on' in terms of containment or 'put a paper cup in a trash can' in terms of tight vs. loose fitting. Results demonstrated that while Korean speakers typically categorized spatial relations according to tight vs. loose fitting (e.g., choosing 'put a paper cup in a trash can'), English speakers typically rely on containment (e.g., choosing 'put gloves on'). Critically, bilinguals showed greater tendency to rely on containment than Korean speakers but weaker tendency than English speakers. Also, their tendency to rely on tight vs. loose fitting was greater than English speakers but weaker than Korean Speakers. Furthermore, the researchers found that bilinguals' L2 proficiency was positively correlated with the L2-specific pattern while negatively correlated with the L1-specific pattern. The distinct pattern of bilinguals was interpreted as evidence for L1-L2 converged conceptual representations. Compared to Alonso (2016), results in Park and Ziegler (2014) were stronger indicators of conceptual convergence.

7.3.4. *Restructuring of L1 concepts*

Von Stutterheim (2003) also tested the processing of motion events in German learners of English. She found that, unlike English learners of German who exhibited L1-based pattern in the L2 context, German learners of English resembled English speakers by typically omitting endpoints in their descriptions while they significantly differed from German speakers. Furthermore, it took German learners significantly shorter to speak compared to German speakers after the onset of a stimulus. The researcher claimed that the conceptual representation of motion events in the mind of German learners were partially restructured towards progressiveness-focus, which is typical of English speakers. Von Stutterheim (2003) showed that the existing L1-specific routines can be restructured in bilinguals.

Comparable empirical evidence comes from the domain of grammatical number. As discussed in chapter 3, Lucy and colleagues (Lucy, 1992; Lucy & Gaskins, 2001, 2003) demonstrated that grammatical number is associated with the categorization of objects. Specifically, English speakers who distinguish countable and mass nouns were more likely to categorize stable objects (e.g., nails) by shape than Yucatec speakers whose language lacks the grammatical number. Built on the language-mediated categorization, Cook and colleagues (2006) investigated the conceptual changes in Japanese (lacks grammatical number like Yucatec) learners of English due to their acquisition of the grammatical number in L2. The researchers designed a triads-matching task using complex objects (e.g., a ceramic lemon squeezer), simple objects (e.g., a cork pyramid) and substances (e.g., hand cream put in C shape). In each trial, participants saw a target item (e.g., a cork pyramid), and were instructed to choose another item that was of the best resemblance to the target from one shape-matching alternate (e.g., a plastic pyramid) and one material-matching alternate (e.g., a piece of cork). The researchers found overall greater preference for shape-matching alternates in English speakers compared to Japanese speakers, which is in line with the language-specific categorization found in previous studies (Lucy, 1992; Lucy & Gaskins, 2001, 2003). Critically, the preference for matching items by shape in bilinguals who lived in English-speaking countries for more than three years was in-between that of Japanese and English speakers. The researchers concluded that bilingual's knowledge is restructured due to L2 acquisition. There is one limitation with the triads-matching paradigm in Cook et al. (2006). It may not be a true nonverbal experiment considering that participants could have silently verbalized the names of the objects and substances.

Similar restructuring of L1-specific categorization of objects has also been reported in Athanasopoulos and Kasai (2008). The researchers tested two groups of Japanese-English bilinguals with intermediate and advanced L2 proficiencies respectively and two monolingual control groups in a triads-matching task. In each trial, participants first saw a target object and two alternates, and then they were instructed to choose one alternate that they thought resembled the target object the most. Unlike previous studies (Cook et al., 2006; Lucy, 1992; Lucy & Gaskins, 2001, 2003), all the stimuli were artificial objects, and the two alternates differed from the target object either in shape or in colour. The researchers found that bilinguals with intermediate L2 proficiencies resembled the pattern of Japanese speakers who were less likely to categorize objects by shape than English speakers. In contrast, advanced bilinguals showed English-specific pattern with greater tendency to categorize objects by shape than Japanese speakers. These results revealed that the categorization of advanced bilinguals was shifting from L1-based towards L2-based as a function of L2 proficiency.

Empirical evidence suggesting restructuring of L1 concepts has also been found in the domain of colour perception. The colour *blue* in English is further divided into *ble* 'dark blue' and *ghalazio* 'light blue' in Greek. To explore whether the perception of the colour *blue* is L1-based or L2-based in Greek-English bilinguals, Athanasopoulos (2009) instructed Greek-English bilinguals and English speakers to rate the similarity of two coloured chips in each trial. The two coloured chips were either within-category (i.e., two *ble* 'dark blue' chips or two *ghalazio* 'light blue' chips) or cross-category (i.e., one *ble* 'dark blue' chip and one *ghalazio* 'light blue' chip). After the similarity judgment, the researcher instructed participants to list all the colours they could think of in order to examine the semantic saliency of *ble* and *blue* in their mind. Results showed that bilinguals who listed *ble* at the bottom and *blue* at the top in their lists distinguished significantly fewer cross-category differences, which resembled the pattern of English speakers. Also, the number of cross-category differences bilinguals can distinguish was negatively correlated with the length of stay in the United Kingdom. These results suggested that the L1-based conceptual categories of *ble* and *ghalazio* can be restructured as a function of length of stay in a L2 speaking country.

On the basis of Athanasopoulos (2009), Athanasopoulous and colleagues (2011) extended the investigation on the strength of language influence on processing colour differences to another group of bilinguals. Like Greek speakers, Japanese speakers also distinguish light blue *mizuiro* and dark blue *ao.* In the experiment, Japanese-English bilinguals and two control groups of English and Japanese speakers were asked to rate the similarity between two coloured stimuli which either fell into the category of *mizuiro* 'light blue' or *ao* 'dark blue'. The researchers also manipulated the levels of lightness so that there were near-colours and far-colours. Results showed that Japanese speakers distinguished significantly more differences when one stimulus fell into the category of *mizuiro* 'light blue' while the other fell into the category of *ao* 'dark blue' in comparison to when both stimuli fell into the same category. However, this is limited to when two colours were far away from each other in terms of lightness. Japanese-English bilinguals' performance was in-between that Japanese and English speakers. Specifically, bilinguals did not show distinction between *mizuiro and ao*, resembling that of English speakers; however, their performance was different for near-colours and far-colours comparisons, comparable to that of Japanese speakers. Also, bilinguals who self-reported higher L2 English use in daily activities distinguished fewer cross-category differences. The researchers concluded that these results gave support to *linguistic relativity* in the sense that linguistic categories modulate the way in which English and Japanese speakers process the same colours, and bilinguals' cognition was susceptible to change towards speakers of their L2.

In brief, if L1-specific conceptual representations are restructured in the mind of bilinguals, they would shift from using L1-based pattern towards L2-based pattern. In von Stutterheim (2003), German learners showed English-like expressions and reaction times when they described motion events in the L2 context; in Cook et al. (2006) and Athanasopoulos and Kasai (2008), Japanese learners of English showed L2-based categorization of objects; and in Athanasopoulos (2009) and Athanasopoulous et al. (2011), Greek-English bilinguals and Japanese-English bilinguals were found to approach the performance of English speakers when they distinguished different blue colours. According to these studies, the variations in answering negative questions between Chinese-English bilinguals and monolinguals speakers of Chinese and English could lead to conceptual restructuring in bilinguals.

7.3.5. Transfer of L2 concepts

Some experimental studies revealed that bilinguals can show a L2-based pattern even when they use their native language. As discussed earlier, English is a satellite-framed system which encodes manner of motion events in main verbs (e.g., *A ball* *rolls down the hill*). Unlike English, Japanese is a verb-framed system that typically encodes path of motion events in main verbs and leave manner out of main verbs (e.g., Booru-ga saka-wo korogatte iku '*A ball goes rolling on the hill*'). Focusing on this crosslinguistic contrast between English and Japanese, Brown and Gullberg (2008) investigated the way in which Japanese learners of English describe and gesture motion events in their L1 and L2. Bilinguals and two monolingual control groups first saw video clips containing motion events (e.g., *A ball rolling down the hill*), and then they were instructed to retell what they had seen. The researchers found that bilinguals were less likely to describe manner in their retellings in both English and Japanese compared to English speakers. This pattern resembled Japanese speakers. The researchers interpreted these results as evidence that bilinguals transferred their L1-based routine to L2 production by not including manner in the main verbs. However, when Japanese speakers mentioned manner in speech, it was often accompanied by gestures encoding manner. Unlike Japanese speakers, bilinguals did not show such pattern, which resembled English speakers. This result suggested that bilinguals, like English speakers, did not use gesture to background manner information when they use their L2. This L2-based pattern was also transferred when they described motion events in L1 Japanese. Brown and Gullberg (2008) showed that bilinguals' habitual thinking can be completely L2-based. In light of the L2-based pattern found in Brown and Gullberg (2008), in this study, Chinese-English bilinguals would differ from Chinese speakers but resemble English speakers when processing negative questions in English and in Chinese.

L2 influence on L1-specific conceptualization of motion events was also reported in Spanish-Swedish bilinguals. As discussed earlier, many empirical studies (Athanasopoulos & Bylund, 2013; von Stutterheim, 2003) suggested a link between the availability of grammatical aspect and the tendency to encode endpoints of motion events. To explore the way in which bilinguals, who use different grammatical aspects in their L1 and L2, conceptualize motion events, Bylund and Jarvis (2011) tested a group of Spanish-Swedish bilinguals. While Swedish lacks grammatical aspect, Spanish can verbally express aspect via morphological means. In the experiment, participants were instructed to watch video clips that showed motion events with a potential endpoint in the background (e.g., a person walking towards a village), and then describe what was happening in L1 Spanish. Besides the production task, participants also received a grammaticality judgment task in which they heard Spanish sentences and judged whether the structure was correct of not by button press. The researchers found that bilinguals were more likely to include endpoints in their descriptions compared to Spanish speakers. Moreover, they found a negative correlation between the performance of grammatical judgement and their preference for mentioning endpoints, which indicated that the less sensitive to errors in grammatical aspects, the greater tendency to express endpoints. These results suggested that bilinguals' processing of motion events was L2-driven, focusing on the completeness rather than the progressiveness. However, without a nonverbal experiment, the findings in Bylund and Jarvis (2011) are difficult to interpret. The results may indicate that bilinguals tend to include endpoints of motion events in their descriptions due to the crosslinguistic influence from L2 to L1. Alternatively, the results may suggest conceptual changes in bilinguals i.e., they developed a new routine following which they process complete motion events including the endpoints. To avoid this pitfall, both verbal and nonverbal experiments were designed in this study to distinguish crosslinguistic influence and conceptual changes.

Chapter 8. The processing of negative questions in Chinese-English bilinguals

8.1. Introduction

In response to a negative yes-no question (e.g., *Doesn't she like cats?*), typical responses dramatically differ between the polarity-based system (-> *Yes, she does/No*, *she doesn't*) and the truth-based system (-> *No, she does/Yes, she doesn't*). The sharp contrasts in the two systems raise the question in bilinguals who can use both the polarity-based and the truth-based systems. Previous studies suggest that there is crosslinguistic influence from the polarity-based system to the truth-based system in the mind of bilinguals (Akiyama, 1979; Choi, 2014). To illustrate, when answering Japanese negative questions (e.g., *Can't you eat a block?*), while Japanese children preferred using the truth-based system (->*hai* 'yes'), Japanese-English bilingual children preferred following the polarity-based system (->*iie* 'no') (Akiyama, 1979). Similar crosslinguistic influence has also been suggested in Korean-English bilingual children. For an illustration, when answering Korean negative questions (e.g., *Didn't the second pig build his house out of mud?* and the case was that *The second pig didn't build his house out of mud*), Korean-English bilingual children made significantly more errors (e.g., they answered *niyo* 'no' when *ye* 'yes' was the correct answer following the truth-based system) than Korean children (Choi, 2014). The aim of this chapter is to extend current exploration to Chinese-English bilinguals who use both the truth-based (i.e., Mandarin Chinese) and the polarity-based (i.e., English) systems.

There is empirical evidence suggesting that the use of different answering systems is associated with different processing of negation from developmental studies (Akiyama, 1979, 1985, 1992; Choi, 1991). These studies revealed that the truth-based system is acquired relatively later by Japanese and Korean Children, and thus it is more difficult than the polarity-based system. Choi (1991) attributed the greater difficulty in the truth-based system to an additional processing operation. Given that accumulating evidence from recent empirical studies showed that English speakers can process negation in a single step (Nieuwland & Kuperberg, 2008; Orenes et al., 2014; Tettamanti et al., 2008; Tian et al., 2010), if Chinese-English bilinguals answer negative questions using the polarity-based system, they may take one step to process negation; alternatively, if Chinese-English bilinguals answer negative questions following the truth-based system, they may need longer two steps to process negation, i.e., first process the positive statement and then process the negative statement.

Crosslinguistic influence has been suggested as a two-way interplay in the mind of bilinguals, i.e., both from L1 to L2 as well as from L2 to L1. For example, Alonso (2016) found crosslinguistic influence from L1 to the use of L2 prepositions. In that study, when using L2 English prepositions (e.g., *a notice on a door*), both Danish learners and Spanish learners of English differed from English speakers in the same items where Danish speakers and Spanish speakers differed from English speakers.

This result was interpreted as evidence that bilinguals relied on their L1 knowledge when they used L2 prepositions. Also, the acquisition of a second language has been reported to affect bilinguals' use of L1 expressions. For example, one piece of empirical evidence suggesting reverse crosslinguistic influence comes from Pavlenko and Malt (2011) who investigated the naming of kitchen vessels. They found that Russian learners of English preferred naming a glass for drinking beer as *stakan* 'glass', which resembled English speakers who also typically named the same vessel *glass*. In contrast, monolingual Russian speakers predominately named this glass vessel for drinking beer as *bokal* which is the Russian expression for tall container for liquors. Pavlenko and Malt (2011) argued that these results suggested L2 influence on L1 when naming concrete objects. Considering the bi-directional crosslinguistic influence reported in bilinguals, bilinguals' performance in both L1 Chinese and L2 English contexts is investigated to test possible L1 influence on processing L2 negative questions and L2 influence on processing L1 negative questions in this chapter.

To the best of the author's knowledge, the processing of negation in negative questions in Chinese-English bilinguals has not been tested. This is the research gap this chapter aims to fill. If Chinese-English bilinguals follow the polarity-based system when they answer negative questions, it is used here to signal that they take one step to process negation; alternatively, if Chinese-English bilinguals follow the truth-based system when they answer negative questions, it is used here to signal that they take two steps to process negation. Despite the link between verbal expressions and the processing of negation, the measure of response alone is not transparent enough for the investigation of the processing of negation. One reason is that responses are susceptible to semantic transfer, i.e., bilinguals can use *yes/no* responses according to the English form-meaning mappings while they still process negative questions like Chinese speakers. Another reason is that different processing of negation may not necessarily lead to variation in verbal expressions.

To strengthen the validity of the measure of response, the response speed of bilinguals when they answer negative questions would also be measured, and their performance would be compared with that of English and Chinese monolingual speakers tested in Chapter 6. The use of an additional step when bilinguals process negative questions is expected to manifest itself in longer times than when they process positive questions. This is because a large body of empirical studies which suggest that processing a negative statement incurs an additional step than processing a positive statement found that it took longer to process negative sentences than positive sentences (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983; Kaup et al, 2006, 2007; Lüdtke et al., 2008; Tian et al., 2010; Sherman, 1973, 1976). Also, if bilinguals take two steps to process negation, they would be slowed down more when they answer *yes* than *no* to negative questions. This prediction is built on Clark and Chase (1972) who argued that using two steps to verify negative sentences when they were true took longer than when they were false.

Building on crosslinguistic influence suggested in answering systems (Akiyama, 1979; Choi, 2014) and other domains (e.g., Alonso, 2016; Pavlenko & Malt, 2011), and on conceptual change taxonomies (Athanasopoulos, 2015; Pavlenko, 2011), three alternative hypotheses are proposed regarding the steps in Chinese-English bilinguals when they process negation in negative questions.

a) *L2-based processing of negation.* The first hypothesis is that bilinguals take a single step to process negative questions like English speakers. If this hypothesis holds true, bilinguals would differ from Chinese speakers while resemble English speakers in their responses to negative questions. On the within-group level, bilinguals would use the polarity-based system to answer negative questions (see Table 5.1 which is repeated here as Table 8.1). Also, if this hypothesis holds, bilinguals would show similar response speed compared to English speakers when they answer negative questions. Specifically, in comparison to English speakers, bilinguals would not be slowed down more by negative questions than positive questions. However, in comparison to Chinese speakers, bilinguals would be slowed down less when they process negative questions than positive questions. On the within-group level, it would not take bilinguals longer to answer *yes* than *no* to negative questions.

Table 8. 1 Polarity-based and truth-based responses in Chinese-English bilinguals

Question type	Example (The case is that *she likes cats.*)	Responses	
		polarity-based	truth-based
Positive (control)	*Does she like cats?*	*yes*	*yes*
Positive (control)	*Does she like dogs?*	*no*	*no*
Negative (critical)	*Doesn't she like cats?*	***yes***	***no***
Negative (critical)	*Doesn't she like dogs?*	***no***	***yes***

b) *L1-based processing of negation.* The second hypothesis is that bilinguals take two steps to process negative questions like Chinese speakers. If this hypothesis holds true, bilinguals would differ from English speakers while they would resemble Chinese speakers in their responses to negative questions. On the within-group level, bilinguals would use the truth-based system to answer negative questions (see Table 8.1). In terms of response speed, if this hypothesis holds, bilinguals would resemble Chinese speakers in their response-speed pattern. That is, in comparison to English speakers, bilinguals would be slowed down more when they process negative questions than positive questions. There is no contrast expected between bilinguals and Chinese speakers when they process negative questions than positive questions. On the within-group level, it is expected to take bilinguals longer to answer *yes* than *no* to negative questions.

c) *In-between L2-based and L1-based processing of negation.* The third hypothesis is that bilinguals' processing of negation is restructured from being L1-based towards being L2-based. If this hypothesis holds true, bilinguals are predicted to approximate English speakers while they would diverge from Chinese speakers in their responses to negative questions. On the within-group level, bilinguals would shift from using the truth-based (see Table 8.1) to the polarity-based system when they answer negative questions. Also, if this hypothesis holds, bilinguals are predicted to show a response-speed pattern in-between that of English and Chinese speakers. Specifically, bilinguals would be slowed down more than English speakers when they process negative questions compared to positive questions. However, bilinguals would be slowed down less than Chinese speakers when they process negative questions compared to positive questions. On the within-group level, it would not take bilinguals longer to answer *yes* than *no* to negative questions.

To test the validity of these three alternative hypotheses, a production experiment (Expt. 5) and a *yes/no* choice experiment (Expt. 6) were designed in this chapter. The same stimuli were used here in Expt. 5 as in previous Expt. 1 (see Chapter 6). In Expt. 5, Chinese-English bilinguals answered negative questions (critical trials) and positive questions (control trials) out loud. Then their responses were compared with that of English and Chinese speakers who were tested in Expt. 1. For the *yes/no* choice experiment, the same stimuli were used in Expt. 6 here in this chapter as in previous Expt. 2 (see chapter 6). Chinese-English bilinguals answered negative questions (critical trials) and positive questions (control trials) with yes/no button presses. Their response speed was compared with that of English and Chinese speakers tested in Expt. 2.

8.2. Experiment 5. Bilinguals' versus English and Chinese monolinguals' processing of negative questions in a *yes/no* production experiment

8.2.1. **Participants**

40 Chinese learners of English (39 females) took part in this experiment. All participants were recruited from a university in the UK at the time of testing. All participants were right-handed and reported no fluency in any language other than Chinese and English. The background information summary of bilinguals at the time of testing is shown in Table 8.2 including their age, time spent in the UK, frequency of speaking and writing English per day, age of onset of learning English as an L2 and the level of English proficiency. The background information is used for analyses later.

Table 8. 2 Bilingual participants' background information

Measure	Mean (SD)
Age (years)	22.45 (1.08)
Time in the UK (months)	2.07 (1.12)
Daily speaking of English (%)	38.00 (15.72)
Daily writing of English (%)	60.63 (27.11)
Onset of learning English as L2	9.13 (1.98)
Oxford Placement Test score (maximum 100)	72.60 (7.50)

8.2.2. Materials and procedure

Materials for this experiment were identical to that for Expt. 1 (see chapter 6), i.e., 24 sentences, 48 yes-no questions and 24 fillers in English and Chinese. Comparable to Expt. 1, the sentences and yes-no questions appeared in four conditions, negative-true (critical), negative-false (critical), positive-true (control) and positive-false (control) (see Table 8.3). The aim of this experiment was to examine the prevalence of *yes* vs. *no* responses in Chinese-English bilinguals when they answered negative questions. Bilingual participants were instructed to read each sentence carefully and answer each question (including *yes/no* whenever possible) aloud appropriately and as quickly as possible. Their responses were recorded and then coded following the same procedure in Expt. 1 (see Chapter 6). Participants had the experiment in both the English setting and the Chinese setting with a minimum two weeks between the two testing times. The sequence of the two settings was counterbalanced. That is, half of the participants were randomly assigned to the English setting before the Chinese setting, and the other half were assigned to the Chinese setting before the English setting.

Table 8. 3 Examples of questions in English and Chinese. The sentence was *"Mr. Fox stole a roast duck from a farm."*

Question type	Condition	Language	answer	*Example*
positive	positive-true	English	*yes*	*Did Mr. Fox steal a roast duck from a farm?*
		Chinese	*shi (de)* 'yes'	*Hu li xian sheng cong nong chang tou le yi zhi kao ya ma?* fox sir from farm steal a roast duck Q 'Did Mr. Fox steal a roast duck from a farm?'
positive	positive-false	English	no	*Did Mr. Fox steal a roast chicken from a farm?*
		Chinese	*bu (shi de)* 'no'	*Hu li xian sheng cong nong chang tou le yi zhi kao ji ma?* fox sir from farm steal a roast chicken Q 'Did Mr. Fox steal a roast chicken from a farm?'
negative	negative-true	English	yes	*Didn't Mr. Fox steal a roast duck from a farm?*
		Chinese	*bu (shi de)* 'no'	*Hu li xian sheng mei cong nong chang tou le yi zhi kao ya ma?* fox sir Neg from farm steal a roast duck Q 'Did Mr. Fox not steal a roast duck from a farm?'
negative	negative-false	English	no	*Didn't Mr. Fox steal a roast chicken from a farm?*
		Chinese	*shi (de)* 'yes'	*Hu li xian sheng mei cong nong chang tou le yi zhi kao ji ma?* fox sir Neg from farm steal a roast chicken Q 'Did Mr. Fox not steal a roast chicken from a farm?'

8.2.3. Results

This section is organized in the following sequence: 8.2.3.1 presents the responses of bilinguals when they answered L2 English negative questions; 8.2.3.2 shows bilinguals' responses to L1 Chinese negative questions; and lastly 8.2.3.3 shows the correlations between bilinguals' background variables and their use of L2-like polarity-based responses when they answered English negative questions.

8.2.3.1. Results of bilinguals in the L2 setting (English)

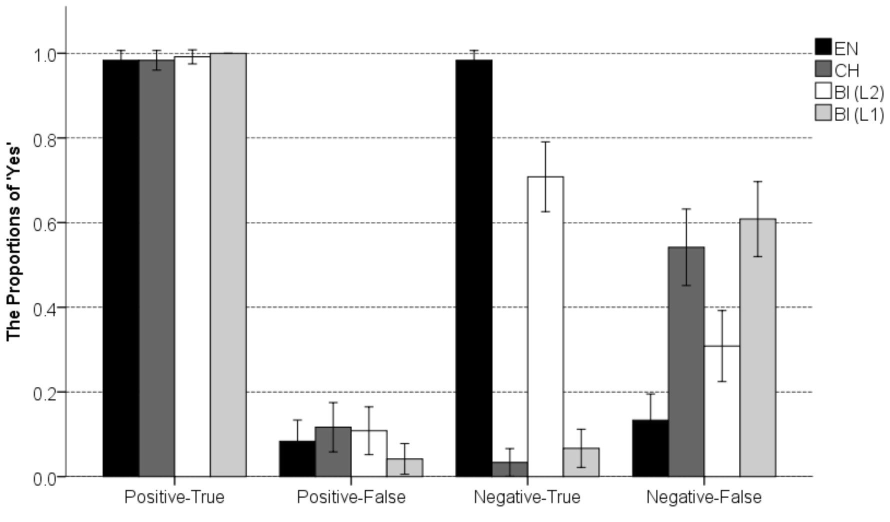


Figure 8. 1 Group mean proportions of *yes* answers of bilinguals (Expt. 5) and that of English and Chinese monolingual speakers (Expt. 1) (Error bars indicate the 95% confidence interval around the mean).

Fig. 8.1 shows responses of bilinguals in the L2 setting in Expt. 5. In the critical negative-true condition, the predominant answer given by bilingual participants was *yes* (M = .71, SD = .46). In the critical negative-false condition, the proportion of their *yes* answer (M = .31, SD = .46) was lower than that of *no*. In the control positive-true condition, bilingual participants almost exclusively answered *yes* (M = .99, SD = .09). In the control positive-false condition, bilingual participants seldomly answered *yes* (M = .11, SD = .31). To test the effect of language group on the proportion of *yes/no* answers in each condition, mixed-effect regression models were built using the lme4 package (Baayen, Davidson, & Bates, 2008) in the R software (Version 3.5.1; R Development Core Team 2018). Since crosslinguistic contrasts between English and Chinese monolinguals were only found in negative questions, the comparisons of bilinguals' responses versus English and Chinese monolinguals' responses centred on negative questions. Focusing on the between group contrast, separate models were built to test preferred responses in the negative-true condition and the negative-false condition. The fixed effect factor was *Group* (English/Bilingual(EN) & Chinese/Bilingual(EN)), the random effect factors with random intercepts were *Participant* and *Item*, the binary dependent variable was *Answer* (*yes*/*no*). The model glmer(answer~group + (1|participant) + (1|item)) confirmed that, in the critical negative-true condition, English speakers were significantly (β = 3.86, *SE* = 0.99, *Z* = 3.92, p <.001) more likely to answer *yes* than bilinguals, but Chinese speakers were significantly (β = -6.08, *SE* = 1.15, *Z* = -5.29, p <.001) less likely to answer *yes* than bilinguals. These results indicated that bilinguals used in-between English-typical and Chinese-typical responses when they answered English negative questions in the negative-true condition. Analogously, in the critical negative-false condition, the same model also confirmed that while English speakers were significantly (β = -1.19, *SE* = 0.39, *Z* = -3.04, p = .002) less likely to answer *yes* than bilinguals, Chinese speakers were significantly (β = 1.13, *SE* = 0.35, *Z* = 3.19, p = .001) more likely to answer *yes* than bilinguals. These results further confirmed that bilinguals' responses to English negative questions were in-between the typical responses of English and Chinese monolingual speakers.

8.2.3.2. Results of bilinguals in the L1 setting (Chinese)

Fig. 8.1 also shows answers of bilinguals in the L1 setting in Expt. 5. In the critical negative-true condition, bilingual participants rarely answered *shi (de)* 'yes' (M = .07, SD = .25). In the critical negative-false condition, their predominant answer was *shi (de)* 'yes' (M = .61, SD = .49). In the control positive-true condition, bilingual participants exclusively answered *shi (de)* 'yes' (M = 1.00, SD = 0). In the control positive-false condition, bilingual participants seldomly answered *shi (de)* 'yes' (M = .04, SD = .20). To test whether bilinguals' responses to Chinese negative questions differ from that of Chinese speakers, the proportion of *shi (de)* 'yes' in bilinguals when they answered Chinese negative questions were compared with that of Chinese speakers. Comparable to the analyses for the English setting, answers of bilinguals and Chinese speakers were analysed using the lme4 package in the R software. The random effect factors with random intercepts were *Participant* and *Item*, and the binary dependent variable was *Answer* (*yes*/*no*). *Group* was not described in the model (i.e., glmer(answer~ (1|participant) + (1|item)) for either of the two critical conditions (negative-true and negative-false). These results revealed that bilinguals' responses were L1-like when they answered Chinese negative questions.

Bilinguals' responses to Chinese negative questions were also compared with their responses to English negative questions. The fixed effect factor was *Group* (Bilingual(EN)/Bilingual(CH)), the random effect factors with random intercepts were *Participant* and *Item*, the binary dependent variable was *Answer* (*yes*/*no*). The model glmer(answer~group + (1|participant) + (1|item)) confirmed that, in the critical negative-true condition, bilinguals were more likely to answer *yes* to English negative questions compared to Chinese negative questions ($\beta = 5.43$, $SE = 1.05$, $Z = 5.19$, p <.001). In the critical negative-false condition, the same model confirmed that bilinguals were less likely to answer *yes* to English negative questions compared to Chinese negative questions (β = -1.85, *SE* = 0.53, *Z* = -3.28, *p* <.001). These results showed that bilinguals' response patterns were different when answering English and Chinese negative questions.

8.2.3.3. Bilinguals' background variables and the use of English-specific answers

Background variables were examined to better understand what drives changes in bilinguals' use of L2-specific answers, including age of the L2 acquisition (L2 AoA), L2 proficiency (OPT score), frequency of L2 speaking per day and frequency of L2 writing per day. These background variables are likely to affect bilinguals' performance (Pavlenko, 2011), and were examined in previous studies (e.g., Vanek & Selinker, 2017). To test the relationship between the use of L2-specific answers to negative questions and each variable, bilinguals' *Answers* (true/false) to English negative questions were analysed using the lme4 package in the R software. The random effect factors with random intercepts were *Participant* and *Item.* None of the four background variables was found a significant predictor on their own. This result suggests that no background variable tested on its own predicted the use of L2-specific answers to negative questions

8.2.4. Discussion

The most important finding of this experiment is that bilinguals were shifting from using Chinese-like responses towards English-like responses when they answered negative questions in English. This finding gives support to the hypothesis that bilinguals' processing of negation in negative questions is in-between L1-based and L2-based. The predominant responses of bilinguals when they answered English negative questions were polarity-based. For example, bilinguals predominantly answered *Didn't he steal a duck?* with *yes* when the sentence was *he stole a duck*. In contrast, the truth-based answer typical of Chinese speakers was *bu (shi de)* 'no' for the same combination of sentence and yes-no question. Previous studies showed that the polarity-based system is less difficult compared with the truth-based system (Akiyama, 1979, 1985, 1992; Choi, 1991) arguably because there is an additional processing operation in the truth-based system (Choi, 1991). In light of the view advocated by Choi (1991), the use of the polarity-based system by bilinguals may suggest that they take a more direct route compared to Chinese speakers who typically use the truth-based system. In other words, bilinguals can process negative questions immediately like English speakers who have been argued to process negative sentences in a single step (Nieuwland & Kuperberg, 2008; Orenes et al., 2014; Tettamanti et al., 2008; Tian et al., 2010). For an illustration of the one-step model in bilinguals, to respond to *Didn't he steal X?*, bilinguals can process 'Is it true or not that [he stole X]' in one step. In contrast, Chinese native speakers would process 'Is it true that [he stole X]' in the first step, and then 'Is it true that [he didn't steal X] in the second step.

Bilinguals' responses between that of L1 and L2 controls can be accounted for by that their L1-specific processing of negative questions is partially restructured. In a related study on the processing of motion events (von Stutterheim, 2003), German learners of English resembled English speakers by typically omitting endpoints when they were asked to describe motion events in English (e.g., two people walking along the road) while they differed from German speakers who typically included endpoints (e.g., two people walking along the road towards a house). Based on this finding, the researcher argued that the acquisition of L2-specific linguistic patterns can restructure the L1-based processing of motion events in bilinguals. Comparably, in this study, Chinese-English bilinguals resembled English speakers by typically using the polarity-based system instead of the truth-based system which is typical of Chinese speakers when they answered English negative questions. In line with von Stutterheim (2003), the current finding is attributed to that L1-based processing of negative questions can be partially restructured in the mind of bilinguals. If bilinguals had processed English negative questions in the L1-specific way i.e., transfer of L1 concepts as reported in other related domains (e.g., Vanek & Selinker, 2017), we would have found that bilinguals used the truth-based system even in a L2 context when they answered English negative questions.

Notably, the argument here is that the L1-specific processing of negative questions is partially restructured rather than fully restructured in bilinguals. One reason is that, tracking the responses to English negative questions, between-group differences were still found between bilinguals and English speakers. These differences may suggest that there is crosslinguistic influence from L1 when bilinguals use their L2, which is in line with the view of Alonso (2016). Another reason is that bilinguals did not use English-specific answers when they responded to Chinese negative questions. Previous studies that tested Japanese-English and Korean-English bilingual children showed that bilinguals fully/partly used English-specific answers when they responded to Japanese/Korean negative questions (Akiyama, 1992; Choi, 2014). Unlike Japanese-English and Korean-English bilinguals, advanced Chinese learners of English still used Chinese-specific responses when they answered Chinese negative questions. For example, in response to *Didn't he steal a duck?,* bilinguals predominantly answered *bu (shi de)* 'no' typical of Chinese speakers when the sentence was *he stole a duck.* The different patterns found between the bilinguals in this study and those in Akiyama (1992) and Choi (2014) may be accounted for by the age of L2 acquisition. While the participants in this study were sequential bilinguals, those in Akiyama (1992) and Choi (2014) were early bilinguals.

Another possible explanation for bilinguals' response pattern which is in-between that of L1 and L2 controls is semantic transfer i.e., bilinguals use *yes/no* responses according to the English form-meaning mappings. The use of the polarity-based system by bilinguals is interpreted as evidence that their processing of negation is partially restructured from being Chinese-like to English-like. However, the response pattern of bilinguals can also be accounted for by transfer of the semantic meanings of *yes/no* according to the view advocated by Alonso (2016). In other words, bilinguals can answer negative questions like English speakers while they continue to process negative questions like Chinese speakers. To illustrate the possible semantic transfer, when the question was *Didn't he steal a duck?* and the sentence was *he stole a duck*, bilinguals typically answered *yes* because it can indicate the positive pole 'He stole a duck'. This alternative explanation is built on Roelofsen and Farkas (2015) who argued that *yes* in English has double functions, which can indicate the absolute value [+] and the relative value [agree]. The so-called absolute value [+] refers to the positive pole.

Examining responses in Expt.5 alone cannot distinguish whether the L1-specific processing of negative questions is partially restructured in bilinguals, or the semantic meanings of *yes/no* in English is transferred to their L1 expressions. To address this problem, Expt. 6 was designed to examine the response speed of bilinguals when they choose *yes/no* answers to negative questions.

8.3. Experiment 6. Bilinguals' versus English and Chinese monolinguals' processing of negative questions in a *yes/no* choice experiment

In light of the view of Alonso (2016) that crosslinguistic influence observed in bilinguals' verbal performance can be attributed to conceptual changes or semantic transfer, Expt. 6 was designed on the basis of Expt. 5 to test which explanation holds true. Unlike Expt. 5 in which only bilinguals' responses to negative questions were examined, in Expt. 6, their response speed when answering negative questions would also be measured along with their responses. If the argument of this chapter holds true that L1-specific processing of negative questions is partially restructured in bilinguals as they tend to use a single step, it would take bilinguals relatively shorter compared to Chinese speakers to answer negative questions. This is because Chinese speakers take an additional processing step, which according to previous studies (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983; Kaup et al, 2006, 2007; Lüdtke et al., 2008; Tian et al., 2010; Sherman, 1973, 1976) would take longer. However, in comparison to English speakers, bilinguals would be slowed down more by negative questions. Within the group of bilinguals, it may not take them longer to answer *yes* than *no* to negative questions. Alternatively, if bilinguals process negative questions in the same way as Chinese speakers do, one can expect no differences between bilinguals and Chinese in their response speed when they answer negative questions. In contrast, compared to English speakers, bilinguals would be slowed down more by negative questions. Also, it would take bilinguals longer to answer *yes* than *no* to negative questions. This is because using two steps to verify negative sentences when they were true took longer than when they were false (Clark & Chase, 1972).

8.3.1. Participants

The same participants in Expt. 5 were tested in Expt. 6 immediately after Expt. 5.

8.3.2. Materials and procedure

Materials and the procedure for this experiment were identical to that for Expt. 2 (see Chapter 6). Participants were instructed to choose verbal responses to negative and positive questions as quickly as possible. Their preferred answers were examined and their response speed were measured. Their answer choices were coded following the procedure in Expt. 2 (see Chapter 6). Participants had the experiment in both the English setting and the Chinese setting with a minimum two weeks between the two testing times. The two-week interval was to ensure that the participants were not too familiar with the experimental stimuli and each participant had similar familiarity with the experimental stimuli when tested again. The sequence of the two settings was counterbalanced. That is, half participants were randomly assigned to the English setting before the Chinese setting, and the other half were assigned to the Chinese setting before the English setting. The language setting of Expt. 6 was kept the same as that of Expt. 5. For example, if one participant first had Expt. 5 in Chinese, then he/she was tested in Chinese in Expt. 6 immediately after Expt. 5. After two weeks, that same participant returned to the lab and had Expt. 5 and Expt.6 in English.

8.3.3. Results

In this section, bilinguals' responses are reported first and then their reaction times (RT) are presented. This is because the expected responses for each condition when bilinguals answered English and Chinese questions need to be checked. Then RTs of their expected answers can be analysed. In the English setting, the expected answers were *yes* for the critical negative-true condition and the control positive-true condition and *no* for the critical negative-false condition and the control positive-false condition. In the Chinese setting, the expected answers were *shi (de)* 'yes' for the critical negative-false condition and the control positive-true condition and *bu (shi de)* 'no' for the critical negative-true condition and the control positive-false condition. To compare RTs of only their expected answers is to ensure crosslinguistic comparability of the RTs

8.3.3.1. Responses of bilinguals in the L2 setting (English)

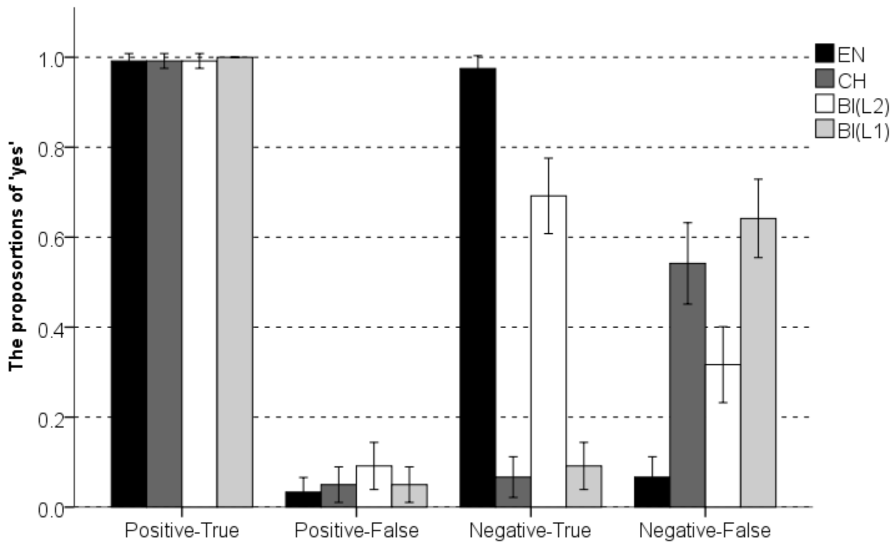


Figure 8. 2 Group mean proportions of *yes* answers given by bilinguals in Expt. 6 and

those given by English and Chinese monolingual speakers in Expt. 2 (Error bars indicate the 95% confidence interval around the mean).

Figure 8.2 shows the responses of bilinguals when they answered English negative questions in Expt. 6. In the critical negative-true condition, bilingual participants predominantly answered *yes* (M = .69, SD = .46). In the critical negative-false condition, the proportion of *yes* (M = .32, SD = .47) was lower than that of *no*. In the control positive-true condition, bilingual participants almost exclusively answered *yes* (M = .99, SD = .09). In the control positive-false condition, bilingual participants rarely answered *yes* (M = .09, SD = .30). To test the effect of language group on the proportion of *yes/no* answers in each condition, mixed-effect regression models were built using the lme4 package (Baayen, Davidson, & Bates, 2008) in the R software (Version 3.5.1; R Development Core Team 2018). Given that crosslinguistic contrasts between English and Chinese monolingual speakers were only found in negative questions and negative questions are the focus of this study, the comparisons of bilinguals' responses versus English and Chinese monolinguals' responses centred on negative questions. The random effect factors with random intercepts were *Participant* and *Item* and the binary dependent variable was *Answer* (*yes*/*no*). In the critical negative-true condition, *Group* (English/Bilingual(EN)) was not described in the model (i.e., glmer(answer~ (1|participant) + (1|item)) when comparing the answers of English speakers and bilinguals. However, the model glmer(answer~group + (1|participant) + (1|item)) confirmed that Chinese speakers were significantly (β = -18.64, *SE* = 2.95, *Z* = -6.31, *p* <.001) less likely to answer *yes* than bilinguals in English. These results showed that bilinguals used English-typical responses when they answered English negative questions in the negative-true condition. In the critical negative-false condition, the model glmer(answer~group + (1|participant) + (1|item)) confirmed that English speakers were significantly (β = -2.55, *SE* = 0.68, *Z* = -3.73, *p* <.001) less likely to answer *yes* than bilinguals, but

Chinese speakers were significantly (β = 1.39, *SE* = 0.51, *Z* = 2.71, *p* = .007) more likely to answer *yes* than bilinguals. These results replicated the response pattern of bilinguals found in Expt. 5 (see Fig. 8.1), and indicated that bilinguals' responses to English negative questions were in-between that of L1 and L2 controls.

8.3.3.2. Responses of bilinguals in the L1 setting (Chinese)

Figure 8.2 also shows responses of bilinguals in the L1 setting in Expt. 6. In the critical negative-true condition, bilingual participants seldomly answered *shi (de)* 'yes' (M = .09, SD = .29). In the critical negative-false condition, their majority answer was *shi (de)* 'yes' (M = .64, SD = .48). In the control positive-true condition, bilingual participants exclusively answered *shi (de)* 'yes' (M = 1.00, SD = 0). In the control positive-false condition, bilingual participants rarely answered *shi (de)* 'yes' (M = .05, SD = .22). To test whether bilinguals' responses to Chinese negative questions differ from that of Chinese speakers, the proportion of *shi (de)* 'yes' in bilinguals when they answered Chinese negative questions were compared with that of Chinese speakers using the lme4 package in the R software. The random effect factors with random intercepts were *Participant* and *Item*, and the binary dependent variable was *Answer* (*yes*/*no*). *Group* (Chinese/Bilingual(L1)) was not described in the model (i.e., glmer(answer~ (1|participant) + (1|item)) in either of the two critical conditions (negative-true and negative-false). These responses confirmed the response pattern of bilinguals found in Expt. 5 (see Fig 8.1), indicating that bilinguals' responses were L1-like when they answered Chinese negative questions.

Next, bilinguals' responses to Chinese negative questions were compared with their responses to English negative questions. The fixed effect factor was *Group* (Bilingual(EN)/Bilingual(CH)), the random effect factors with random intercepts were *Participant* and *Item*, and the binary dependent variable was *Answer* (*yes*/*no*). The model glmer(answer~group + (1|participant) + (1|item)) confirmed that, in the critical negative-true condition, bilinguals were more likely to choose *yes* when answering English negative questions compared to Chinese negative questions (β = 18.67, SE = 2.85, Z = 6.56, p <.001). In the critical negative-false condition, the same model confirmed that bilinguals were less likely to choose *yes* to answering English negative questions compared to Chinese negative questions (β = -2.12, SE = 0.59, Z = -3.57, p <.001). These results, replicating those in Expt. 5 (see Fig. 8.1), indicated that bilinguals preferred using different answers to English and Chinese negative questions.

8.3.3.3. Bilinguals' background variables and the use of English-specific answers

To test the relationship between the use of L2-specific responses to English negative questions and each background variable including age of the L2 acquisition (L2 AoA), L2 proficiency (OPT score), frequency of L2 speaking per day and frequency of L2 writing per day, bilinguals' *Answers* (true/false) to English negative questions were analysed using the lme4 package in the R software. The fixed effect factors were AOA/OPT/L2 speaking/L2 writing. The random effect factors with random intercepts were *Participant* and *Item*. The model glmer(answer~L2speaking + (1|participant) + (1|item)) confirmed that the frequency of L2 speaking per day was a significant predictor (β = .13, SE = .04, Z = 2.94, p = .003) for the use of L2-specific responses to negative questions. This significant result indicated that increase in the frequency of bilinguals' L2 speaking predicted increase in their L2-specific *yes/no* answers to negative questions. The other background variables i.e., age of the L2 acquisition (L2 AoA), L2 proficiency (OPT score) and frequency of L2 writing per day were not significant predictors on their own.

8.3.3.4. Inclusion criteria for reaction times

Next, the reaction times from Expt. 6 were analysed. The inclusion criteria for RTs of bilinguals were the same as those of English and Chinese monolinguals speakers. RTs of the expected answers for each condition when bilinguals answered

English and Chinese questions were analysed. Specifically, RTs were only included in the analyses if a bilingual answered *yes* for the positive-true and the negative-true conditions in the L2 setting. Analogously, RTs were only analysed if a bilingual answered *no* for the positive-false and the negative-false conditions in the L2 setting. For the L1 language setting, RTs were included in the analyses if a bilingual answered *shi (de)* 'yes' for the positive-true and the negative-false conditions and *bu (shi de)* 'no' for the positive-false and the negative-true conditions. 8 data entries (2% of total RTs of typical English answers) in the L2 setting were more than 2.5 standard deviations from the group mean in each condition following Keating and Jegerski (2015) and Norris (2015). These 8 outliers were replaced by the cut-offs (group mean +/- 2.5 SDs). In the L1 setting, 12 data entries (3% of total RTs of typical Chinese answers) were more than 2.5 standard deviations from the group mean in each condition. These were also replaced by the cut-offs.

8.3.3.5. Reaction times of bilinguals in the L2 setting (English)

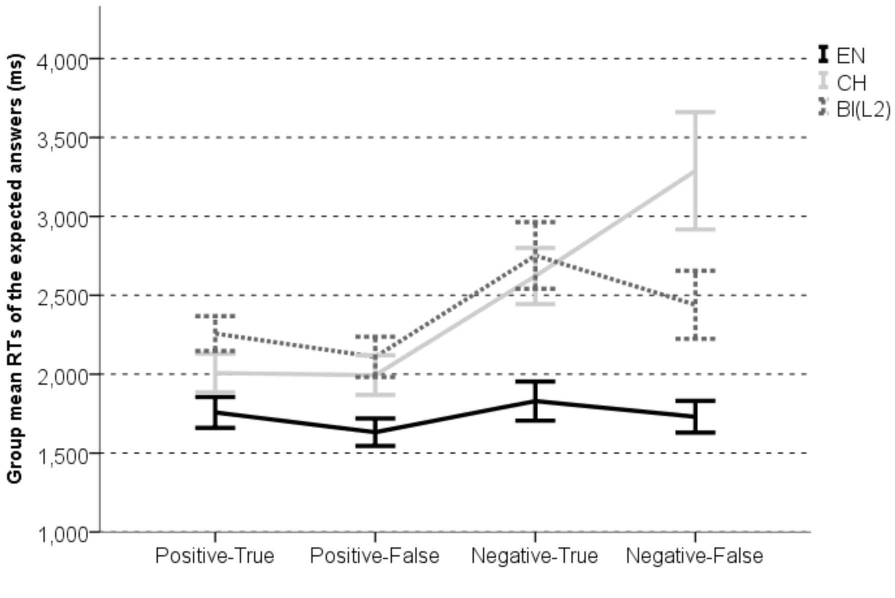


Figure 8. 3 Group mean RTs of bilinguals in the L2 setting in Expt. 6 and those of English and Chinese speakers in Expt. 2 (Error bars indicate the 95% confidence interval around the mean).

Fig. 8.4 shows bilinguals' RTs in the L2 setting in this experiment together with the RTs of English and Chinese speakers tested in Expt. 2. When processing English negative questions, it took bilinguals 2752 ms (SD = 969) on average to answer *yes* in the negative-true condition and 2440 ms (SD = 981) on average to answer *no* in the negative-false condition. When processing English positive questions, it took bilinguals 2258 ms (SD = 607) on average to answer *yes* in the positive-true condition and 2110 ms (SD = 673) on average to answer *no* in the positive-false condition. The mixed-effects models used to analyse reaction time data included *Group* (English/Bilingual(L2) & Chinese/Bilingual(L2)), *Question* (positive/negative) and *Truth* (true/false) as fixed effect factors, *Participant* and *Item* as random effect factors. RTs of bilinguals were compared with those of English and Chinese monolingual speakers separately. Specifically, the model for the comparisons between bilinguals and English speakers is lmer(RT ~ truth * group + question * group + (1|item) + (1|participant)). The model for the comparisons between bilinguals and Chinese speakers is lmer(RT ~ question * truth * group + (1|item) + (1|participant)). The results are shown in Table 8.4.

Table 8. 4 Coefficients of a mixed effects model fitted to the RTs of English/Chinese speakers and that of bilinguals (L2) in Expt. 6

BI(L2) and EN				
Fixed effects	Estimate	SE	t value	*p*
Intercept	2560.82	86.54	29.59	< .001**
Question (positive/negative)	-477.06	58.12	-8.21	< .001**
Truth (true/false)	215.08	55.38	3.88	< .001**
Group (EN/BI)	-844.58	113.05	-7.47	< .001**
Group × truth	-95.46	75.03	-1.27	.204
Group × question	394.71	77.09	5.12	< .001**
Random effects	Variance		SD	

Participants (intercept)	160157		400.20	
Item (intercept)	8210		90.61	
BI(L2) and CH				
Fixed effects	Estimate	SE	t value	*p*
Intercept	2496.64	113.21	22.05	< .001**
Question (positive/negative)	-371.17	109.15	-3.40	< .001**
Truth (true/false)	331.97	115.11	2.88	.004*
Group (CH/BI)	792.06	161.63	4.90	< .001**
Question × truth	-198.47	150.72	-1.32	.188
Group × question	-917.11	159.50	-5.75	< .001**
Group × truth	-1024.59	163.81	-6.25	< .001**
Group × question × truth	900.15	213.35	4.22	< .001**
Random effects	Variance		SD	
Participants (intercept)	207892		455.95	
Item (intercept)	8441		91.87	

Note: A single asterisk * indicates p < .05 and double asterisks ** indicate p < .001

RTs of bilinguals in the L2 setting and RTs of English speakers were compared first. The intercept refers to the estimated mean RT of bilinguals processing negative questions when they were false. A simple effect of *Question* was found. This result indicated that bilinguals and English speakers spent significantly longer (i.e., they were slowed down more) when they answered negative questions than positive questions. Moreover, the simple effect was qualified by interaction with *Group*, which revealed it took bilinguals significantly longer (i.e., they were slowed down more) than English speakers to answer negative compared to positive questions. Also, the model returned a simple effect of *Group.* As shown in Fig. 8.4, this result revealed that it took bilinguals significantly longer than English speakers to answer English yes-no questions. The simple effect of *Truth* was also significant but there was no interaction between *Truth* and *Group*, which demonstrated that it took both bilinguals and English speakers longer when the state of affairs was true than when it was false.

In other words, it took both bilinguals and English speakers longer to answer *yes* than *no* to yes-no questions.

When comparing RTs of bilinguals in the L2 setting and RTs of Chinese speakers, the intercept refers to the estimated mean RT of bilinguals processing negative questions when they were false. A significant simple effect of *Question* was found. This result indicated that bilinguals and Chinese speakers were slowed down more when they answered negative questions compared to positive questions. Importantly, there was a significant interaction between *Question* and *Group*. As shown in Fig. 8.4, this interaction indicated that it took bilinguals significantly shorter than Chinese speakers to answer negative compared to positive questions. The model also returned a significant simple effect of *Group,* which showed that it took bilinguals significantly shorter than Chinese speakers to answer yes-no questions. A significant effect of *Truth* and a significant interaction between *Truth* and *Group* were found. These results demonstrated that while bilinguals' RTs were longer when the state of affairs was true than when it was false, Chinese speakers' RTs were shorter when the state of affairs was true than when it was false. Critically, there was a significant interaction among the three independent variables. This interaction revealed that it only took Chinese speakers longer to answer negative questions when the state of affairs was false. That is, it only took Chinese speakers but not bilinguals longer to answer *yes* than *no* to negative questions.

8.3.3.6. Correlations between bilinguals' background variables and their slowdowns in RTs to English negative questions than English positive questions.

Table 8. 5 Correlation matrix showing Pearson's *r* of bilinguals' slowdowns between RTs to English negative questions and English positive questions and their background variables.

	Slowdown	L2 AoA	OPT score	L2 speaking	L2 writing

Slowdown	1	-.117	-.023	-.248	.111
L2 AoA		1	-.122	.086	.025
OPT score			1	-.147	-.224
L2 speaking				1	.414*
L2 writing					1

Pearson product-moment correlation coefficients were computed to test the relationship between bilinguals' slowdowns between RTs to English negative questions and positive questions and background variables including age of the L2 acquisition (L2 AoA), L2 proficiency (OPT score), frequency of L2 speaking per day and frequency of L2 writing per day following Vanek and Selinker (2017). As shown in Table 8.5, there was no significant correlation found between bilinguals' slowdowns in RTs and any background variable.

8.3.3.7. Reaction times of bilinguals in the L1 setting

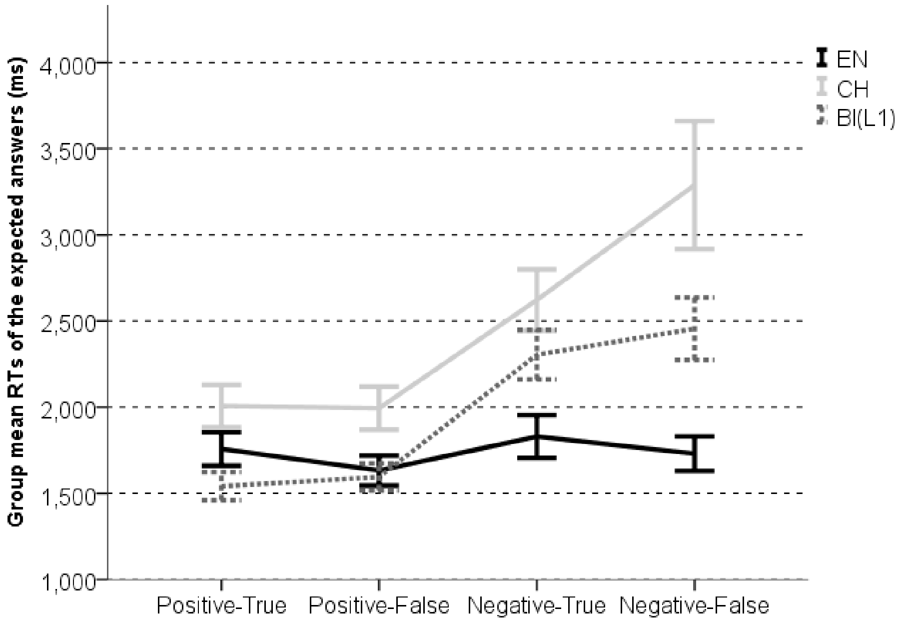


Figure 8. 4 Group mean RTs of bilinguals in the L1 setting in Expt. 6 and those of

English and Chinese speakers in Expt. 2 (Error bars indicate the 95% confidence interval around the mean).

Fig. 8.5 shows bilinguals' RTs to Chinese questions in this experiment together with the RTs of English and Chinese speakers tested in Expt. 2. When processing Chinese negative questions, it took bilinguals 2455 ms (SD = 799) on average to answer *shi (de)* 'yes' in the negative-false condition and 2305 ms (SD = 758) on average to answer *bu* (*shi de)* 'no' in the negative-true condition. When processing Chinese positive questions, it took bilinguals 1542 ms (SD = 453) on average to answer *shi (de)* 'yes' in the positive-true condition and 1595 ms (SD = 424) on average to answer *bu* (*shi de)* 'no' in the positive-false condition. Comparable to the analyses for the L2 setting, the mixed-effects models used to analyse reaction time data included *Group* (English/ Bilingual(CH) & Chinese/Bilingual(CH)), *Question* (positive/negative) and *Truth* (true/false) as fixed effect factors, *Participant* and *Item* as random effect factors. RTs of bilinguals were compared with those of English and Chinese monolingual speakers separately. Specifically, the model for the comparisons between bilinguals and English speakers is lmer(RT ~ truth * group + question * group + (1|item) + (1|participant)). The model for the comparisons between bilinguals and Chinese speakers is lmer(RT ~ question * truth * group + (1|item) + (1|participant)). The results are shown in Table 8.6.

Table 8. 6 Coefficients of a mixed effects model fitted to the RTs of English/Chinese speakers and those of bilinguals (CH) in Expt. 6

BI(CH) and EN				
Fixed effects	Estimate	SE	t value	*p*
Intercept	2419.23	73.31	33.00	< .001**
Question (positive/negative)	-800.67	46.42	-17.25	< .001**
Truth (true/false)	-97.02	45.91	-2.11	.035*
Group (EN/BI)	-702.94	98.68	-7.12	< .001**

Group × truth	217.59	62.99	3.45	< .001**
Group × question	717.02	63.35	11.32	< .001**
Random effects	Variance		SD	
Participants (intercept)	126760		356.03	
Item (intercept)	2795		52.87	
BI(CH) and CH				
Fixed effects	Estimate	SE	t value	*p*
Intercept	2455.20	104.00	23.61	< .001**
Question (positive/negative)	-858.23	99.55	-8.62	< .001**
Truth (true/false)	-153.59	99.98	-1.54	.125
Group (CH/BI)	828.08	148.34	5.58	< .001**
Question × truth	98.32	132.34	0.74	.458
Group × question	-423.21	144.86	-2.92	.004*
Group × truth	-534.77	145.37	-3.68	< .001**
Group × question × truth	597.62	190.25	3.14	.002*
Random effects	Variance		SD	
Participants (intercept)	174915		418.23	
Item (intercept)	4803		69.30	

Note: A single asterisk * indicates p < .05 and double asterisks ** indicate p < .001

First, RTs of bilinguals in the L1 setting and RTs of English speakers were compared. The intercept refers to the estimated mean RT of bilinguals processing negative questions when they were false. The model returned a significant simple effect of *Question*, which indicated that bilinguals and English speakers were slowed down more when they answered negative questions than positive questions. Another significant effect was *Group,* which showed that it took bilinguals longer to answer yes-no questions compared to English speakers. Moreover, there was a significant interaction between *Question* and *Group*. As shown in Fig. 8.5, this interaction demonstrated that it took bilinguals significantly longer than English speakers to answer negative questions compared to positive questions. Also, an effect of *Truth* was found significant and there was a significant interaction between *Truth* and

Group. These results showed that while it took bilinguals longer to respond when the state of affairs was false than when it was true, it took English speakers shorter to respond when the state of affairs was false than when it was true.

Next, RTs of bilinguals in the L1 setting were compared with RTs of Chinese speakers. The intercept refers to the estimated mean RT of bilinguals processing negative questions when they were false. A simple effect of *Question* was found, which revealed that bilinguals and Chinese speakers were slowed down more when they answered Chinese negative questions than when they answered Chinese positive questions. There was a significant effect of *Group*, indicating that the mean RT of bilinguals in the Chinese setting was significantly shorter than that of Chinese speakers. In terms of interactions, there was a significant interaction between *Question* and *Group*. As shown in Fig. 8.5, this interaction indicated that it took bilinguals significantly shorter than Chinese speakers to answer negative questions compared to positive questions. Also, an interaction between *Truth* and *Group* was found significant. This result indicated that Chinese speakers were slowed down more when the state of affairs was false than when it was true compared to bilinguals. Critically, there was a significant interaction among the three independent variables, which demonstrated that it only took Chinese speakers longer to answer negative questions when the state of affairs was false. In other words, it only took Chinese speakers but not bilinguals longer to answer *yes* than *no* to negative questions.

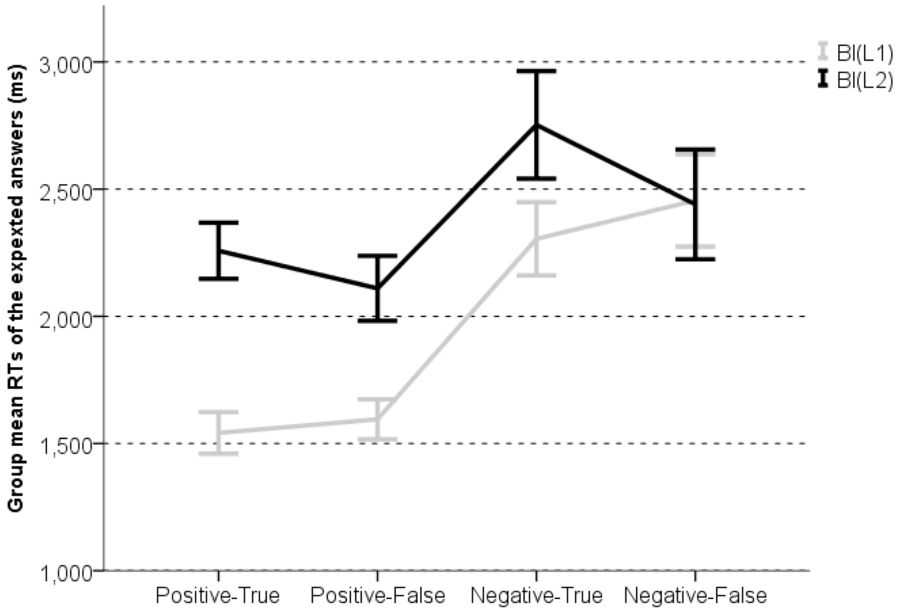


Figure 8. 5 Group mean RTs of bilinguals in the L1 setting and those in the L2 setting in Expt. 6 (Error bars indicate the 95% confidence interval around the mean).

Lastly, bilinguals' RTs in the two language settings were compare. Fig. 8.5 shows the RTs of bilinguals when they answered yes-no questions in English and in Chinese. The mixed-effects models built to analyze the RTs of bilinguals included *Group* (bilingual (EN)/ bilingual (CH)), *Question* (positive/negative) and *Truth* (true/false) as fixed effect factors, *Participant* and *Item* as random effect factors. The model was lmer(RT ~ truth * group + question * group + (1|item) + (1|participant)) and the results are shown in Table 8.7.

Table 8. 7 Coefficients of a mixed effects model fitted to the RTs of bilinguals (EN) and those of bilinguals (CH) in Expt. 6.

BI(CH) and BI(EN)				
Fixed effects	Estimate	SE	t value	*p*
Intercept	2420.28	85.67	28.25	< .001**
Question (positive/negative)	-801.99	59.42	-13.50	< .001**
Truth (true/false)	-97.52	58.79	-1.66	.098

Group (BI(EN)/BI(CH))	133.45	116.91	1.14	.255
Group × truth	313.56	84.21	3.72	< .001**
Group × question	330.54	86.77	3.81	< .001**
Random effects	Variance		SD	
Participants (intercept)	142791		377.88	
Item (intercept)	6485		80.53	

The intercept refers to the estimated mean RT of bilinguals processing Chinese negative questions when they were false. The model returned a significant simple effect of *Question,* indicating that bilinguals were slowed down more when they answered negative questions than positive questions. The interaction between *Group* and *Question* was significant, which demonstrated that bilinguals were slowed down more by Chinese negative questions than Chinese positive questions in comparison to the extent they were slowed down by English negative questions than English positive questions. There was also a significant interaction between *Group* and *Truth.* This result showed that in the English setting, it took bilinguals shorter to respond when the state of affairs was false than when it was true; in contrast, it took them longer to respond when the state of affairs was false than when it was true in the Chinese setting.

8.3.4. Discussion

Setting out to investigate whether bilinguals, English and Chinese native speakers process negative questions in different ways, this experiment found that bilinguals' responses and response speed were in-between that of L1 and L2 controls when they answered English negative questions. When answering Chinese negative questions, bilinguals resembled Chinese speakers in their responses. However, differences were found between bilinguals vs. Chinese speakers and bilinguals vs. English speakers in their response speed. On the within-group level, bilinguals preferred using the polarity-based system when they answered English negative questions while they preferred using the truth-based system when they answered Chinese negative questions. Also, it took bilinguals a similar amount of time to answer *yes* and *no* to English and Chinese negative questions. These findings give support for the hypothesis that bilinguals' processing of negation in negative questions is moving from Chinese-like towards English-like.

Reaction-time differences found between bilinguals and Chinese speakers suggest varied processing of negative questions in the two groups. When processing English negative questions, bilinguals were slowed down less compared to Chinese speakers. There is a great amount of empirical evidence suggesting that processing a negative statement is more difficult than processing a positive statement because the former incurs an additional step (Carpenter & Just, 1975; Clark & Chase, 1972; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al., 2007; Lüdtke et al., 2008). In light of this view, the relatively shorter slowdown in reaction time in bilinguals, compared with Chinese speakers, can be explained as a result of a weaker tendency to process negation in two steps i.e., negation is processed via its positive counterpart. For an illustration of the two-step model, to respond to *Didn't he steal X?*, the first step would be to process 'Is it true that [he stole X]', and then process 'Is it true that [he didn't steal X] in the second step. In other words, compared to Chinese speakers, bilinguals are more likely to process English negative questions in a single step given that speakers of the polarity-based system can process negation immediately (Nieuwland & Kuperberg, 2008; Orenes et al., 2014; Tettamanti et al., 2008; Tian et al., 2010). For an illustration of the one-step route in bilinguals, to respond to *Didn't he steal X?*, bilinguals are more likely to process 'Is it true or not that [he stole X]' straight away. If bilinguals had the same tendency to use one step/two steps compared to Chinese speakers when they processed English negative questions, there would have been no between-group differences observed in the slowdown in reaction time between the two groups.

The within-group pattern of bilinguals' response speed provides another piece of evidence that they are likely to use one step to process English as well as Chinese negative questions. In the experiment, it did not take bilinguals longer to respond *yes* than *no* to English and Chinese negative questions. This finding suggests that bilinguals are unlikely to use two negations suggested by Clark and Chase (1972) to answer *yes* to a negative question. For an illustration of the two negations in Chinese speakers when they answer *yes* to a negative question, if the question is *Didn't he steal a chicken?*, then the first negation would be over the positive statement of the question 'Is it true that [he stole a chicken]'-> 'It is false', followed by the second negation over the truth value of the positive statement 'it is false that [it is false]', i.e., *Yes (he didn't steal a chicken)*. In contrast, there would be only one negation for Chinese speakers to answer *no* to *Didn't he steal a duck?*. To illustrate, they process the positive statement first 'Is it true that [he stole a duck]'-> 'It is true', and then reverse the truth value of the positive statement 'it is false that [it is true]', i.e., *No (he stole a duck)*. Given the different number of negations between answering *yes* versus *no* to a negative question, if bilinguals had used two negations when they answered *yes* to a negative question, it should have taken them longer to respond *yes/shi (de) 'yes' than no/bu (shi de) 'no'* to English and Chinese negative questions. However, this was not the case for bilinguals. Longer response speed in *yes* than *no* to negative stimuli was taken as evidence that it takes two steps to process negation by Clark and Chase (1972). Then the finding that bilinguals showed comparable response speed when they answered *yes* and *no* to a negative question is a strong indication that bilinguals, like English speakers, process negation immediately in a single step.

In addition, bilinguals' response pattern gives more empirical support to the argument that they tend to take a more direct route compared to Chinese speakers when they process negative questions. When answering English negative questions, bilinguals significantly differed from Chinese speakers in their susceptibility to answer *yes/no*. Also, within groups, bilinguals preferred using the polarity-based system instead of the truth-based system typical of Chinese speakers when they answered English negative questions. It suggests that they may not take two steps to process negative questions given the possible additional processing operation argued for the truth-based system (Choi, 1991).

Taken together, all the empirical findings suggest that L1-specific processing of negative questions is partially restructured in the mind of bilinguals. Advanced Chinese-English bilinguals are moving from processing negative questions in two steps typical of Chinese speakers to processing negative questions in a single step typical of English speakers.

In a comparable study in a different domain, previous research on colour perception showed that Greek-English bilinguals began to resemble English speakers when categorizing blue-coloured chips (Athanasopoulos, 2009). Greek-English bilinguals for whom the English colour word *blue* was semantically more salient than the Greek colour word *ble* ‘dark blue’ distinguished significantly fewer differences between *ble* ‘dark blue’ chips and *ghalazio* ‘light blue’ chips. This was the same pattern observed in English speakers. These results were explained as a result of the restructured L1-based conceptual categories of *ble* and *ghalazio* in the mind of bilinguals. Analogously, in this experiment, the claim is that the L1-like processing of negation is partially restructured when bilinguals process negative questions. Thus, this experiment gives support to the idea that acquisition of a second language can change mental processing in bilinguals. A large number of empirical studies on bilingualism showed that L2 acquisition can give rise to differences between bilinguals and monolinguals speakers when they process time, motion events, colour, space, shape and materials of objects (Athanasopoulos, 2009; Athanasopoulos & Kasai, 2008; Brown & Gullberg, 2008; Bylund & Athanasopoulos, 2017; Park & Ziegler, 2014; Pavlenko & Malt, 2011; Vanek & Selinker, 2017; von Stutterheim, 2003). By arguing that bilinguals’ L1-based processing of negative questions can be partially restructured, this experiment contributes to existing findings from the domain of negation that has not yet been tested fin bilingualism research.

The claim here is that bilinguals' L1-based processing of negative questions is partially restructured instead of fully restructured. For one reason, differences were still found between bilinguals' responses to English negative questions and those of English speakers. Considering the positive correlation observed between bilinguals' L2-specific responses to English negative questions and the frequency of bilinguals' L2 speaking per day, this gap can be accounted for by the L1-specific responses given by those bilingual participants who rarely English every day. This finding is in line with Athanasopoulos et al. (2011) who reported a negative correlation between the frequency of L2 use and L1-specific patterns. For another reason, bilinguals' responses to Chinese negative questions were comparable to those of Chinese speakers. If their L1-like processing of negation had been fully restructured, bilinguals would have used the polarity-based system to answer Chinese negative questions. The third reason is that, in comparison with English speakers, it took bilinguals longer to process English and Chinese negative questions than positive questions. Many experimental studies (Carpenter & Just, 1975; Clark & Chase, 1972; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al., 2007; Lüdtke et al., 2008) attributed the greater difficulty in processing negation to an additional processing step to the processing of positive statements. In light of this view, the relatively longer slowdown in reaction time in bilinguals may suggest that they have a greater tendency to process negative questions in two steps. However, within the group of bilinguals, it took them similar amount of time to answer *yes/shi (de)* 'yes' and *no/bu (shi de)* 'no' to English and Chinese negative questions, which suggests that they are likely to process negation in one step. One plausible explanation is that both bilinguals and English speakers tend to take a single step to process negative questions. Nonetheless, the one-step route is more difficult for bilinguals than for English speaker.

Chapter 9. Chinese-English bilinguals' processing of negation in a nonverbal context

9.1. Introduction

Acquisition of L2-specific linguistic patterns can change bilinguals' thinking from being L1-based towards L2-based not only in a verbal context, but also in a nonverbal context (Athanasopoulos, 2009; Athanasopoulos & Kasai, 2008;

Athanasopoulous et al., 2011; Athanasopoulos et al., 2015; Brown & Gullberg, 2008; Bylund & Athanasopoulos, 2017; Cook et al., 2006; Kersten et al., 2010; Park & Ziegler, 2014). For example, Athanasopoulous et al. (2011) instructed Japanese-English bilinguals and two monolingual control groups to rate the similarity between two coloured stimuli which either fell into the category of *mizuiro* 'light blue' or *ao* 'dark blue'. Results showed that compared to Japanese speakers, Japanese-English bilinguals became less sensitive to the distinction between the light-blue shade in the category *mizuiro* and the dark-blue shade in the category *ao,* which resembled the performance of English native speakers. The researchers concluded that bilinguals' cognition was susceptible to L2 influence. In light of the conceptual restructuring reported in Athanasopoulous et al. (2011), in the current study, Chinese-English bilinguals may shift from using L1-like to L2-like routes when processing negation in a nonverbal context.

Bilinguals may process negation in one step like English speakers. Not a negligible number of empirical studies investigating how negation is processed in speakers of the polarity-based systems (e.g., English, Spanish) argued that it takes two steps to process a negative statement via the corresponding positive statement (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983; Kaup et al, 2006, 2007). However, more recent evidence shows that speakers of the polarity-based system can process negation immediately without having to process the positive counterpart (Nieuwland & Kuperberg, 2008; Orenes et al., 2014; Tettamanti et al., 2008; Tian et al., 2010). Unlike for speakers of the polarity-based system, currently there is no empirical evidence that would indicate speakers of the truth-based system have the option to process negation in one step. They have only been suggested to take two steps when processing negation (Choi, 1991). If differences in the processing of negation are associated with different verbal expressions of negation as suggested by Kaup et al. (2006) and as demonstrated in previous chapters, then bilinguals who acquired the polarity-based system may be able to use the L2-based route to process negation in one step.

What was found in Chapter 8 is a strong indication that the Chinese-like processing of negation in negative questions is partially restructured in the minds of Chinese-English bilinguals. Specifically, compared to Chinese speakers, bilinguals showed a greater tendency to process both English and Chinese negative questions in one step. If the cognitive consequence of L2 acquisition is conceptual changes (Athanasopoulos, 2009; Athanasopoulos & Kasai, 2008; Athanasopoulous et al., 2011; Athanasopoulos et al., 2015; Bassetti et al., 2018; Brown & Gullberg, 2008; Bylund & Athanasopoulos, 2017; Cook et al., 2006; Kersten et al., 2010; Park & Ziegler, 2014; Vanek & Selinker, 2017), to what extent does acquisition of the polarity-based answering system restructure bilinguals' processing of negation in a nonverbal context? This is the research question of this chapter. If bilinguals differ from English and Chinese monolingual speakers when they process negation in nonverbal contexts, varied routes are expected to manifest themselves as variation in response speed. Between bilinguals and English/Chinese speakers, using two steps to process negation is likely to take longer than using one step as suggested in many studies (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983; Kaup et al, 2006, 2007; Lüdtke et al., 2008). On the within-group level, if bilinguals take two steps to process negation, they would be slowed down more to respond *agree* than *disagree* with negative stimuli because to verify a negative statement when it is true is to perform two negations and thus takes longer (Clark & Chase, 1972).

Bilinguals' processing of negation in a nonverbal context with and without the involvement of verification is compared with that of English and Chinese native speakers respectively. Expt. 8 and previous studies that used a verification task (Akiyama et al., 1979; Carpenter & Just, 1975; Clark & Chase, 1972; Dale & Duran, 2011; Fischler et al., 1983; Manning et al., 2018; Sherman, 1973, 1976; Wason & Jones, 1963) cannot separate the processing part and the answering part. In a typical verification task such as that in Manning et al. (2018), participants were instructed to verify true/false positive/negative sentences (e.g., *The jury found him innocent/guilty because the fire was recognized as intentional/not intentional in court*). The limitation of using a verification task to investigate the processing of negation is that the processing of negation and the verification of negation are mixed together. One experimental design that does not involve the verification of negation is a probing recognition paradigm (Kaup et al., 2006; Kaup et al. 2007; Tian et al., 2010; Tian et al. 2016). To illustrate, in Kaup et al. (2007), participants first saw a sentence (e.g., *There was no eagle in the sky*) and then a picture (an eagle with folded/outstretched wings). Their task was to recognize whether the object in the picture was mentioned in the proceeding sentence or not. With the aim to explore the processing of negation in a nonverbal context, two nonverbal tasks were designed in this chapter with and without the involvement of negation verification.

Building on previous research on bilingualism in grammatical number (Athanasopoulos & Kasai , 2008; Cook et al., 2006), time (Bassetti et al., 2018; Bylund & Athanasopoulos, 2017), motion events (Athanasopoulos et al., 2015; Brown & Gullberg, 2008; Kersten et al., 2010; Vanek & Selinker, 2017), colour (Athanasopoulos, 2009; Athanasopoulous et al., 2011) and space (Park & Ziegler, 2014), two alternative hypotheses are proposed regarding the strength with which language could mediate the processing of negation in the minds of bilinguals.

a) *Transfer of L1-specific processing of negation to a nonverbal context.* The first hypothesis is that acquisition of the polarity-based answering system does not change bilinguals' processing of negation in a nonverbal context. Although they tend to process negative questions in one step like English speakers, in a nonverbal context, bilinguals would still take two steps and process negation like Chinese speakers. If this hypothesis holds true, compared to English speakers, bilinguals would be slowed down more by negative stimuli than positive stimuli. In contrast, between bilinguals and Chinese speakers, there would be no difference in slowdowns to negative stimuli compared to positive stimuli. On the within-group level, it is expected to take bilinguals longer to *agree* than *disagree* with negative stimuli.

b) *Restructuring of L1-specific processing of negation in a nonverbal context.* The second hypothesis is that acquisition of the polarity-based answering system changes bilinguals' processing of negation in a nonverbal context. Like English speakers, bilinguals tend to take one step to process negation not only when they process negative questions, but also when they solve a given task without overt language use. If this hypothesis holds true, in comparison to English speakers, bilinguals would not be slowed down more by negative stimuli compared to positive stimuli. However, compared to Chinese speakers, bilinguals would be slowed down less by negative stimuli than positive stimuli. On the within-group level, it would not take bilinguals longer to *agree* than *disagree* with negative stimuli.

To test the validity of hypotheses a) and b), a nonverbal agree-disagree experiment (Expt. 7) was designed. The protocol of Expt. 7 and that of Expt. 3 are analogous. In Expt. 7, Chinese-English bilinguals were instructed to agree/disagree with equations comprising simple shapes and critical negative '≠' or control positive '=' equation symbols. Then their response speed was compared with that of English and Chinese speakers who were tested in Expt. 3.

To further compare the processing of negation without verification between bilinguals and English and Chinese native speakers, Expt. 8 was designed on the basis of Expt. 7. The protocol of Expt. 8 and that of Expt. 4 are analogous. Expt. 8 tested the response speed of bilinguals when they process shape (in)congruence with the presence of the '≠' symbol (critical condition), the '=' symbol (control condition) and without any symbols (control condition). To illustrate, bilinguals were instructed to judge whether the two shapes are the same or not in 'triangle-unequal-tringle'/'triangle-equal-tringle'/'triangle-no-symbol-tringle'. In Expt. 7, bilinguals need to verify the equations. In contrast, Expt. 8 tested the way in which bilinguals process the critical '≠' symbol put in an equation without equation verification. The way in which bilinguals process the critical '≠' symbol is reflected on their shape congruence judgement. If bilinguals, like English speakers, tend to process negation immediately in one step in a nonverbal context, the presence of the '≠' symbol would slow them down more when they judge that two shapes are the same compared to the symbol-free trials. Analogously, the presence of the '≠' symbol would slow them down less when they judge that two shapes are different compared to the symbol-free trials. Alternatively, if bilinguals, like Chinese speakers, tend to process negation immediately in two steps (i.e., first process the positive statement and then process the negative statement), the presence of the '≠' symbol would not accelerate/decelerate their response speed during shape congruence judgment. In contrast to the critical condition with the '≠' symbol, bilinguals would not differ from English or Chinese native speakers in the control conditions i.e., trials with the '=' symbol and the symbol-free trials.

9.2. Experiment 7. Bilinguals' versus English and Chinese monolinguals' processing of negation in a nonverbal agree-disagree experiment

9.2.1. Participants

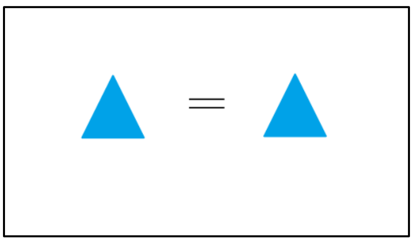
20 randomly selected bilingual participants from Expt. 5 also took part in Expt. 7. Participants first completed the nonverbal Expt. 7 and then the verbal Expt. 5. The background information summary of the 20 bilinguals at the time of testing is shown in Table 9.1 including their age, time spent in the UK, frequency of speaking and writing English per day, age of onset of learning English as L2 and the level of English proficiency.

Table 9. 1 Bilingual participants' background information in the agree-disagree task

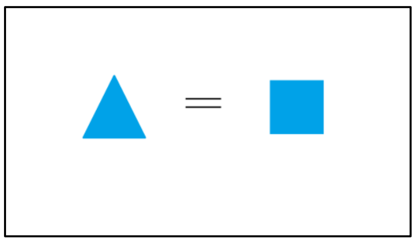
Measure	Mean (SD)
Age (years)	22.75 (1.37)
Time in the UK (months)	2.06 (1.17)
Daily speaking of English (%)	35.00 (15.04)
Daily writing of English (%)	57.50 (29.31)
Onset of learning English as L2 (years)	9.05 (2.31)
Oxford Placement Test score (maximum 100)	71.40 (9.32)

9.2.2. Materials and procedure

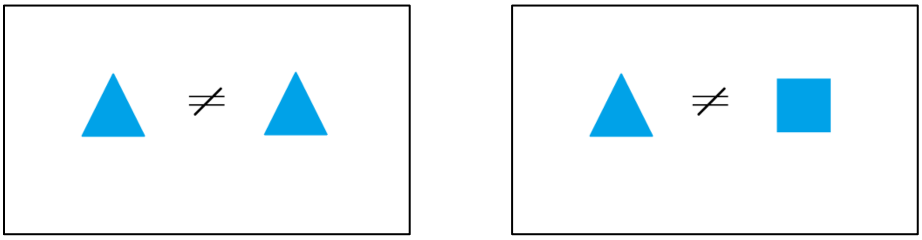
Materials for this experiment were identical with those used for Expt. 3 (see chapter 6), i.e., 24 distinct equations formed by 13 blue-coloured shapes and 2 symbols (i.e., the equal symbol '=' and the unequal symbol '≠'). The combinations of shapes and symbols were divided into four conditions (i.e., positive-true, positive-false, negative-true and negative-false) which are shown in Figure 9.1 with the corresponding correct responses. Also, the procedure of this experiment was the same as that of Expt. 3 (see Chapter 6). Bilingual participants were instructed to *agree/disagree* with the equations as quickly as possible. To counterbalance the language for instruction, following Park and Ziegler (2014), half of the bilingual participants were randomly assigned to have English instruction and the other half Chinese instruction.



Positive-True (↑)



Positive-False (↓)



Negative-True (↓) Negative-False (↑)

Figure 9. 1 Example stimuli in the nonverbal Expt. 7, showing each of the four conditions and the corresponding correct responses in brackets.

9.2.3. Results

Bilinguals' reaction times, when trimmed following the procedures reported in section 9.2.3.1, are compared with the results of English and Chinese speakers tested earlier in Chapter 6 respectively. Following the comparisons, correlations among bilinguals' slowdowns in the nonverbal agree-disagree experiment and possible predictors of conceptual transfer including their background variables, their slowdowns in the verbal context, and the language of instruction are presented next.

9.2.3.1. Inclusion criteria for reaction times

Response accuracy was checked first and then RTs were analysed. The response accuracy of bilingual participants was 94.17%. Only RTs of correct responses were included in the analyses. Also, some sustained pauses were observed because participants made mistakes. As a result, 9 data entries (2.0% of total correct responses) for the trials during which the pauses happened were eliminated from all subsequent analyses. 10 data entries (2.2% of total correct responses) were more than 2.5 standard deviations away from the group mean in each condition following Keating and Jegerski (2015) and Norris (2015). These outliers were replaced by the cut-offs (group mean +/- 2.5 SDs).

9.2.3.2. Reaction times of bilinguals in the agree-disagree task

Figure 9.2 shows bilinguals' RTs in Expt. 7 together with the RTs of English and Chinese speakers tested earlier in Expt. 3. When processing negative equations, bilinguals took 1518 ms on average (SD = 495) to respond in the negative-true condition and 1654 ms on average (SD = 448) in the negative-false condition. When processing positive equations, it took bilinguals 1052 ms on average (SD = 290) to respond in the positive-true condition and 1381 ms on average (SD = 439) in the positive-false condition.

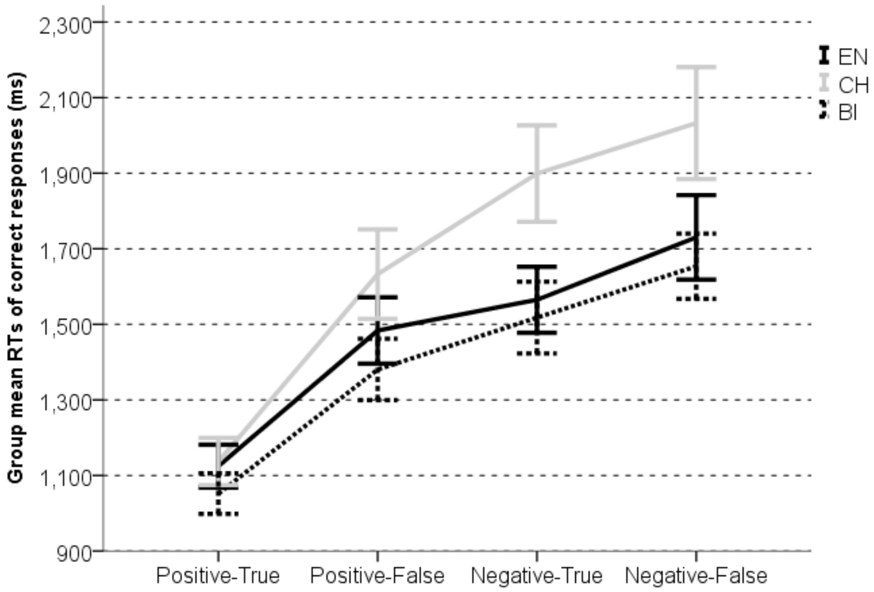


Figure 9. 2 Group mean RTs of correct responses given by bilingual participants in the nonverbal Expt. 7 and RTs of English and Chinese monolingual speakers in the nonverbal Expt. 3 (Error bars indicate the 95% confidence interval around the mean).

To compare the RTs of bilingual participants with those of English and Chinese participants, mixed-effect regression models were built using the lme4 package (Baayen, Davidson, & Bates, 2008) in the R software (Version 3.5.1; R Development Core Team 2018). The fixed effect factor was *Group* (English/bilinguals & Chinese/bilingual), *Equation symbol* (equal/unequal) and *Truth* (true/false) and the random effect factors with random intercepts were *Participant* and *Item*. For the comparison between bilingual and English participants, the model was lmer (RT ~ equationsymbol * truth + (1|participant) + (1|item)). For the comparison between bilingual and Chinese participants, the model was lmer (RT ~ equationsymbol * truth + truth * group + equationsymbol * group + (1|participant) + (1|item)). The reason for building separate models is to compare the RT pattern of bilinguals with those of English and Chinese monolingual speakers respectively. Results are summarized in Table 9.2.

Table 9. 2 Coefficients of a mixed effects model fitted to the RTs of bilinguals in the nonverbal Expt. 7 and those of English and Chinese monolinguals speakers in the nonverbal Expt. 3

BI and EN				
Fixed effects	Estimate	SE	t value	*p*
Intercept	1433.19	54.31	26.39	< .001**
Equation symbol(equal/unequal)	264.12	60.99	4.33	< .001**
Truth (true/false)	-342.81	60.46	-5.67	< .001**
Equation symbol × truth	194.41	86.19	2.26	.036*
Random effects	Variance	SD		
Participants (intercept)	44845	211.77		
Item (intercept)	7101	84.27		
BI and CH				
Fixed effects	Estimate	SE	t value	*p*
Intercept	1403.88	79.18	17.73	< .001**
Equation symbol(equal/unequal)	235.67	75.28	3.13	.004*
Truth (true/false)	-370.07	74.74	-4.95	< .001**
Group (CH/BI)	214.78	96.26	2.23	.030*
Equation symbol × truth	281.19	97.59	2.88	.009*
Group × truth	-90.62	60.88	-1.49	.137
Group × equation symbol	194.98	61.03	3.20	.001*
Random effects	Variance	SD		

Participants (intercept)	65380	255.69
Item (intercept)	8708	93.32

RTs of bilinguals and RTs of English speakers were compared first. The intercept refers to the estimated mean RT for processing equal equations when they were false. There was a significant simple effect of *Equation symbol*, which demonstrated that it took English and bilingual participants longer to process negative equations compared to positive equations. Also, a significant effect of *Truth* and a significant interaction of *Equation symbol* and *Truth* were found. These results showed that it took bilingual and English speakers longer to verify a positive equation when the state of affairs was false (e.g., 'triangle-equal-square') than when it was true (e.g., 'triangle-equal-triangle'). Analogously, it also took bilingual and English speakers longer to verify a negative equation when the state of affairs was false (e.g., 'triangle-unequal-square') than when it was true (e.g., 'triangle-unequal-triangle'). These results showed that it took bilingual and English speakers shorter to *agree* than *disagree* with a positive equation. In contrast, it took both groups longer to *agree* than *disagree* with a negative equation.

Next, RTs of bilinguals and Chinese speakers are compared. The intercept refers to the estimated mean RT of bilinguals processing equal equations when they were false. The model returned a significant simple effect of *Group*, which demonstrated that it took bilinguals significantly shorter to respond than Chinese speakers during equation verification. Also, there was a simple effect of *Equation symbol,* which indicated that bilinguals and Chinese speakers were slowed down more when they processed negative equations than positive equations. Critically, the model returned a significant interaction between *Group* and *Equation symbol*. As shown in Figure 9.2, this result showed that the processing of negative equations was significantly more demanding for Chinese native speakers than it was for bilinguals, even though both groups found negative equations more difficult than positive equations. Also, there was a significant effect of *Truth* and a significant interaction of *Equation symbol* and *Truth*. These results indicated that bilinguals and Chinese native speakers were significantly faster in the positive-true condition (e.g., ‘triangle-equal-triangle’) than the positive-false condition (e.g., ‘triangle-equal-square’), and analogously, they were significantly faster in the negative-true condition (e.g., ‘triangle-unequal-triangle’) than the negative-false condition (e.g., ‘triangle-unequal-square’). That is, it is less difficult for bilinguals and Chinese native speakers to *agree* than *disagree* with a positive equation; however, it is more difficult for bilinguals and Chinese native speakers to *agree* than *disagree* with a negative equation.

9.2.3.3. The impact of individual differences

Pearson product-moment correlation coefficients were computed to test the relationships between bilinguals’ slowdowns in RTs to negative equations compared with positive equations and their background variables including age of the L2 acquisition (L2 AoA), L2 proficiency (OPT score), frequency of L2 speaking per day and frequency of L2 writing per day following Vanek and Selinker (2017). As shown in Table 9.3, no significant correlation was found between bilinguals’ slowdowns in RTs and any background variable.

Table 9. 3 Correlation matrix showing Pearson’s *r* of bilinguals’ slowdowns in RTs to negative equations compared with positive equations and their background variables.

	Slowdown	L2 AoA	OPT score	L2 speaking	L2 writing
Slowdown	1	-.274	-.045	-.177	-.027
L2 AoA		1	-.023	-.114	.060
OPT score			1	-.188	-.200
L2 speaking				1	.233
L2 writing					1

Pearson product-moment correlation coefficients were also computed to test the relationships between slowdowns in RTs to negative equations compared with positive equations and slowdowns in RTs to negative questions compared with positive questions. A positive correlation was found between the slowdowns in the nonverbal agree-disagree task and the slowdowns in the verbal *yes/no* choice task, r (51) = .393, p = .004. This result is shown in the scatterplot (see Figure 9.3). This significant correlation suggests that participants who are slowed down less by negative questions are likely to take shorter when they process negative equations (i.e., generally faster at processing negation).

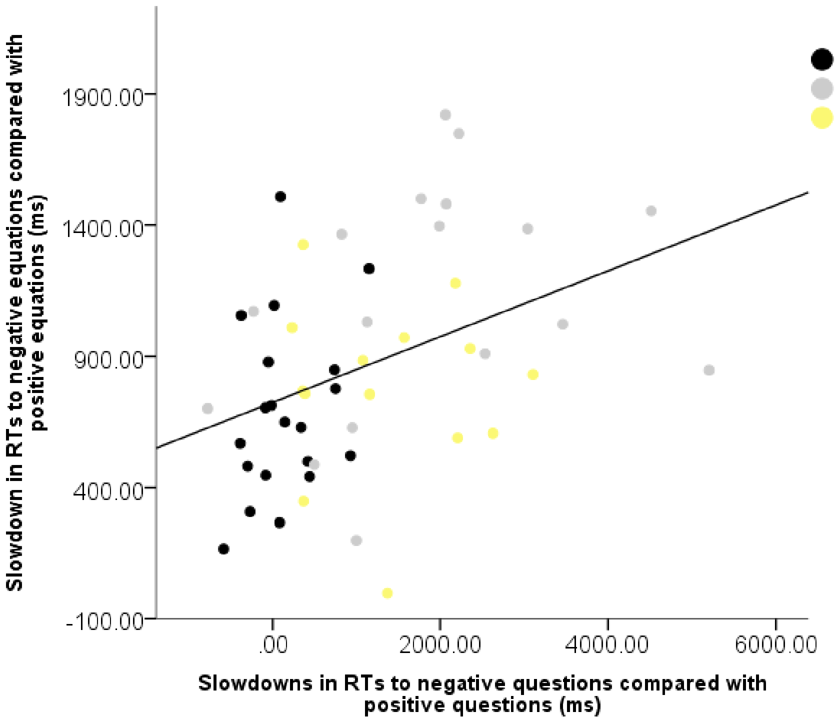


Figure 9. 3 Correlation between slowdowns in RTs to negative equations compared with positive equations and slowdowns in RTs to negative questions compared with positive questions.

To test the relationship between bilinguals' slowdowns in RTs to negative equations compared with positive equations and the language of instruction, Spearman's rank correlation coefficients were computed. Using the Spearman's rank correlation coefficients instead of the Pearson product-moment correlation coefficients is because the language of instruction is a categorical variable, either English or Chinese. No significant correlation was found between bilinguals' slowdowns in RTs and the language of instruction, *rho* (20) = .069, *p* = .771.

9.2.4. Discussion

9.2.4.1. Processing negative equations in bilinguals

This experiment set out to investigate the extent to which acquisition of the polarity-based answering system changes Chinese-English bilinguals' processing of negation in a nonverbal context. On the between-group level, there was no contrast between bilinguals and English speakers when they processed negative equations. However, bilinguals showed a reaction-time advantage over Chinese speakers when they processed negative equations. On the within-group level, it took bilinguals longer to respond *agree* than *disagree* to negative equations. These findings go against the hypothesis that bilinguals take the L1-specific route when they process negation in a nonverbal context. Instead, these results give support to the hypotheses that acquisition of the polarity-based answering system changes bilinguals' processing of negation in a nonverbal context.

Bilinguals tended to process negative equations in one step like English speakers. In comparison to Chinese speakers, bilinguals were slowed down less by negative equations compared with positive equations. A large body of empirical evidence suggests that processing a negative statement is more difficult than processing a positive statement because the former incurs an additional step (Carpenter & Just, 1975; Clark & Chase, 1972; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al, 2006, 2007; Lüdtke et al., 2008; Tian et al., 2010). In light of this view, the shorter slowdown in bilinguals compared to Chinese speakers suggests that bilinguals have a weaker tendency to take two steps which incurs an additional cost when they processed negative equations. For an illustration of the two steps in Chinese speakers when processing negative equations, if the stimulus is 'triangle-unequal-square', the first step would be to verify the positive equation 'triangle-equal-square' is false, and subsequently reverse the truth value of the positive equation to verify that 'triangle-unequal-square' is true in the second step. With the tendency to take two steps to process negative equations drops, bilinguals are likely to use one step to process negation. This argument is built on recent empirical evidence showing that speakers of the polarity-based system can process negation immediately (Nieuwland & Kuperberg, 2008; Orenes et al., 2014; Tettamanti et al., 2008; Tian et al., 2010, 2016). To illustrate the one step when processing negative equations, if the stimulus is 'triangle-unequal-square', the negative equation 'triangle-unequal-square' would be processed directly without processing the corresponding positive equation 'triangle-equal-square'. Recall that English speakers are argued to process negative equations in a one step (see chapter 6). Since bilinguals also tend to process negation immediately in one step, it is not surprising that in comparison to English speakers, bilinguals were not slowed down more by negative equations compared with positive equations.

It is important to readdress here that one-step vs. two-step processing of negation is more likely to be a tendency rather than a strict rule. Although the claim here is that bilinguals, like English speakers, tend to take one step to process negation, this is not to say that they do not process negation in two steps via the corresponding positive counterpart at all. This is because there are two universal features observed in all the three groups though contrasts were found between bilinguals and Chinese speakers when they processed negative equations. The first commonality is that it took bilinguals, English speakers and Chinese speakers longer to process negative equations compared with positive equations. Processing negative sentences incurs an additional step compared to processing positive sentences, and thus the former takes longer (e.g., Fischler et al., 1983; Kaup et al, 2006, 2007). Considering this view, if bilinguals had not used two steps to process negation, it would have taken them a similar amount of time to process negative equations and positive equations. The second common feature shared by bilinguals, English speakers and Chinese speakers is that it took every language group longer to respond *agree* than *disagree* to a negative equation. However, it took every language group shorter to respond *agree* than *disagree* to a positive equation. Built on Clark and Chase (1972), this finding indicates the use of two negations when *agreeing* with a negative equation. In other words, it suggests that bilinguals, English speakers and Chinese speakers could take two steps to process negative equations. Still, based on the contrasts observed between bilinguals and Chinese speakers, this study is arguing that, compared with Chinese speakers, bilinguals have shifted towards having a greater tendency to process negative negation in one step during equation verification. In comparison to English speakers, bilinguals have a similar tendency to process negative equations in one step since there was no between-group contrast.

9.2.4.2. Explanations for processing negative equations in one step in bilinguals

One plausible explanation for using the L2-specific processing of negation during equation verification by bilinguals is that acquisition of the polarity-based answering system offers a cognitive shortcut and changes their L1-specific habitual processing. Supporting this argument, previous Expt. 6, which tested the processing of negative questions in bilinguals, revealed that the L1-based processing of negation in negative questions is partially restructured in the minds of Chinese-English bilinguals. Here in a comparable nonverbal context, bilinguals also diverged from Chinese speakers when they processed negative equations. Furthermore, on the individual-level, there was a significant positive correlation between the slowdowns when participants answered negative questions and the slowdowns when they verified negative equations. This positive correlation suggests that bilinguals who shifted towards processing negative questions in one step and thus were slowed down less by negative questions are more likely to take one step when they process negative equations as well. This positive correlation gives more empirical support to the claim that the restructured processing of negation in bilinguals extends from verbal to nonverbal contexts.

The positive correlation between bilinguals' approximation to L2-based performance in a verbal context and a comparable nonverbal context is in line with Athanasopoulos (2009) and Vanek and Selinker (2017). However, regarding the other variables that have been argued to affect bilinguals' cognition, Chinese-English bilinguals' processing of negation did not shift from L1-specific (two steps) to L2-specific (one step) as a function of L2 proficiency (Athanasopoulos & Kasai, 2008; Park and Ziegler, 2014), age of the L2 acquisition (Kersten et al., 2010; Pavlenko & Malt, 2011), frequency of L2 use (Athanasopoulos et al., 2011) or the language of instruction (Bylund & Athanasopoulos, 2017). This is arguably because, as Vanek and Selinker (2017) pointed out, the backgrounds of the bilinguals in this study are highly similar. For example, Kersten et al. (2010) and Pavlenko and Malt (2011) reported the effect of the age of the L2 acquisition on the performance of bilinguals. While these two studies tested early bilinguals who began to learn English before the age of 5 and late bilinguals, in this experiment, all the bilinguals began to learn L2 English after the age of 5. Another possible reason, according to Bylund (2010), is that self-reported frequency of L1/L2 use as a general percentage is not reliable though many studies used this method (e.g., Athanasopoulos et al., 2011). As for language of instruction, the result that this factor did not correlate with bilinguals' performance may suggest restructuring at the conceptual level rather than semantic transfer. No matter which language is used, bilinguals followed the English-like route to process negative equations.

This experiment contributes to existing empirical evidence with nonverbal tasks (e.g., Athanasopoulos, 2009; Athanasopoulos & Kasai, 2008; Bylund & Athanasopoulos, 2017; Park & Ziegler, 2014; Vanek & Selinker, 2017) showing that acquisition of L2-specific linguistic patterns can change bilinguals' behaviours from monolingual speakers of their L1 in nonverbal contexts. For example, in a comparable study on the processing of time, Bylund and Athanasopoulos (2017) revealed that Swedish speakers were consistently interfered by the length of linear stimuli when they estimated durations (i.e., Swedish speakers tended to think longer lines have longer durations) while Swedish-Spanish bilinguals were interfered either by the length of linear stimuli or the volume of container stimuli depending on their language mode. Furthermore, this experiment gives new empirical support from bilinguals to the *linguistic relativity* hypothesis that language-entrained processing routines play an important role beyond verbal contexts. This argument is based on the view advocated by Odlin (2005) that if cognition varies in accordance with people's language, acquisition of the L2-specific linguistic patterns can change bilinguals' thinking from being L1-based towards L2-based not only in a verbal context, but also in a nonverbal context.

Another explanation for bilinguals' advantage in processing negative equations over Chinese speakers is that bilinguals are good at processing mismatching information. A great amount of empirical evidence suggests that speaking more than one language gives rise to better executive control in bilinguals (e.g., Bialystok & Craik, 2010; Bialystok, Klein, Craik, & Viswanathan, 2004; Antoniou, Grohmann, Kambanaros, & Katsos, 2016). For an illustration, Bialystok et al. (2004) revealed that it took bilinguals shorter than monolinguals speakers to press a relevant button when its position was incongruent with that of the corresponding stimulus on the screen (i.e., a smaller Simon effect for bilinguals compared with monolingual speakers). The advantage in bilinguals' executive control may help them process negative equations faster in this experiment. However, this view cannot explain why bilinguals processed negative equations only faster than Chinese speakers. In contrast, bilinguals processed negative equations like English speakers, which is a strong indication of using L2-specific processing of negation. To tease apart bilingualism effects from shift to an easier routine, future studies can benefit from testing English learners of Chinese in the agree-disagree task. If bilinguals' better executive control gives rise to their advantage at processing unequal equations, English learners would outperform both English and Chinese speakers. Alternatively, if bilinguals shift towards an easier route, English learners of Chinese would only outperform Chinese speakers but not English native speakers.

The third explanation for the L2-based processing of negative equations in bilinguals is associated with their acquisition of the English-specific verbal labelling of the unequal symbol. Recall that in the explanation of the crosslinguistic contrasts between English and Chinese speakers during equation verification (see chapter 6), an alternative account was that the different verbal labels for the unequal symbol in English and Chinese instead of the different answering systems may give rise to language-specific patterns in the nonverbal task. Here, it is also possible that the use of the English-specific processing of negation in bilinguals is related to their acquisition of the expression *unequal* in English. Lexical negation (e.g., *unequal*) has been reported to be processed faster than negative particles (e.g., *not equal*) (Sherman, 1973, 1976; Giora et al. 2004; Kaup et al., 2006). In light of this view, bilinguals could process negative equations faster because they silently verbalized the lexical negation *unequal* while Chinese speakers silently verbalized *bu deng yu* 'not equal'. Like English speakers, the availability of two alternative ways to express the unequal symbol (i.e., *unequal* and *not equal*) could provide bilinguals with greater flexibility in processing negation compared with Chinese speakers, whose verbal label of the unequal symbol is more constraining (i.e., only with a negative particle). If verbal labelling was used in silence to solve the task of equation verification, then it cannot be ruled out that in the nonverbal task participants used "language as a strategy" (Kousta et al., 2008). However, the explanatory power of silent verbalization is undermined by the finding that bilinguals, regardless of language context, showed English-like performance when they verified negative equations. If the view of Kousta et al. (2008) is correct that participants used language as a strategy in nonverbal contexts, bilinguals should have shown language-specific performance in different language context.

9.2.4.3. Limitations

There are some questions left unanswered. First, the design of Expt. 7 cannot separate the comprehension of negative equations from the verification of negative equations. It is possible that bilinguals' answering part rather than the processing part is restructured. Second, it cannot be ruled out that the two alternative ways to express the unequal symbol (i.e., *unequal* and *not equal*) provide bilinguals with greater flexibility in processing negation, which helped them to process negative equations faster. Regarding the first limitation, the next experiment tests the way in which bilinguals process the critical unequal symbol with the verification of negation.

9.3. Experiment 8. Bilinguals' versus English and Chinese monolinguals' processing of negation in a nonverbal facilitation experiment

Bilinguals processed the '≠' symbol like English speakers while differed from Chinese speakers during equation verification in previous Expt. 7. To further investigate whether this result would hold when there is no negation verification involved, here in Expt. 8, bilinguals processed the '≠' symbol during shape congruence judgement. Bilinguals still saw positive/negative equations with the '≠'/ '=' symbols (e.g., 'triangle-unequal-triangle'). Instead of verifying the equations, the task was to judge whether the two shapes were the same or not. The '≠'/'=' symbols were expected to serve as an facilitator/inhibitor during shape congruence judgement in the sense that their presence can accelerate/decelerate the response speed. The '='/ '≠' symbols were assumed to be processed by participants here in light of Bylund and Athanasopoulos (2017), Casasanto (2016) and Casasanto et al. (2004). In those three studies, participants were found to automatically process the length and volume of the stimuli which were irrelevant for the target estimation of duration. Also, the '≠'/ '=' symbols were put between the two shapes so that it was difficult for participant to ignore them. Symbol-free trials (e.g., 'triangle-no-symbol-triangle') were included to serve as a baseline for testing the effect of the '≠'/ '=' symbols on shape congruence judgement.

If the argument for Expt. 7 holds that bilinguals shifted from habitually processing negation in two steps (i.e., first process the positive statement and then process the negative statement) typical of Chinese speakers towards processing negation in one step typical of English speakers, the effect of the '≠' on shape congruence judgement in bilinguals would resemble that in English speakers but differ from that in Chinese speakers. Specifically, if bilinguals tend to process negation in one step in the nonverbal context like English speakers, the presence of the '≠' symbol would slow them down more when they judge that two shapes are the same compared to the symbol-free trials. To illustrate, it would take bilinguals longer to judge the two shapes are the same when the stimulus is 'triangle-unequal-triangle' compared to when the stimulus is 'triangle-no-symbol-triangle'. Also, when bilinguals judge that the two shapes are different, the presence of the '≠' symbol would prime faster responses in them compared to the symbol-free trials. To illustrate, it would take bilinguals shorter to judge the two shapes are different when the stimulus is 'triangle-unequal-square' compared to when the stimulus is 'triangle-no-symbol-square'.

Alternatively, bilinguals can use two steps to process negation like Chinese native speakers. If this hypothesis holds, the effect of the '≠' on shape congruence judgement in bilinguals would resemble that in Chinese speakers but differ from that in English speakers. Specifically, if bilinguals, like Chinese native speakers, tend to process the positive equation in the first step and then process the negative equation, the presence of the '≠' symbol would not decelerate the response speed of bilinguals when they judge that the two shapes are the same in 'triangle-unequal-triangle' compared to ‘triangle-no-symbol-triangle’. Neither would the presence of the ‘≠’ symbol accelerate their response speed when they judge that the two shapes are different in ‘triangle-unequal-square’ compared to ‘triangle-no-symbol-square’.

9.3.1. Participants

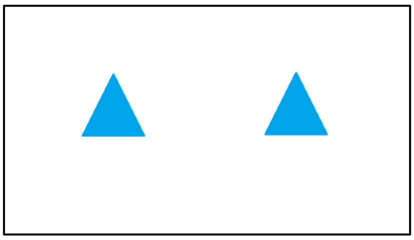
20 Chinese-English bilinguals (19 females) took part in this experiment. All participants were recruited from a university in the UK at the time of testing. All participants were right-handed and reported no fluency in any language other than Chinese and English. The background information summary of the 20 bilinguals at the time of testing is shown in Table 9.4 including their age, time spent in the UK, frequency of speaking and writing English per day, age of onset of learning English as L2 and the level of English proficiency.

Table 9. 4 Bilingual participants background information in the facilitation task

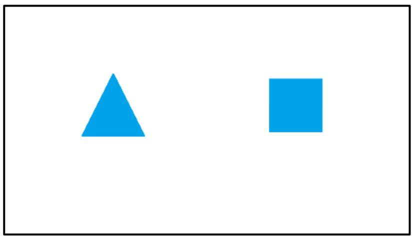
Measure	Mean (SD)
Age (years)	22.75 (1.02)
Time in the UK (months)	1.96 (0.93)
Daily speaking of English (%)	39.20 (21.66)
Daily writing of English (%)	51.05 (31.90)
Onset of learning English as L2 (years)	8.95 (2.52)
Oxford Placement Test score (maximum 100)	72.95 (9.30)

9.3.2. Materials and procedure

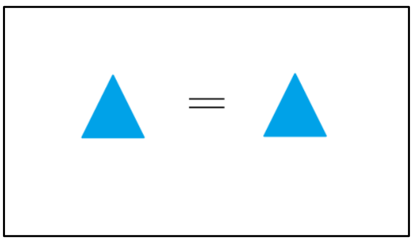
Materials for this experiment were identical with those used for Expt. 4 (see chapter 6), i.e., 24 distinct equations and 12 pairs of shapes without symbols (stimuli). The stimuli were formed by 8 blue-coloured shapes randomly selected from the 13 shapes used for Expt. 3. The shapes were combined with two symbols (i.e., the equal symbol '=' and the unequal symbol '≠') except for the 12 symbol-free trials. The combinations of shapes and symbols constituted six types of conditions (i.e., same-no-symbol, different-no-symbol, same-equal, different-equal, same-unequal and different-unequal) which are shown in Fig. 9.4 with the corresponding correct responses. The purpose of including symbol-free trials is to set a baseline for the verification of shape congruence without '=' and '≠' symbols. With the availability of this baseline, we can tell the effect of the '=' and '≠' symbols on the processing of same/different shapes (i.e., accelerate, slow down or no influence). Procedure of this experiment was also the same as that of Expt. 3 (see chapter 6). Bilinguals participants were instructed to judge whether the two shapes "are the same or not the same" as quickly as possible. When participants asked about the symbols '=' and '≠', the requirement of the task (i.e., to judge whether the two shapes are the same or not the same) would be reiterated orally. To counterbalance the language for instruction, following Park and Ziegler (2014), half of the bilingual participants were randomly assigned English instruction and the other half Chinese instruction.



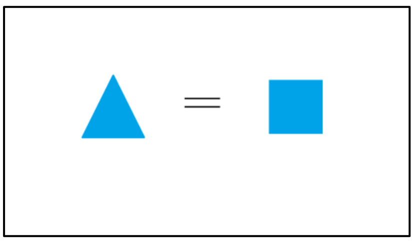
Same-no-symbol (↑)



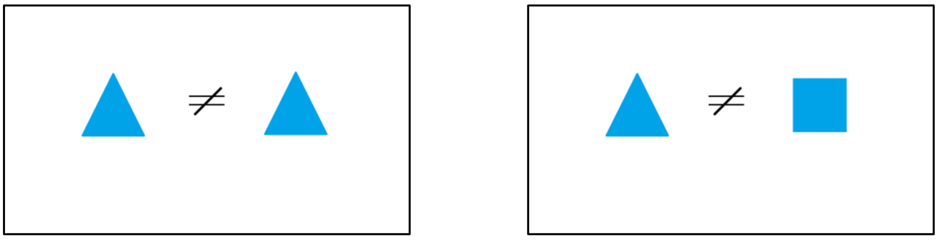
Different-no-symbol (↓)



Same-equal (↑)



Different-equal (↓)



Same-unequal (↑) Different-unequal (↓)

Figure 9. 4 Stimuli for Expt. 8 in each condition with correct responses in the brackets.

9.3.3. Results

Bilinguals' reaction times, once trimmed following the procedures reported in section 9.3.3.1, will be compared with the results of English and Chinese speakers tested earlier in Chapter 6 respectively. Then, correlations among bilinguals' slowdowns in RTs to judging different shapes compared with judging the same shapes, their background variables and the language of instruction will be presented.

9.3.3.1. Inclusion criteria for reaction times

Response accuracy was checked first and then RTs were analysed. The response accuracy of bilingual participants was 98.19%. Only RTs of correct responses were included in the analyses. Also, participants showed some sustained pauses when they made mistakes. As a result, 4 data entries (0.6% of total correct responses) for the trials during which the pauses happened were eliminated from all subsequent analyses. 21 data entries (3.0% of total correct responses) were more than 2.5 standard deviations away from the group mean in each condition and they were replaced by the cut-offs (group mean +/- 2.5 SDs). Figure 9.5 shows bilinguals' RTs in Expt. 8 together with the RTs of English and Chinese speakers tested in previous Expt. 4. In the condition without the equation symbol, bilinguals took 694 ms (SD = 208) on average to respond when the shapes were the same and 715 ms (SD = 176) on average when the shapes were different; in the condition with the equal symbol, it took bilinguals 669 ms (SD = 175) on average when the shapes were the same and 781 ms (SD = 296) on average when the shapes were different; in the condition with the unequal symbol, it took bilinguals 738 ms (SD = 227) on average to respond when the shapes were the same and 690 ms (SD = 183) on average when the shapes were different.

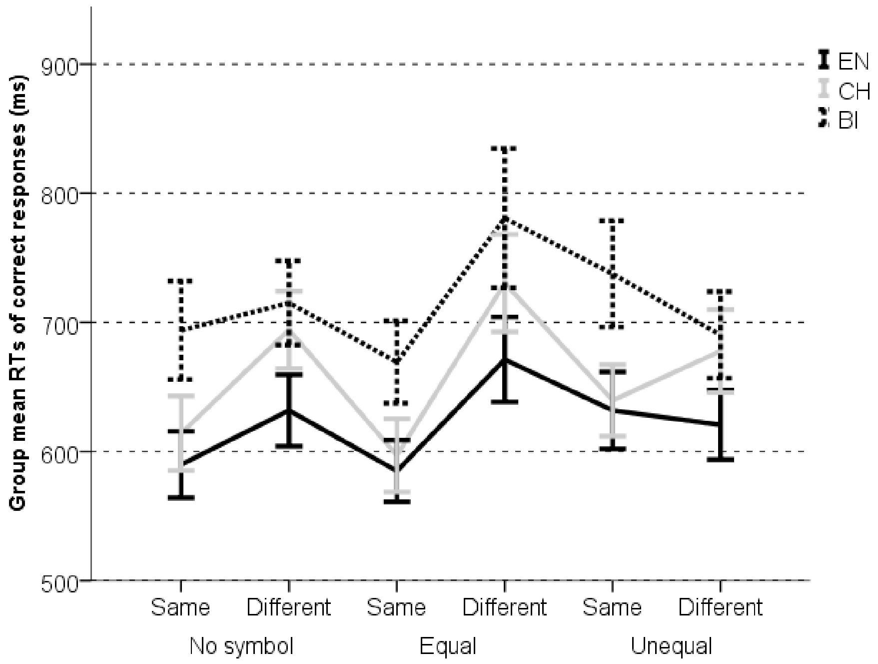


Figure 9. 5 Group mean RTs of correct responses given by bilingual participants in the nonverbal Expt. 8 and those of English and Chinese monolingual speakers in the nonverbal Expt. 4 (Error bars indicate the 95% confidence interval around the mean).

9.3.3.2. RTs of bilinguals in the facilitation task

RTs of bilingual participants together with RTs of English and Chinese participants were analysed using mixed-effects regression models with *Group* (English/bilinguals & Chinese/bilinguals), *Equation symbol* (no-symbol/equal/unequal) and *Sameness* (same/different) as fixed effect factors, *Participant* and *Item* as random effect factors. For the comparison between bilingual and English participants, the model was lmer (RT ~ equationsymbol * sameness +

sameness * group + (1|participant) + (1|item)). The same model was also used to compare the RTs of bilinguals and Chinese participants. The reason for building separate models was to compare the RT pattern of bilinguals with those of English and Chinese monolingual speakers respectively. Results are shown in Table 9.5.

Table 9. 5 Coefficients of a mixed effects model fitted to the RTs of bilinguals in the nonverbal Expt. 8 and those of English and Chinese monolinguals speakers in the nonverbal Expt. 4

BI and EN				
Fixed effects	Estimate	SE	t value	*p*
Intercept	768.94	29.20	26.33	< .001**
Equation symbol (no-symbol)	-52.78	13.56	-3.89	< .001**
Equation symbol (unequal)	-71.27	13.54	-5.26	< .001**
Sameness (same/different)	-93.88	15.61	-6.01	< .001**
Group (EN/BI)	-87.51	38.53	-2.27	.028*
Equation symbol (no-symbol) × sameness	68.98	19.18	3.60	< .001**
Equation symbol (unequal) × sameness	129.69	19.18	6.76	< .001**
Sameness × group	-11.80	15.66	-.75	.452
Random effects	Variance	SD		
Participants (intercept)	13624	116.72		
Item (intercept)	299	17.28		
BI and CH				
Fixed effects	Estimate	SE	t value	*p*
Intercept	768.60	29.36	26.18	< .001**
Equation symbol (no-symbol)	-51.36	14.75	-3.48	< .001**
Equation symbol (unequal)	-71.34	14.74	-4.84	< .001**
Sameness (same/different)	-96.00	16.97	-5.66	< .001**
Group (CH/BI)	-27.98	36.72	-.76	.450
Equation symbol	74.43	20.82	3.58	< .001**

(no-symbol) × sameness				
Equation symbol	130.24	20.83	6.25	< .001**
(unequal) × sameness				
Sameness × group	-54.59	17.00	-3.21	.001*
Random effects	Variance		SD	
Participants (intercept)	12030		109.68	
Item (intercept)	698		26.43	

RTs of bilinguals and RTs of English speakers were compared first. The intercept refers to the estimated mean RT of bilinguals processing two different shapes with the equal symbol. In terms of between-group comparisons, the only simple effect found significant was *Group*, which indicated that bilinguals spent longer than English speakers when they verified shape congruence. This may because the bilingual participants (mean age 22.75, range 4 years) were comparatively older than the English participants (mean age 20.30, range 5 years). Apart from this simple effect of *Group*, there was no other between-group difference found. This result revealed that the RT pattern of bilinguals when they processed shape congruence with/without equation symbols was similar to that of English speakers generally across conditions. As for within-group variables, there was a significant simple effect of *Equation symbol*, which demonstrated that the presence of an equation symbol slowed down English and bilingual participants compared to when there was no equation symbol. There was also a significant simple effect of *Sameness*. This simple effect showed that it took bilinguals and English speakers longer when the shapes were different compared to when the shapes were the same.

The model returned a significant interaction between *Sameness* and *Equation symbol*. In order to explain this interaction, a mixed-effects regression model was built with *Participant* and *Item* as random effect factors and *Equation symbol* as the fixed effect factor. The model lmer (RT ~ equationsymbol + (1|participant) + (1|item)) confirmed that, compared to the symbol-free trials, the presence of the '≠'

symbol significantly slowed down the judgement of two same shapes (Estimate = 42.48, *SE* = 13.45, *t* value = 3.16, *p* = .002) but did not significantly accelerate the judgement of two different shapes (Estimate = -17.95, *SE* = 11.25, *t* value = -1.60, *p* = .111). The same model also confirmed that, compared to the symbol-free trials, the presence of the '=' symbol significantly slowed down the judgement of two different shapes (Estimate = -51.55, *SE* = 15.36, *t* value = -3.36, *p* < .001) but did not significantly accelerate the judgement of two same shapes (Estimate = 16.14, *SE* = 11.19, *t* value = 1.44, *p* = .150). The RT pattern shared by English and bilingual participants indicated that the incongruence of *Sameness* and *Equation symbol* (e.g., 'triangle-unequal-triangle'/ 'triangle-equal-square') interfered with the formulation of responses for both bilinguals and English speakers. However, the congruence of *Sameness* and *Equation symbol* ('triangle-equal-triangle'/ 'triangle-unequal-square') did not prime faster responses for either language group.

Next, RTs of bilinguals in Expt. 8 were compared with those of Chinese speakers tested in Expt. 4. The intercept refers to the estimated mean RT of bilinguals processing two different shapes with the equal symbol. The mixed-effect model returned a significant simple effect of *Sameness*, which indicated that different shapes slowed down bilinguals and Chinese speakers more than the same shapes. Critically, unlike for the comparisons between bilinguals and English speakers, a significant interaction between *Sameness* and *Group* was found. As shown in Figure 9.5, this interaction revealed that it took bilinguals significantly shorter to process different shapes compared with the same shapes than Chinese speakers, even though both language groups were slowed down more by different shapes than the same shapes. In other words, for bilinguals, the processing of two different shapes was less difficult than for Chinese speakers. There was also a significant simple effect of *Equation symbol*, which demonstrated that the presence of an equation symbol slowed down Chinese and bilingual participants compared to when there was no equation symbol.

9.3.3.3. Exploratory analyses

Although the model did not describe an interaction among the three independent variables, Fig 9.5 indicated that the shorter slowdowns in bilinguals than Chinese native speakers when processing different shapes compared to the same shapes can be mainly accounted for by the different patterns in the unequal conditions. As exploratory, to further compare the patterns of bilinguals and Chinese speakers, a mixed-effects regression model was built with *Sameness* and *Group* as fixed effect factors and *Participant* and *Item* as random effect factors. The model lmer (RT ~ sameness * group + (1|participant) + (1|item)) confirmed that, in the unequal conditions, the patterns of bilinguals and Chinese speakers were significantly different (sameness * group: Estimate = -84.78, *SE* = 27.56, *t* value = -3.08, *p* = .002). With the presence of the '≠' symbol, while it took bilinguals shorter to judge that two shapes are different compared to judging that two shapes are the same, it took Chinese speakers longer to judge that two shapes are different compared to judging that two shapes are the same. The same model was also used to compare the patterns of bilinguals and Chinese speakers in the control conditions. In the symbol-free condition, bilinguals were slowed down less when judging two shapes are different compared to judging two shapes are the same than Chinese speakers (sameness * group: Estimate = -61.67, *SE* = 26.16, *t* value = -2.36, *p* = .019). This result might be suggestive that bilinguals were less likely to process negation in two steps which incurs additional processing cost compared to Chinese speakers. In the equal conditions, bilinguals did not significantly differ from Chinese speakers (sameness * group: Estimate = -19.98, *SE* = 32.62, *t* value = -0.61, *p* = .540). Importantly, these tentative results need further replication.

A significant interaction between *Sameness* and *Equation* was found. Considering the comparisons between bilinguals vs. English speakers and those between English vs Chinese speakers, the significant interaction indicated that the incongruence of shape and equation symbol (e.g., triangle-unequal-triangle/triangle-equal-square) slowed down both bilinguals and Chinese speakers. Also, the congruence of shape and equation symbol (triangle-equal-triangle/triangle-unequal-square) did not prime faster responses for either language group.

9.3.3.4. The impact of individual differences

Pearson product-moment correlation coefficients were computed to test the relationships between bilinguals' slowdowns in RTs to different shapes compared with the same shapes in the unequal conditions and their background variables including age of the L2 acquisition (L2 AoA), frequency of L2 speaking per day and frequency of L2 writing per day following Vanek and Selinker (2017). As for the relationship between bilinguals' L2 proficiency (OPT score) and their slowdowns in the facilitation task, Spearman's rank correlation coefficients were used because the OPT scores were not normally distributed (i.e., skewness= -1.725, kurtosis= 5.148). Spearman's *rho* was also used to examine the relationship between bilinguals' slowdowns and the categorical variable, language of instruction. As shown in Table 9.6, there was a positive correlation between the slowdowns in the unequal conditions and the age of L2 acquisition, r (20) = .444, p = .050. This result is shown in the scatterplot (see Figure 9.6). This significant correlation suggests that the earlier bilinguals started learning English as their second language, the faster they judged two shapes are different compared to judging two shapes are the same (or the slower they judged two shapes are the same compared to judging two shapes are different) with the presence of the '≠' symbol. No significant correlation was found between bilinguals' slowdowns in RTs and any of the other background variables.

Table 9. 6 Correlation matrix showing Pearson's *r* (L2 AoA, L2 speaking, L2 writing) and Spearman's *rho* (OPT, instruction) of bilinguals' slowdowns in RTs to judging different shapes compared with judging the same shapes in the unequal condition, their background variables and the language of instruction

	Slowdown	L2 AoA	OPT score	L2 speaking	L2 writing	Instruction
Slowdown	1	.444*	-.039	.164	.023	-.191
L2 AoA		1	-.328	.051	-.072	-.131
OPT score			1	-.209	-.196	.174
L2 speaking				1	.212	-.325
L2 writing					1	.070
Instruction						1

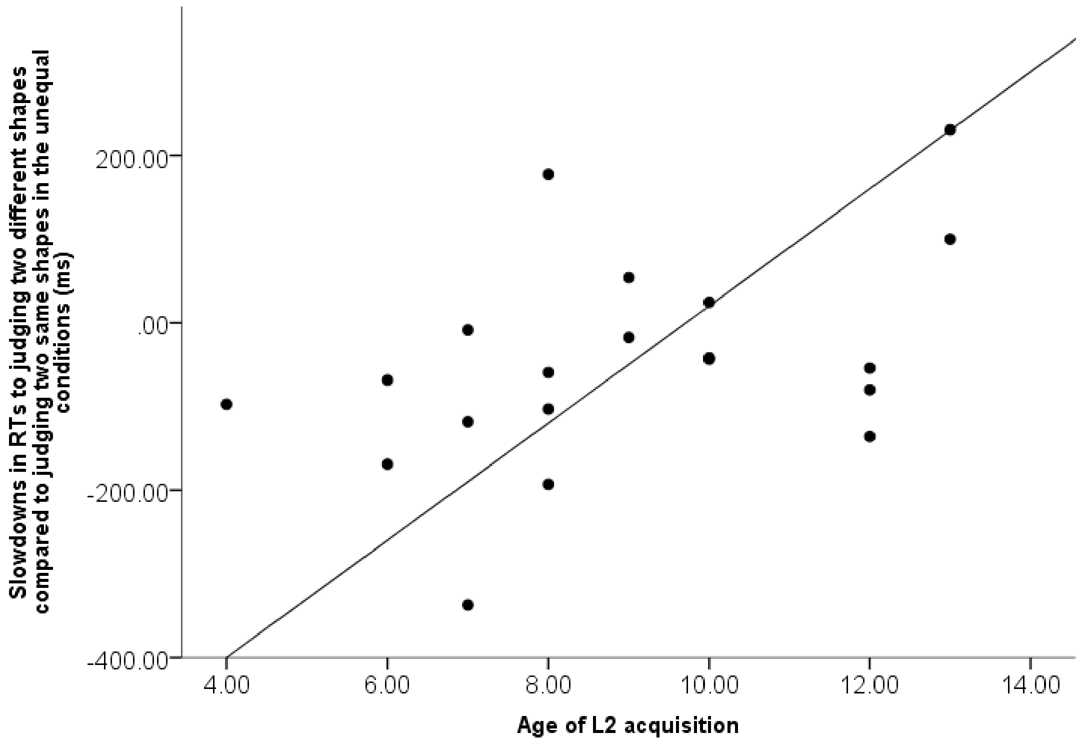


Figure 9. 6 Correlation between slowdowns in RTs to judging two different shapes compared with judging two same shapes and the age of L2 acquisition.

9.3.4. Discussion

This experiment set out to further explore the extent to which acquisition of the polarity-based answering system changes Chinese-English bilinguals' processing of negation in a nonverbal context. By testing the response speed of bilinguals when they judged sameness with the '≠' symbol, this experiment found that, the effect of the '≠' symbol on shape congruence judgement was stronger for bilinguals compared to that for Chinese native speakers. In contrast, the effect of the '≠' symbol on shape congruence judgement was comparable for bilinguals and English native speakers. These findings give support to the hypothesis that the L1-specific processing of negation in bilinguals is restructured.

9.3.4.1. Processing the '≠' symbol during shape congruence judgement in bilinguals

Bilinguals tended to take one step like English speakers when they processed the '≠' symbol put in an equation during shape congruence judgement. The experimental evidence for this argument is that the effect of the '≠' symbol on shape congruence judgement was stronger for bilinguals compared to that for Chinese native speakers. To illustrate, resembling English speakers, when the shapes were presented with the '≠' symbol, it took bilinguals longer to judge that two shapes are the same (e.g., 'triangle-unequal-triangle') compared to judging that two shapes are different (e.g., 'triangle-unequal-square'). In contrast, as observed in Expt. 4, even with the presence of the '≠' symbol, it still took Chinese speakers shorter to judge that two shapes are the same ('triangle-unequal-triangle') compared to judging that two shapes are different ('triangle-unequal-square'). With regards to bilinguals, the presence of the '≠' symbol in an equation slowed down their response speed when they judged that two shapes are the same. For example, it took bilinguals longer to judge that the two shapes are the same when the stimulus was 'triangle-unequal-triangle' compared to when the stimulus was 'triangle-no-symbol-triangle'. The interpretation for the interference from the '≠' symbol on shape congruence judgement is that bilinguals processed the '≠' symbol put in an equation in one step. This interpretation is in line with the view that negation can be processed in one step (Dale & Duran, 2011; Nieuwland & Kuperberg, 2008; Orenes et al., 2014; Tettamanti et al., 2008; Tian et al., 2010, 2016). Considering the argument for the two-step model (Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983; Kaup et al, 2006, 2007; Lüdtke et al., 2008), if bilinguals had not processed the '≠' symbol put in an equation immediately in one step, the presence of the '≠' symbol would not decelerate their response speed when judging that two shapes are the same. With a greater tendency to process negation in one step, bilinguals were interfered more by the '≠' symbol when they judged shape congruence compared to Chinese native speakers. In comparison to bilinguals, Chinese native speakers were not interfered by the '≠' symbol so much that it still took them shorter to process 'triangle-unequal-triangle' compared to 'triangle-unequal-square'. As discussed in Chapter 6, the explanation for a weaker effect of the '≠' symbol on shape congruence judgement in Chinese speakers is that when processing a negative equation such as 'triangle-unequal-triangle', Chinese speakers tend to first process its positive counterpart 'triangle-equal-triangle' before they process 'triangle-unequal-triangle'.

With regards to the finding that bilinguals were slowed down more when they processed 'triangle-unequal-triangle' compared to 'triangle-no-symbol-triangle', instead of processing the '≠' symbol in one step which interfered with subsequent response, an alternative explanation is that there is more information in 'triangle-unequal-triangle'. However, it was also found that bilinguals processed the arguably more loaded 'triangle-unequal-square' as fast as they processed 'triangle-no-symbol-square'. Then one may further argue that the presence of the '≠' symbol can prime faster responses for 'triangle-unequal-square', which compensates the longer slowdowns caused by processing additional information. Nonetheless, if the '≠' symbol can prime faster responses for 'triangle-unequal-square', then we are back to the argument that it takes bilinguals one step to process the unequal symbol otherwise there would be no facilitation effect. It appears that the account for varied cognitive load of information underlying different slowdowns during shape congruence judgment is unlikely to hold true alone. This account, together with the argument for taking one step to process the '≠' symbol can explain the response speed of bilinguals.

9.3.4.2. Explanations for processing the '≠' symbol in one step in bilinguals

Bilinguals' use of English-specific route when they processed the '≠' symbol during shape congruence judgement can be linked to the acquisition of the polarity-based system that changes their L1-specific habitual processing. The previous *yes/no* choice experiment (Expt. 6) showed that the L1-based processing of negation is partially restructured in the minds of Chinese-English bilinguals when they processed negative questions. Here in Expt. 8, when processing negation in a nonverbal context, bilinguals were interfered more by the '≠' symbol compared to Chinese speakers, which is interpreted as evidence for a greater tendency to use one step to process negation in bilinguals. According to previous studies arguing for restructuring of L1-specific concepts in bilinguals (Athanasopoulos, 2009; Athanasopoulos & Kasai, 2008; Athanasopoulous et al., 2011; Cook et al., 2006), acquisition of the L2-specific linguistic patterns can change bilinguals' thinking from being L1-based towards becoming L2-based not only in a verbal context, but also in a nonverbal context. In light of this view, the claim here is acquisition of the polarity-based system trains bilinguals to process negation in a new way (one step) when they process negative questions, and this novel route becomes routinised in the minds of bilinguals with L2 context, extending to the processing of the '≠' symbol in a nonverbal context.

Acquisition of L2-specific verbal expressions can change bilinguals' mental processing. Testing the *linguistic relativity* hypothesis that languages direct their speakers to process information differently in a nonverbal context, recent studies examined bilinguals with nonverbal tasks (Athanasopoulos, 2009; Athanasopoulos & Kasai, 2008; Athanasopoulous et al., 2011; Athanasopoulos et al., 2015; Bylund & Athanasopoulos, 2017; Cook et al., 2006; Kersten et al., 2010; Park & Ziegler, 2014; Vanek & Selinker, 2017). These studies showed that bilinguals' behaviours can diverge from monolingual speakers of their L1 while they resemble that of native speakers of their L2 in a nonverbal context due to L2 acquisition. For example, in a related study in the domain of grammatical number, Athanasopoulos and Kasai (2008) investigated the conceptual changes in Japanese learners of English as a result of their acquisition of the grammatical number. The researchers instructed Japanese learners to categorize solid objects presented in triads (e.g., a metal nail, a scrap of metal and a wooden pencil). Results showed that advanced bilinguals showed English-specific pattern with greater tendency to categorize objects by shape than Japanese speakers (e.g., Consider a metal nail more similar to a wooden pencil compared to a scrap of metal). Comparably, in Athanasopoulous et al. (2011), Japanese-English bilinguals and two monolingual control groups were instructed to rate the similarity between two coloured stimuli which either fell into the category of *mizuiro* ‘light blue’ or *ao* ‘dark blue’. Like English speakers but differing from Japanese speakers, bilinguals did not show distinction between the light-blue shade in the category *mizuiro* and the dark-blue shade in the category *ao*. The findings in these two studies were interpreted as evidence that L1-specific categorization is restructured in bilinguals. Here, in the nonverbal context when processing the ‘≠’ symbol during shape congruence judgement, Chinese-English bilinguals shifted from using two steps to process negation typical of Chinese speakers, towards using one step typical of English speakers. Following Athanasopoulos and Kasai (2008) and Athanasopoulous et al. (2011), this pattern is argued to arise because the way in which bilinguals habitually process negation is restructured under the influence of the L2.

Instead of restructuring of L1-based processing, one alternative explanation for processing ‘triangle-unequal-square’ faster than ‘triangle-unequal-triangle’ in bilinguals is that they have better executive control, which helped them process incongruent information (i.e., triangle is not a square) faster than Chinese monolingual speakers. This explanation is built on previous empirical evidence suggesting the cognitive advantage of bilinguals compared with monolingual speakers (Bialystok & Craik, 2010; Bialystok, et al., 2004; Antoniou et al., 2016). Again, the flaw with this argument discussed in Expt. 7 also holds here. If this explanation holds true, bilinguals are likely to be slowed down by 'triangle-unequal-square' less than both English and Chinese speakers. However, the result was that bilinguals resembled English speakers when they processed 'triangle-unequal-square' compared to 'triangle-unequal-triangle'. It gives support to the argument of this study for domain-specific restructuring rather than a general cognitive advantage associated with bilingualism.

Another possible explanation for the L2-based processing of the '≠' symbol during shape congruence judgement in bilinguals is associated with the acquisition of L2-specific verbal labelling. The '≠' symbol can be verbally expressed in English by the use of the lexical negation *unequal* and the negative particle *not equal,* there is no direct one-to-one translation equivalent to *unequal* in Chinese. In Chinese, the '≠' symbol can only be verbally expressed as *bu deng yu* 'not equal'. There is empirical evidence suggesting that negative information is processed faster when lexical negation (e.g., *unequal*) is used compared with when a negative particle (e.g., *not equal*) is used (Giora et al., 2004; Kaup et al., 2006; Sherman, 1973, 1976). In light of this view, bilinguals could process the '≠' symbol faster because they silently verbalized the lexical negation *unequal* while Chinese speakers silently verbalized *bu deng yu* 'not equal'. If verbal labelling was used in silence to solve the task of shape congruence judgment, then it cannot be ruled out that in the nonverbal task participants used "language as a strategy" (Kousta et al., 2008). However, as discussed earlier in Expt.7, if the view of silent verbalization of language-specific verbal labels holds true, bilinguals should have shown L1-like and L2-like performance in corresponding language contexts. What was found is that bilinguals, regardless of language context, showed English-like performance when they processed the '≠' symbol during shape congruence judgement.

It is important to readdress here that the one-step vs. two-step routes are tendencies rather than strict rules. In the control condition (i.e., trials with the '=' symbol and the symbol-free trials), it still took bilinguals longer to judge that two shapes are different compared to judging two shapes are the same. This pattern is comparable to English and Chinese native speakers. One explanation for the greater cognitive difficulty in processing shape incongruence is that bilinguals did not use one step exclusively to process two different shapes. Rather, they can process different shapes in two steps, which incurs additional processing cost. The use of two steps in bilinguals when they verified negative equations in previous Expt. 7 gives support to this explanation. Another explanation is that bilinguals may process 'triangle is different from square' exclusively in one step, and this one step for processing negation takes longer than the one step for processing 'triangle is the same as triangle'. This explanation builds on the finding from previous (e.g., Clark & Chase, 1972) and current research that it is more difficult to process positive stimuli when the state of affairs is false than when it is true even though both are carried out within one step in terms of the explanation advocated in this thesis.

9.3.4.3. Limitations

This experiment cannot rule out the possibility that, instead of habitual change, the relatively stronger effect of the '≠' symbol on shape congruence judgement in bilinguals compared to Chinese native speakers is associated with greater cognitive flexibility provided by using different verbal labelling of *unequal/not equal*. Further studies would benefit from employing nonverbal negation-denoting stimuli with direct one-to-one translation equivalents in English and Chinese (e.g., *wrong/cuo* 'wrong'). Alternatively, further studies may test other polarity-based and truth-based languages that have a direct one-to-one translation equivalent to label the unequal symbol. Also, this experiment does not provide conclusive evidence for the greater difficulty underlying the processing of 'triangle is different from square' compared to 'triangle is the same as triangle' in bilinguals. It is possible that bilinguals did not use one step exclusively to process negation; or bilinguals may process 'triangle is different from square' exclusively in a one step, and this one step for processing negation takes longer than the one step for processing the corresponding positive counterpart. It will be helpful for further studies to test the eye-movement of bilinguals when they process different shapes to check whether there is extended gaze at the same shapes.

Chapter 10. General discussion and conclusions

10.1. Conclusions

Yes/no answers to negative questions in English and Chinese substantially differ.

The reason is that, when answering negative questions, Chinese speakers typically attach negation to the statement of the question and respond to the negative statement i.e., *Doesn't she like cats?* -> 'Is it true that [she doesn't like cats]' while English speakers typically attach negation to the polarity of the question and respond to the positive proposition i.e., *Doesn't she like cats?* -> 'Is it true or not that [she likes cats]'. Different attachment of negations is associated with varied routines when English and Chinese speakers process negation. Furthermore, by acquiring the English answering system, Chinese learners of English were redirected in the way they process negation, from taking two steps via the positive statement typical of Chinese speakers to taking the one-step shortcut like English speakers. With the processing of negation in focus, this study investigates the impact of language on thinking by examining the responses and reaction times of English and Chinese monolingual speakers and Chinese-English bilinguals when they answer negative questions. This study also examines the reaction times of the three language groups when they process the unequal symbol '≠' during equation verification and shape congruence judgment. Results of this study revealed that the responses of Chinese speakers to negative questions significantly differed from those of English speakers. Also, it took Chinese speakers significantly longer compared to English speakers to process negations when answering negative questions, verifying negative equations (e.g., triangle-unequal-square) and processing the unequal symbol '≠' during shape congruence judgment. Regarding Chinese-English bilinguals, their responses and response speed were found in-between those of English and Chinese speakers when answering negative questions. Bilinguals also showed similar slowdowns compared to English speakers when processing the unequal symbol '≠' during the verification of negative equations and during shape congruence judgement while it took Chinese speakers comparatively longer. The implications of these results for research on the processing of negation, *linguistic relativity* and bilingualism are discussed in this chapter alongside with limitations of the current exploration and suggestions for future studies.

10.2. The processing of negation

10.2.1. Proposed mechanism for the processing of negation in negative questions

This study proposes an underlying mechanism that explains the greater difficulty to process negative questions in Chinese speakers compared to English speakers. This mechanism is built on language-specificity in the processing of negation in negative questions. While it takes Chinese speakers two steps to process negation in Chinese negative questions, it only takes English speakers one step to process negation in English negative questions. To illustrate, in response to *Doesn't she like cats?*, when the case is that she likes cats, English speakers attach negation to the polarity of the question, and answer *yes* to the question in one step, i.e., 'Is it true or not that [she likes cats]) -> 'It is true', i.e., *Yes (she likes cats*). In truth-based Chinese, speakers attach negation to the statement of the question *Doesn't she like cats?* -> 'Is it true that [she doesn't like cats]'. To answer *no* to the negative statement, Chinese speakers first process the corresponding positive statement of the negative question 'Is it true that [she likes cats]'-> 'It is true'. Then the additional processing operation is a reversal of the truth value of the positive statement 'It is false that [it is true]', i.e., *No (she likes cats)*.

Analogously, when the question is *Doesn't she like cats?* and the case is that she doesn't like cats, English speakers answer *no* in one step, i.e., 'Is it true or not that [she likes cats]) -> 'It is false', i.e., *No (she doesn't like cats)*. In contrast, Chinese speakers answer *yes* in two steps, first, they process the corresponding positive statement of a negative question 'Is it true that [she likes cats]'-> 'It is false', and second, they reverse the truth value of the positive statement 'It is false that [it is false]', i.e., *Yes (she doesn't like cats)*. Following this mechanism, the *yes* answer to a negative question in Chinese rests on two negations, which incurs an additional processing cost. This two-step mechanism when Chinese speakers process negative questions is in line with Choi (1991), who also attributed greater difficulty in the truth-based vs the polarity-based system to an additional processing operation in the former. The mechanism for processing negation in negative questions are summarized in Table 10.1.

Table 10. 1 Mechanism for processing negation in English and Chinese speakers

Stimuli	Response	Group	Mechanism
Negative questions (*Doesn't she like cats?*)	yes	EN	'Is it true or not that [she likes cats]) -> 'It is true', i.e., *Yes (she likes cats*)
		CH	1st step: 'Is it true that [she likes cats]'-> 'It is false'; 2nd step: 'It is false that [it is false]', i.e., *Yes (she doesn't like cats)*
	no	EN	'Is it true or not that [she likes cats]) -> 'It is false', i.e., *No (she doesn't like cats)*
		CH	1st step: 'Is it true that [she likes cats]'-> 'It is true'; 2nd step: 'It is false that [it is true]', i.e., *No (she likes cats)*
Negative equations ('triangle-unequal-triangle'/ 'triangle-unequal-square')	agree	EN	'triangle-unequal-square'
		CH	1st step: 'triangle-equal-square' 2nd step: 'triangle-unequal-square'
	disagree	EN	'triangle-unequal-triangle'
		CH	1st step: 'triangle-equal-triangle' 2nd step: 'triangle-unequal-triangle'

<table>
<tr><td rowspan="4">Negative equations (‘triangle-unequal-triangle’/ ‘triangle-unequal-square’)</td><td rowspan="2">same</td><td>EN</td><td>‘triangle-unequal-triangle’</td></tr>
<tr><td>CH</td><td>1st step: ‘triangle-equal-triangle’
2nd step: ‘triangle-unequal-triangle’</td></tr>
<tr><td rowspan="2">different</td><td>EN</td><td>‘triangle-unequal-square’</td></tr>
<tr><td>CH</td><td>1st step: ‘triangle-equal-square’
2nd step: ‘triangle-unequal-square’</td></tr>
</table>

10.2.2. The processing of negative equations

The one-step versus two-step mechanisms for processing of negation in the polarity-based English and the truth-based Chinese can extend to explain the crosslinguistic differences found in the nonverbal context. When processing negative equations, English speakers showed faster response speed compared to Chinese speakers. Analogously to the processing of negative questions, this finding suggests a greater tendency to use one step to process negation in English speakers. For an illustration, if the stimulus is ‘triangle-unequal-square’, English speakers would process the negative equation ‘triangle-unequal-square’ directly without processing the corresponding positive equation ‘triangle-equal-square’. The argument that English speakers can process negation in one step is in line with Dale and Duran (2011), Nieuwland and Kuperberg (2008) and Tian et al. (2010, 2016). In contrast, the relatively slower response speed in Chinese speakers suggests that they tend to process the same negative equation in two steps i.e., via the positive equation ‘triangle-equal-square’ in the first step, and subsequently reversing the truth value of the positive equation to process ‘triangle-unequal-square’ in the second step. Analogously, if the stimulus is ‘triangle-unequal-triangle’, English speakers would process the negative equation ‘triangle-unequal-triangle’ in one step without processing the corresponding positive equation ‘triangle-equal-triangle’. Unlike English speakers, Chinese speakers are likely to first process the positive equation ‘triangle-equal-triangle’ and then process the negative equation ‘triangle-unequal-triangle'. The mechanisms for processing negation during equation verification in English and Chinese speakers is summarized in Table 10.1.

10.2.3. The processing of the unequal symbol '≠' during shape congruence judgment

The one-step versus two-step routes for processing negation in the polarity-based English and the truth-based Chinese also hold in the nonverbal facilitation task (i.e., judge whether two shapes are the same or not with/without the presence of the '='/'≠' symbol). Comparable to the processing of negative questions and negative equations, English speakers are more likely to process the '≠' symbol in one step during shape congruence judgement while Chinese speakers in two steps. For an illustration, when the stimulus was 'triangle-unequal-triangle', English speakers were likely to process the '≠' symbol in one step which interfered with their subsequent response that 'triangle is the same as triangle'. In contrast, Chinese speakers, who were not interfered so much by the presence of the '≠' symbol compared to English speakers, were likely to first process the positive equation 'triangle-equal-triangle' before they can process the negative equation 'triangle-unequal-triangle'. The mechanisms for processing the '≠' symbol during shape congruence judgement in English and Chinese speakers are summarized in Table 10.1.

The crosslinguistic differences found in the processing of the '≠' symbol during shape congruence judgement suggest that it is the comprehension part rather than the answering part that is language-specific. The design of answering negative questions and verifying negative equations cannot separate the comprehension of negation from the verification of negation like previous studies that used verification tasks (Akiyama et al., 1979; Carpenter & Just, 1975; Clark & Chase, 1972; Fischler et al., 1983; Lüdtke et al., 2008). In this respect, judging the congruence of two shapes does not require verification of a negative equation; rather, it targets at the comprehension of the '≠' symbol put in an equation.

10.2.4. Language-specific processing of negation and answering systems

Language-specific routines in English and Chinese speakers when they process negative questions and negative equations can be linked to different answering systems. English speakers, who typically use the polarity-based system and attach negation to the polarity of a question when answering negative questions, are more strongly directed by their language to the distinction between the positive and the negative pole. This is because the negative pole is an equal counterpart of the positive pole for English speakers but not for Chinese speakers. To illustrate this claim, when Chinese speakers process the negative question *Doesn't she like cats?*, they typically attach negation to the statement of the question and process the negative statement in two steps. First, they take the truth value of the positive statement 'Is it true that [she likes cats]', and then they reverse its truth value in a subsequent step down the processing stream. If we assume that Chinese speakers rely more heavily on the positive statement when they process negation, then, unlike for English speakers, Chinese speakers derive the negative statement 'Is it true that [she doesn't like cats]' from the positive statement in subsequent steps, rather than process the negative statement immediately as an equal counterpart of the positive statement. In other words, for Chinese speakers, negation processing is aptly characterised as a reversal of the truth value of the positive statement (Akiyama, 1979; Choi, 1991; Holmberg, 2015). However, when English speakers process the negative question *Doesn't she like cats?*, they are more likely to process 'Is it true or not that [she likes cats]' in one step with negation attached to the polarity of the question rather than 'Is it true that [she doesn't like cats]' with negation attached to the statement. This argument is in line with the claim that speakers of the polarity-based system process negation immediately (Nieuwland & Kuperberg, 2008; Orenes et al., 2014; Tettamanti et al., 2008; Tian et al., 2010). If a polarity-based system directs its speakers to process negation straight away but a truth-based system trains its speakers to detour via the positive statement and only process the negative statement in a second step, then it is not surprising to find that English and Chinese speakers also vary in a nonverbal context during the processing of negative equations.

Importantly, the argument here is not that English speakers do not use two steps to process negation in verbal and nonverbal contexts at all. Alongside the crosslinguistic differences found between English and Chinese speakers, common characteristics in the processing of negation were observed. In a verbal context, responses to negative questions are not exclusively polarity-based in English speakers. For example, English speakers can also answer *No, she does* to *Doesn't she like cats?* like Chinese speakers. The availability of both truth-based and polarity-based answers in English speakers suggests that English speakers can also process negative questions in a similar manner as Chinese speakers. In other words, English speakers are not restricted by the polarity-system when processing negative questions. In the nonverbal experiments, like Chinese speakers, it took English speakers longer to process negative equations than positive equations, and it took them longer to judge 'triangle is different from square' than 'triangle is the same as triangle'. If English speakers processed negation exclusively in one step, there would have been no reaction time difference between the processing of positive and negative stimuli. Also comparable to Chinese speakers, English speakers were slowed down more by negative equations when their response was *agree* than *disagree*, which suggests the use of two negations according to earlier studies (Clark and Chase, 1972; Carpenter & Just, 1975). Regarding these common characteristics, the explanation is that English speakers can also use two steps when process negation. This argument gives support to the view that negation is processed sequentially in two steps, moving from the positive statement to the negative statement (Carpenter & Just, 1975; Clark & Chase, 1972; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al, 2006, 2007; Lüdtke et al., 2008; Tian et al., 2010, 2016). However, this thesis further argues that the tendency to use two steps is language-specific, lower in English speakers than in Chinese speakers.

10.3. Linguistic relativity and bilingualism in the domain of negation

10.3.1. The strength of language influence on negation processing

To what extent does the way we speak influences the way we think? With the processing of negation in focus, this study reveals that answering systems mediate habitual processing of negation in verbal and nonverbal contexts. English speakers showed a reaction-time advantage over Chinese speakers not only in the processing of negative questions but also in the processing of negative equations. The reaction-time advantage of English speakers was attributed to fewer processing steps compared with Chinese speakers. The argument for language-specific processing of negation in verbal and nonverbal contexts goes against the view of linguistic universalist (e.g., Jackendoff, 1996), according to which crosslinguistic differences only exist in language but not extend to thinking. Also, while *thinking for speaking* (Slobin, 1987, 1996) can explain the language-specific processing of negative questions, it would not predict crosslinguistic differences in nonverbal contexts (i.e., process equations such as 'triangle-unequal-triangle').

The findings in English and Chinese speakers were interpreted as novel empirical evidence for *linguistic relativity* (Whorf, 1956), showing that crosslinguistic differences in the processing of negation can extend from verbal to nonverbal contexts. Language-specific processing that extends from verbal to nonverbal contexts has been reported in previous research (Athanasopoulos & Bylund, 2013; Casasanto et al., 2004; Fuhrman et al., 2011; Kersten et al., 2010; Park & Ziegler, 2014; Vanek & Selinker, 2017). For example, Athanasopoulos and Bylund (2013) revealed that Swedish speakers habitually attend more to endpoints when they processed motion events than English speakers both in verbal and nonverbal contexts. This study contributes to existing evidence from other domains (such as motion event cognition, e.g., Athanasopoulos & Bylund, 2013; duration estimates, e.g., Casasanto et al., 2004) and provides empirical support for the *linguistic relativity* hypothesis that language-entrained processing routines play an important role also beyond verbal contexts.

Besides the argument here for language-entrained processing routines, there is alternative explanations for the crosslinguistic differences reported when English and Chinese speakers processed negation in nonverbal contexts. It is possible that participants silently verbalise *unequal/not equal* when they solve the equation verification task and when they judge shape congruence. The '≠' symbol can be verbally expressed as *unequal* and *not equal* in English; however, it can only be expressed as *bu deng yu* 'not equal' in Chinese. Lexical negation (e.g., *unequal*) has been reported to be processed faster than negative particles (e.g., *not equal*) (Sherman, 1973, 1976, Giora et al. 2004; Kaup et al. 2006). If verbal labelling was used in silence to solve the task of equation verification, then it cannot be ruled out that Slobin's (1996) view that language influences thinking for speaking can apply here even without overt verbalisation.

However, the explanatory power of silent verbalization is undermined by the finding that bilinguals, regardless of language context, showed English-like performance when they processed negative equations. Following Kousta et al. (2008), if participants used language as a strategy in nonverbal contexts, bilinguals should have shown language-specific performance in different language context. To illustrate, when processing the '≠' symbol in negative equations, bilinguals were expected to silently verbalize the Chinese label *bu deng yu* 'not equal' when they received instruction in Chinese and show Chinese-like response speed. Analogously, they were expected silently verbalize the English label *unequal* when they received instruction in English and show English-like response speed. However, the finding was that the language of instruction was not correlated with bilinguals' slowdowns when they processed negative equations during equation verification and shape congruence judgement. That is to say, it is unlikely that participants silently verbalized the verbal expressions of the '≠' symbol in 'triangle-unequal-triangle'/'triangle-unequal-square'.

Language mediation may not outweigh arguably shared cognition. This view is line with Athanasopoulos and Bylund (2013) who argued for an attenuation effect of language on thinking. The researchers revealed that in motion event cognition, even though the progressiveness of motion events was more salient for English speakers than for Swedish speakers as the former group chose significatnly more [-endpoint] alternates, both English and Swedish speakers showed greater preference for [-endpoint] alternates than [+endpoint] alternates. The saliency of ongoingness in English speakers was attributed to the English aspect that requires differentiation between progressiveness and completeness of motion events. In this study, the processing of negative stimuli without context may be universally more difficult than the processing of a positive stimuli despite the language-specificities. The availability of the one step shortcut to process negation in English speakers only reduces difficulty probably inherent in the processing of negation. It took the three groups significantly longer to process negation when they answered negative questions, verified negative equations and judged two different shapes. The claim for augmented difficulty in the processing of negation is also in line with the large amount of evidence suggesting greater difficulty in processing negative sentences than processing positive sentences (Carpenter & Just, 1975; Clark & Chase, 1972; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al, 2006, 2007; Lüdtke et al., 2008; Tian et al., 2010; Sherman, 1973, 1976; Wason & Jones, 1963).

10.3.2. Conceptual changes in bilinguals' processing of negation

Crosslinguistic influence from L2 to L1 can occur even in late bilinguals. L1->L2 influence is well documented in late bilinguals (Alonso, 2016; Bassetti et al., 2018; Hohenstein et al., 2006; Pavlenko & Malt, 2011; Pavlenko & Jarvis, 2002;

Vanek & Selinker , 2017; von Stutterheim, 2003). For example, Alonso (2016) found that when using English prepositions (e.g., *a notice on a door*), both Danish and Spanish learners showed behaviours that corresponded to L1-specific patterns. Unlike the finding in Alonso (2016), in the current study, Chinese learners are shifting from using Chinese-like responses (*yes, she doesn't/ no, she does*) towards English-like responses (*yes, she does/ no, she doesn't*) when they answered negative questions. This change in response suggests reverse crosslinguistic influence from L2 to L1.

Using a L2 is not always difficult if the L2 offers a processing shortcut. Manning et al. (2018) found that there was additional processing cost for L2 learners compared to L1 speakers when they processed negative sentences, and the researchers attributed the difficulty in L2 learners to the use of two processing steps while L1 speakers use one step. This study, confirms the finding in Manning et al. (2018) considering that Chinese-English bilinguals did show difficulty answering L2 negative questions, i.e., they were slowed down more by English negative questions compared to English speakers. However, when comparing Chinese-English bilinguals' processing of L2 negative questions with Chinese speakers' processing of negative questions in their mother tongue, it was the bilinguals who showed faster response speed. If the argument of Manning et al. (2018) held true that the use of two steps to process negation in bilinguals gave rise to their greater processing difficulty in L2, Chinese-English bilinguals in this study would not have outperformed Chinese speakers in both English and Chinese contexts. To explain the advantage of bilinguals in the L2 context over Chinese native speakers, the argument here is that bilinguals are prone to take the easier route (i.e., one processing step) thus compensating the difficulty of L2. This claim is in line with the view of Bassetti et al. (2018) who argued that bilinguals use the easier strategy regardless of the language setting. Empirical evidence supporting this explanation was also found when bilinguals processed Chinese negative questions and negative equations. When processing Chinese negative questions, bilinguals showed a pattern suggesting the use of one processing step while

Chinese speakers took two processing steps. When processing negative equations in the nonverbal context, bilinguals were slowed down less by negative stimuli compared to Chinese speakers.

Besides language-specificities found in English and Chinese speakers, results of bilinguals provided another piece of evidence for the link between language and cognition. After learning the polarity-based English answering system, Chinese-English bilinguals showed English-like performance wherever crosslinguistic differences were found between Chinese and English speakers. For example, diverging from Chinese speakers, it did not take bilinguals longer to respond *yes* than *no* to English and Chinese negative questions. It suggests that bilinguals were unlikely to use two negations advocated by Clark and Chase (1972) to answer *yes* to a negative question. Also, in comparison to Chinese speakers, bilinguals were slowed down less by negative equations compared with positive equations. Instead, bilinguals verified negative equations as fast as English speakers did, which suggests that bilinguals acquired the one-step route to process negation typical of English speakers. To account for the English-like performance in bilinguals, the argument of this thesis is that the L1-specific processing of negation is partially restructured in the mind of bilinguals.

Advanced Chinese-English bilinguals are moving from habitually processing negative questions in two steps typical of Chinese speakers to the new routine which is processing negative questions in one step typical of English speakers. The claim that learning a second language can change existing processing routines is in line with previous studies that argued for conceptual restructuring in other comparable domains (Athanasopoulos, 2009; Athanasopoulos & Kasai, 2008; Athanasopoulous et al., 2011; Cook et al., 2006; von Stutterheim, 2003). For example, when categorizing light blue and dark blue colours, Japanese-English bilinguals were reported to approach the performance of English speakers (Athanasopoulous et al., 2011). By revealing that Chinese-English bilinguals shifted from using two steps to one step to process negation, this study contributes to existing evidence from other domains on bilingual cognition.

10.4. Limitations and main contributions

10.4.1. Limitations

There are still questions left unanswered. First, the present experiments do not provide conclusive evidence whether it is the comprehension part or the answering part that is language-specific when answering negative questions. The design of the production task (Expt. 1 & 5) and the *yes/no* choice task (Expt. 2 & 6) cannot separate the comprehension of negative questions from the verification of negative questions since participants were asked to answer the given questions in both tasks. Unlike the verbal experiments, this problem was addressed in the nonverbal agree-disagree task (Expt. 3 & 7) and the facilitation task (Expt. 4 & 8). While participants were instructed to verify positive and negative equations (e.g., 'triangle-unequal-square') in the agree-disagree task, there was no verification of statements involved in the facilitation task. Further studies would benefit from teasing apart the negative question comprehension from answering. This could be achieved for instance by measuring brain responses to true/false positive/negative questions only (e.g., Is/Isn't scuba-diving safe/dangerous with proper equipment?) vs. to positive/negative questions together with yes/no answers. Greater sensitivity can be expected for the Chinese speakers (i.e., increased negativity in brain responses at around 400 ms after stimulus onset) when they process a negative question and the state of affairs is false rather than when it is true. Conversely, greater sensitivity can be expected for the English speakers when they process a negative question and the state of affairs is true than when it is false.

Second, it cannot be ruled out that instead of the different answering systems, it is the different verbal labels for the unequal symbol in English and Chinese that gave rise to language-specific patterns in the nonverbal task. Analogously, the English-like pattern observed in bilinguals when they processed the unequal symbol may be attributed to the acquisition of English-specific verbal labels rather than the L2 answering system. Further studies may find it useful to employ nonverbal negation-denoting stimuli with direct one-to-one translation equivalents in English and Chinese (e.g., *wrong/cuo* ‘wrong’). Alternatively, further studies may test other polarity-based and truth-based languages that have a direct one-to-one translation equivalent to label the unequal symbol.

10.4.2. Summary of main contributions

This study fills a number of research gaps. First, growing evidence for relativistic effects have been reported in grammatical number (Lucy, 1992; Lucy & Gaskins, 2001, 2003), motion events (Athanasopoulos & Bylund, 2013), time (Casasanto et al., 2004; Fuhrman et al., 2011), grammatical gender (Sera, Berge, and Pintado, 1994), colour (Davidoff et al., 1999), space (Brown & Levinson, 1993; Levinson, 1996) and quantity (Gordon, 2004). However, to the best of the author’s knowledge, this is the first study that brings empirical evidence showing language-specific effects on the processing of negation in a nonverbal context. Second, conceptual changes in bilinguals have been observed in grammatical number (Athanasopoulos & Kasai , 2008; Cook et al., 2006), time (Bassetti et al., 2018; Bylund & Athanasopoulos, 2017), motion events (Athanasopoulos et al., 2015; Brown & Gullberg, 2008; Kersten et al., 2010; Vanek & Selinker, 2017), colour (Athanasopoulos, 2009; Athanasopoulous et al., 2011) and space (Park & Ziegler, 2014). By innovatively testing the processing of negation in Chinese-English speakers, this study gives further support in a new domain to the view that L2 acquisition can restructure a bilingual mind. Third, by testing Chinese speakers, this study is an innovative contribution to research on the processing of negation. Unlike the numerous empirical studies on the processing of negation in the polarity-based system (i.e., English: Akiyama et al., 1979; Carpenter & Just, 1975; Clark & Chase, 1972; Dale & Duran, 2011; Fischler et al., 1983; Kaup et al, 2007; Nieuwland & Kuperberg, 2008; Tian et al., 2010, 2016; Sherman, 1973, 1976; Wason & Jones; 1963. Spanish: Orenes et al., 2014. Italian: Tettamanti et al., 2008), very little is known about the truth-based system in this respect. Building on knowledge from developmental studies (Akiyama, 1979; Choi, 1991), reaction-time slowdowns in this study provide empirical support for the idea that it is more demanding to process negative questions for Chinese speakers than it's for English speakers. The greater difficulty of negation processing in the truth-based system can be attributed to an additional processing step compared to the polarity-based system. This study may serve as a useful springboard to investigate the processing of negation across a variety of truth and polarity-based language systems. Moreover, this study also extends current exploration in the processing of negation in monolinguals speakers to bilinguals. The processing of negation in bilinguals received little attention. Two welcome exceptions are Manning et al. (2018) and Ćoso and Bogunović (2019). Together with Manning et al. (2018), this study showed that the processing of negation in bilinguals can differ from that of monolingual speakers. This study also revealed that there may not necessarily be additional processing cost for bilinguals when processing negation in L2, which is in line with Ćoso and Bogunović (2019). Much of negation processing may be shared regardless of the languages we speak, however, this study highlights that the distinct ways in which negation is encoded in truth-based versus polarity-based systems impact speakers' performance in verbal as well as nonverbal tasks.

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Appendices

Appendix 1

Information sheet

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You are invited to participate in a study on how people answer questions. This research study is carried out by Zhang Haoruo (Vicky) under the supervisions of Dr. Norbert Vanek and Dr. Danijela Trenkic at the Centre for Research in Language Learning and Use (CReLLU), Department of Education, the University of York.

What would this mean for me?

In this study, you will be asked to answer some questions presented on a computer screen. You will be audio recorded in one task so that your answers can be analyzed later. You can ask to see the transcript of your recordings within two weeks after the data is collected.

There are no physical, psychological, social or economic risks associated with participation in this study, other than the time spent tasking part (approx. 30 minutes). You will receive £5 at the end of the experiment.

Anonymity

The data that you provide (i.e., audio recordings and test results) will be stored by code number. Any information that identifies you will be stored separately from the data.

Storing and using your data

Data will be stored on a password protected computer. The data will be kept until fully analyzed. The data may be used for future analysis and shared for research or training purposes, but participants will not be identified individually. If you do not want your data to be included in any information shared as a result of this research, please do not sign this consent form.

You are free to withdraw from the study at any time during data collection and up to one week after the data is collected by contacting the researcher via email hz1004@york.ac.uk.

Information about confidentiality

The data that I collect (i.e., audio recordings and test responses) will be kept in anonymous formats. Any information that will make it possible to identify any individual participant will not be included in any reports I may publish. However, any information passed on that causes concern about the well being of the participant or the well being of others will not be kept confidential.

I hope that you will agree to take part. If you have any questions about the study that you would like to ask before giving consent or after the data collection, please feel free to contact Vicky by email hz1004@york.ac.uk. If you have ethical concerns regarding this study, you can contact the Chair of Ethics Committee via email education-research-administrator@york.ac.uk.

Please keep this information sheet for your own records.

Thank you for taking the time to read this information.

Consent Form

Please tick each box if you are happy to take part in this research.

I confirm that I have read and understood the information given to me about research project and I understand that this will involve me taking part as described above. ☐

I understand that the purpose of the research is to study how people answer questions. ☐

I understand that data will be stored securely on a password protected computer and only Dr Norbert Vanek, Dr Danijela Trenkic and Zhang Haoruo will have access to any identifiable data. I understand that my identity will be protected by use of a code. ☐

I understand that my data will not be identifiable and the data may be used in publications and in presentations that are mainly read and attended by university academics. ☐

I understand that data will be kept until fully analyzed. ☐

I understand that data could be used for future analysis or other purposes e.g., teaching. ☐

I understand that I can withdraw my data at any point during data collection and up to one week after data is collected. ☐

Name: ______________________________

Signature of the participant: ______________________________

Date: ______________________________

Appendix 2

English Yes–No Questions for Experiments 1, 2, 5 & 6

List A	List B	List C	List D
Positive-True [English-style answer: Yes] [Chinese-style answer: Yes]	Positive-False [English-style answer: No] [Chinese-style answer: No]	Negative-True [English-style answer: Yes] [Chinese-style answer: No]	Negative-False [English-style answer: No] [Chinese-style answer: Yes]
Mr. Fox stole a roast duck from a farm.			
1. Did Mr. Fox steal a roast duck from a farm?	**1. Did Mr. Fox steal a roast chicken from a farm?**	**1. Didn't Mr. Fox steal a roast duck from a farm?**	**1. Didn't Mr. Fox steal a roast chicken from a farm?**
Mrs. Fox baked a cake for her family.			
2. Did Mrs. Fox bake a cake for her family?	**2. Did Mrs. Fox bake some potatoes for her family?**	**2. Didn't Mrs. Fox bake a cake for her family?**	**2. Didn't Mrs. Fox bake some potatoes for her family?**
Mr. Sheep watched a football game on Friday.			
3. Did Mr. Sheep watch a football game on Friday?	**3. Did Mr. Sheep watch a basketball game on Friday?**	**3. Didn't Mr. Sheep watch a football game on Friday?**	**3. Didn't Mr. Sheep watch a basketball game on Friday?**
Positive-False [English-style answer: No] [Chinese-style answer: No]	Negative-True [English-style answer: Yes] [Chinese-style answer: No]	Negative-False [English-style answer: No] [Chinese-style answer: Yes]	Positive-True [English-style answer: Yes] [Chinese-style answer: Yes]

Mrs. Sheep read the newspaper after dinner.

4. Did Mrs. Sheep read the novel after dinner?	**4. Didn’t Mrs. Sheep read the newspaper after dinner?**	**4. Didn’t Mrs. Sheep read the novel after dinner?**	**4. Did Mrs. Sheep read the newspaper after dinner?**

Mr. Duck lost his watch during his trip to Europe.

5. Did Mr. Duck lose his scarf in a trip?	**5. Didn’t Mr. Duck lose his watch in a trip?**	**5. Didn’t Mr. Duck lose his scarf in a trip?**	**5. Did Mr. Duck lose his watch in a trip?**

Mrs. Duck had her piano class on Tuesday.

6. Did Mrs. Duck have her dance class on Tuesday?	**6. Didn’t Mrs. Duck have her piano class on Tuesday?**	**6. Didn’t Mrs. Duck have her dance class on Tuesday?**	**6. Did Mrs. Duck have her piano class on Tuesday?**

Negative-True	Negative-False	Positive-True	Positive-False
[English-style answer: Yes]	[English-style answer: No]	[English-style answer: Yes]	[English-style answer: No]
[Chinese-style answer: No]	[Chinese-style answer: Yes]	[Chinese-style answer: Yes]	[Chinese-style answer: No]

Mr. Swan gave a necklace to his wife.

7. Didn’t Mr. Swan give a necklace to his wife?	**7. Didn’t Mr. Swan give a ring to his wife?**	**7. Did Mr. Swan give a necklace to his wife?**	**7. Did Mr. Swan give a ring to his wife?**

Mrs. Swan cleaned her feathers in a lake.

8. Didn’t Mrs. Swan clean her feathers in a lake?	**8. Didn’t Mrs. Swan clean her boots in a lake?**	**8. Did Mrs. Swan clean her feathers in a lake?**	**8. Did Mrs. Swan clean her boots in a lake?**

Mr. Lion sent a box of DVDs to his cousin.

9. Didn’t Mr. Lion send a box of DVDs to his cousin?	**9. Didn’t Mr. Lion send a box of chocolates to his cousin?**	**9. Did Mr. Lion send a box of DVDs to his cousin?**	**9. Did Mr. Lion send a box of chocolates to his cousin?**

Negative-False [English-style answer: No] [Chinese-style answer: Yes]	Positive-True [English-style answer: Yes] [Chinese-style answer: Yes]	Positive-False [English-style answer: No] [Chinese-style answer: No]	Negative-True [English-style answer: Yes] [Chinese-style answer: No]
Mrs. Lion broke a glass in her kitchen.			
10. Didn’t Mrs. Lion break a plate in her kitchen?	**10. Did Mrs. Lion break a glass in her kitchen?**	**10. Did Mrs. Lion break a plate in her kitchen?**	**10. Didn’t Mrs. Lion break a glass in her kitchen?**
Mr. Dove opened his gift shop in the city center.			
11. Didn’t Mr. Dove open his restaurant in the city center?	**11. Did Mr. Dove open gift shop in the city center?**	**11. Did Mr. Dove open his restaurant in the city center?**	**11. Didn’t Mr. Dove open his gift shop in the city center?**
Mrs. Dove bought a coat during the Christmas sale.			
12. Didn’t Mrs. Dove buy a hat during the Christmas sale?	**12. Did Mrs. Dove buy a coat during the Christmas sale?**	**12. Did Mrs. Dove buy a hat during the Christmas sale?**	**12. Didn’t Mrs. Dove buy a coat during the Christmas sale?**

Appendix 3

Chinese Yes-No Questions for Experiments 1, 2, 5 & 6

List A	List B	List C	List D
Positive-True [English-style answer: Yes] [Chinese-style answer: Yes]	Positive-False [English-style answer: No] [Chinese-style answer: No]	Negative-True [English-style answer: Yes] [Chinese-style answer: No]	Negative-False [English-style answer: No] [Chinese-style answer: Yes]
狐狸先生从农场偷了一只烤鸭。			
1. 狐狸先生从农场偷了一只烤鸭吗？	**1. 狐狸先生从农场偷了一只烤鸡吗？**	**1. 狐狸先生没有从农场偷一只烤鸭吗？**	**1. 狐狸先生没有从农场偷一只烤鸡吗？**
狐狸夫人为家人烤了一个蛋糕。			
2. 狐狸夫人为家人烤了一个蛋糕吗？	**2. 狐狸夫人为家人烤了一些土豆吗？**	**2. 狐狸夫人没为家人烤一个蛋糕吗？**	**2. 狐狸夫人没为家人烤一些土豆吗？**
绵羊先生星期五看了场足球比赛。			
3. 绵羊先生星期五看了场足球比赛吗？	**3. 绵羊先生星期五看了场篮球比赛吗？**	**3. 绵羊先生星期五没看场足球比赛吗？**	**3. 绵羊先生星期五没看场篮球比赛吗？**
Positive-False [English-style answer: No] [Chinese-style answer: No]	Negative-True [English-style answer: Yes] [Chinese-style answer: No]	Negative-False [English-style answer: No] [Chinese-style answer: Yes]	Positive-True [English-style answer: Yes] [Chinese-style answer: Yes]

绵羊夫人晚饭后看了报纸。			
4.绵羊夫人晚饭后读了一本小说吗？	**4. 绵羊夫人晚饭后没看报纸吗？**	**4. 绵羊夫人晚饭后没读一本小说吗？**	**4.绵羊夫人晚饭后看报纸了吗？**
鸭子先生在欧洲旅行时丢失了手表。			
5. 鸭子先生在欧洲旅行时丢失了围巾吗？	**5. 鸭子先生在欧洲旅行时没丢失手表吗？**	**5. 鸭子先生在欧洲旅行时没丢失了围巾吗？**	**5. 鸭子先生在欧洲旅行时丢失了手表吗？**
鸭子夫人周二上了钢琴课。			
6. 鸭子夫人周二上了舞蹈课吗？	**6. 鸭子夫人周二没上钢琴课吗？**	**6. 鸭子夫人周二没上舞蹈课吗？**	**6. 鸭子夫人周二上了钢琴课吗？**
Negative-True [English-style answer: Yes] [Chinese-style answer: No]	Negative-False [English-style answer: No] [Chinese-style answer: Yes]	Positive-True [English-style answer: Yes] [Chinese-style answer: Yes]	Positive-False [English-style answer: No] [Chinese-style answer: No]
天鹅先生送给他妻子一条项链。			
7. 天鹅先生没送给他妻子一条项链吗？	**7. 天鹅先生没送给他妻子一个戒指吗？**	**7. 天鹅先生送给他妻子一条项链吗？**	**7. 天鹅先生送给他妻子一个戒指吗？**
天鹅夫人在湖中清理了羽毛。			
8. 天鹅夫人没在湖中清理羽毛吗？	**8. 天鹅夫人没在湖中清理靴子吗？**	**8. 天鹅夫人在湖中清理了羽毛吗？**	**8. 天鹅夫人在湖中清理了靴子吗？**

狮子先生送给他表弟一盒光盘。

9. 狮子先生没送给他表弟一盒光盘吗？	**9. 狮子先生没送给他表弟一盒巧克力吗?**	**9. 狮子先生送给他表弟一盒光盘吗？**	**9. 狮子先生送给他表弟一盒巧克力吗?**
Negative-False [English-style answer: No] [Chinese-style answer: Yes]	Positive-True [English-style answer: Yes] [Chinese-style answer: Yes]	Positive-False [English-style answer: No] [Chinese-style answer: No]	Negative-True [English-style answer: Yes] [Chinese-style answer: No]

狮子夫人在厨房里打破了一个玻璃杯。

10. 狮子夫人没在厨房里打破了一个盘子吗？	**10. 狮子夫人在厨房里打破了一个玻璃杯吗？**	**10. 狮子夫人在厨房里打破了一个盘子吗？**	**10. 狮子夫人没在厨房里打破了一个玻璃杯吗?**

鸽子先生在市中心开了家礼品店。

11. 鸽子先生没在市中心开了家餐厅吗？	**11. 鸽子先生在市中心开了家礼品店吗？**	**11. 鸽子先生在市中心开了家餐厅吗？**	**11. 鸽子先生没在市中心开了家礼品店吗？**

鸽子夫人在圣诞打折期间买了件新外套。

12. 鸽子夫人没在圣诞打折期间买了顶新帽子吗？	**12. 鸽子夫人在圣诞打折期间买了件新外套吗？**	**12. 鸽子夫人在圣诞打折期间买了顶新帽子吗？**	**12. 鸽子夫人没在圣诞打折期间买了件新外套吗？**

Appendix 4

English fillers for Experiments 1, 2, 5 & 6

Mr. Dog received a letter from his grandpa.
1. Who received a letter from his grandpa? (Mr. Dog /Mr. Fox)
2. What did Mr. Dog receive from his grandpa? (a phone call/a letter)

Mrs. Dog went to the museum this afternoon.
3. Who went to the museum this afternoon?(Mrs. Fox/ Mrs. Dog)
4. Where did Mrs. Dog go this afternoon? (the museum / the zoo)

Mr. Cat fixed his fridge at the weekend.
5. Who fixed his fridge at the weekend? (Mr. Cat/ Mr. Sheep)
6. What did Mr. Cat fix at the weekend? (his fridge/his washing machine)

Mrs. Cat played computer games after work.
7. Who played computer games after work? (Mrs. Sheep/Mrs. Cat)
8. What did Mrs. Cat play after work? (computer games/cards)

Mr. Wolf collected stamps in his spare time
9. Who collected stamps in his spare time? (Mr. Wolf/ Mr. Duck)
10. What did Mr. Wolf collect in his spare time (coins/ stamps)

Mrs. Wolf met her friend on her way home.
11. Who met her friend on her way home? (Mrs. Duck/ Mrs. Wolf)
12. Who did Mrs. Wolf meet on her way home? (her friend/her mother)

Mr. Bear visited his brother yesterday morning.
13. Who visited his brother yesterday morning? (Mr. Bear/Mr. Swan)
14. Who did Mr. Bear visit yesterday morning. (his sister/his sister)

Mrs. Bear sold her car to her neighbor.
15. Who sold her car to her neighbor? (Mrs. Swan/Mrs. Bear)
16. What did Mrs. Bear sell to her neighbor? (her car/ her house)

Mr. Horse got a haircut before the meeting.
17. Who got a haircut before the meeting? (Mr. Horse/ Mr. Lion)
18. What did Mr. Horse get before the meeting? (a paper cut/ a haircut)

Mrs. Horse borrowed a plate from her neighbor.
19. Who borrowed a plate from her neighbor? (Mrs. Lion/Mrs. Horse)
20. What did Mrs. Horse borrow from her neighbor? (a plate/a vase)

Mr. Pig planted some carrots in his garden.
21. Who planted some carrots in his garden? (Mr. Pig/Mr. Dove)

22. What did Mr. Pig plant in his garden? (some flowers/some carrots)

Mrs. Pig washed her dress in the evening.
23. Who washed her dress in the evening? (Mrs. Dove/ Mrs. Pig)
24. What did Mrs. Pig wash in the evening? (her dress/her socks)

Appendix 5

Chinese fillers for Experiments 1, 2, 5 & 6

狗先生收到了他爷爷寄来的信。

1. 谁收到了他爷爷寄来的信？（狗先生/狐狸先生）

2. 狗先生从爷爷那收到了什么？（打来的电话/寄来的信）

狗夫人今天下午去了博物馆。

3. 谁今天下午去了博物馆？（狐狸夫人/狗夫人）

4. 狗夫人今天下午去了哪里？(博物馆/动物园)

猫先生在周末修好了冰箱。

5. 谁在周末修好了冰箱？(猫先生/ 绵羊先生)

6. 猫先生在周末修好什么？(冰箱/ 洗衣机)

猫夫人下班后玩了会电脑游戏。

7. 谁下班后玩了电脑游戏？(绵羊夫人/猫夫人)

8. 猫夫人下班后玩了什么？(电脑游戏/ 扑克牌)

狼先生在业余时间收集邮票。

9. 谁在业余时间收集邮票? (狼先生/ 鸭子先生)

10. 狼先生在业余时间收集什么？(硬币/ 邮票)

狼夫人在回家路上遇到了一个朋友。

11. 谁在回家路上遇到了一个朋友? (鸭子夫人/ 狼夫人)

12. 狼夫人在回家路上遇到了谁？(她的朋友/她的妈妈)

熊先生昨天早上拜访了他的哥哥。

13. 谁昨天早上拜访了他的哥哥？(熊先生/天鹅先生)

14. 熊先生昨天早上拜访了谁？(他的哥哥/ 他的姐姐)

熊夫人把自己的车卖给了邻居。

15. 谁把自己的车卖给了邻居？(天鹅夫人/熊夫人)

16. 熊夫人把什么卖给了邻居? (她的车/她的房子)

马先生在会议前剪了头发。

17. 谁在会议前剪了头发？(马先生/ 狮子先生)

18. 马先生在会议前怎么了？(被纸划伤了/ 剪了头发)

马夫人向她的邻居借了一个盘子。

19. 谁向她的邻居借了一个盘子? (狮子夫人/马夫人)

20. 马夫人向她的邻居借了什么? (一个盘子/一个花瓶)

猪先生在花园里种了一些胡萝卜。

21. 谁在花园里种了一些胡萝卜？(猪先生/鸽子先生)

22. 猪先生在花园里种了什么？(一些花/ 一些胡萝卜)

猪夫人晚上洗了一条连衣裙。

23. 谁晚上洗了一条连衣裙? (鸽子夫人/ 猪夫人)

24. 猪夫人晚上洗了什么？(她的连衣裙/ 她的袜子)

Appendix 6

Questionnaire for the intuitive judgment task

Completion Instructions: You will see ten texts. In each text, there is one blank to be filled in. Under each text, you will be given three choices. First, you need to **read each text carefully** and briefly imagine the situation as described. Then, you need to fill in the blanks with **only one answer** which you think is **the most appropriate** out of the three choices provided.

1. Mary ordered tea for David and herself but coffee for Jack. Assuming that Jack does not drink tea, David asked Mary "_______________"

   A. Does Jack not drink tea?

   B. Does Jack drink not tea?

   C. Doesn't Jack drink tea?

2. Both David and Jack had a paper due in two days. When David was burying himself in his homework, he noticed that Jack was playing computer games. David believed that Jack should be working on his paper, so he asked Jack "_______________"

   A. Don't you need to study?

   B. Do you not need to study?

   C. Do you need not to study?

3. Jack and David were discussing the new season of the Games of Thrones while Mary did not show any interest in this topic. Jack suspected that Mary did not know this TV series, so he asked her "_______________"

   A. Have you not seen it?

   B. Haven't you seen it?

   C. Have you seen not it?

4. David saw Jack applying for a replacement student card when he entered the administration office. He roughly remembered that Jack lost his student card last month. David asked Jack "_______________"

A. Didn’t you lose your student card last month?

B. Did you not lose your student card last month?

C. Did you lose not your student card last month?

5. Mary and Jack had morning classes starting at 9:00. It was already 8:58 in the morning but Jack had not arrived yet. Wondering if Jack was not coming to the class, Mary called him and asked “_______________”

A. Are you not coming today?

B. Aren’t you coming today?

C. Are you coming not today?

6. Mary and David were about to leave for the welcome party while they noticed that Jack was still lying on a couch. Mary thought Jack may not intend to go to the party by asking him “_______________”

A. Aren’t you going to the party?

B. Are you not going to the party?

C. Are you going not to the party?

7. David had told Jack that he had a meeting at lunch time so he would not join him for lunch. On the next day, David sat down next to Jack. Remembering that David should be at a meeting, Jack asked him “_______________”

A. Should you be not at your meeting?

B. Should you not be at your meeting?

C. Shouldn’t you be at your meeting?

8. David knew that Mary is allergic to dogs. So when he saw Mary playing with a dog, he asked her “_______________”

A. Are you not allergic to dogs?

B. Aren’t you allergic to dogs?

C. Are you allergic not to dogs?

9. Jack made his New Year resolution that he would run five miles every

morning in the coming year. The next day when David wanted to ask Jack to run with him, he found Jack still in his pyjamas. Suspecting that Jack would not keep his resolution, David asked him "________________"

A. Aren't you coming for a run?

B. Are you not coming for a run?

C. Are you coming not for a run?

10. Mary was not aware of that the university cafeteria which had been temporarily closed was reopened. When she saw Jack headed to the cafeteria, Mary asked "________________"

A. Is it closed not?

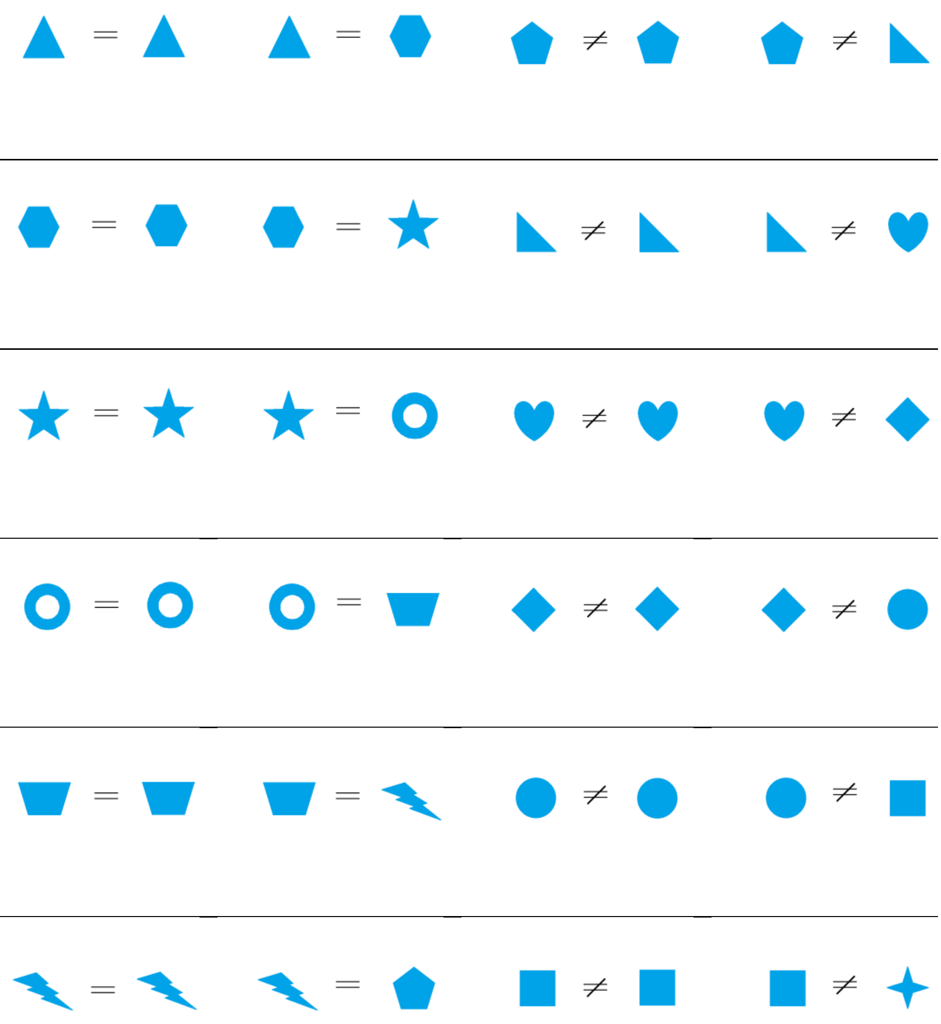
B. Isn't it closed?

C. Is it not closed?

Appendix 7

Equation stimuli for Experiments 3 & 7

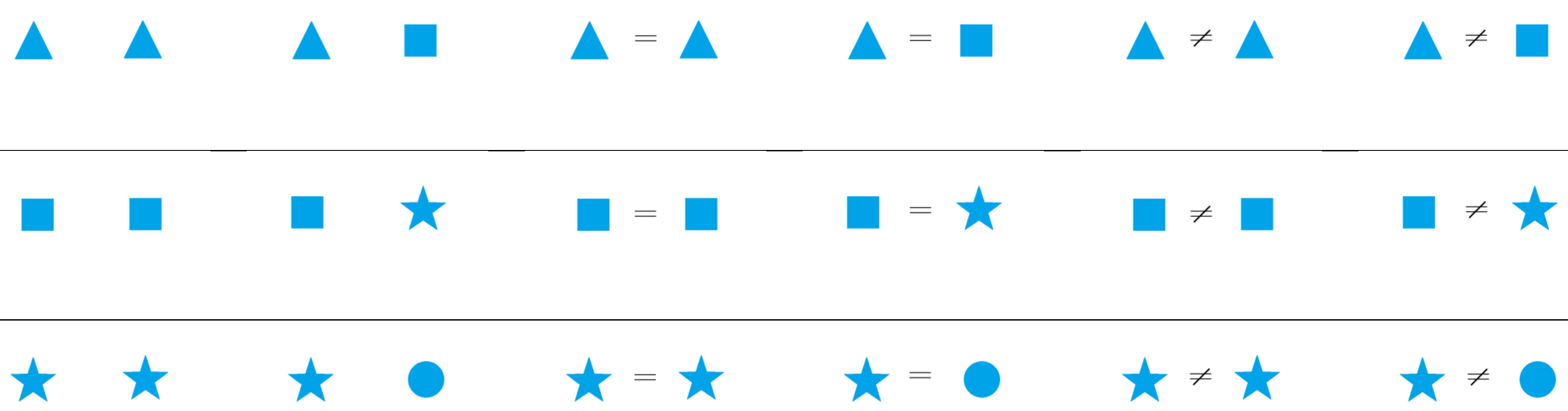
Positive-True	Positive-False	Negative-True	Negative - False



Appendix 8

Stimuli for Experiments 4 & 8

same (control)	different (control)	same-equal	different-equal	same-unequal	different-unequal



● ●	● ◆	● = ●	● = ◆	● ≠ ●	● ≠ ◆
◆ ◆	◆ ♥	◆ = ◆	◆ = ♥	◆ ≠ ◆	◆ ≠ ♥
♥ ♥	♥ ⬟	♥ = ♥	♥ = ⬟	♥ ≠ ♥	♥ ≠ ⬟