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Negation processing in Chinese English bilinguals: Insights from the Stroop paradigm and an Orientation task

Abstract

Previous experimental work shows that negation processing can be direct in bipolar contexts where positive/negative states of affairs can be expressed by available lexical opposites (*remember/forget*) in monolingual speakers. However, in a unipolar context where such opposites are not available (*sing/not sing*), the processing first proceeds through the positive and only then the negative state of affairs. We test this claim with bilinguals to answer two questions. To what extent do a) the processing routes and b) the conceptual representation of the negated statement differ in bipolar/unipolar contexts when bilinguals process negation in their L1 and L2? 40 Chinese-English bilinguals were tested in a Negative Stroop Task (Expt.1), in which they were instructed to verify whether the positive/negative English/Chinese colour expressions matched the colour they were printed in, either in a bipolar (black/white) or a unipolar context (green/not green). We also zoomed in on the conceptual representations of negation and tested another 40 Chinese-English bilinguals in an Orientation Task (Expt. 2). Participants compared positive/negative descriptions against pictures regarding the location of a star in either a bipolar (left/right) or a unipolar context (East/not East). The results suggest that language can drive changes when bilinguals process negation, with variations in the bipolar and unipolar contexts.

Keywords: negation, conceptual representation, bilingual, two-step model, fusion model

Introduction

Explorations of negation processing in monolingual speakers suggest that the processing of a negative sentence (e.g., *She has not forgotten the lyrics*) first proceeds through the representation of the positive state of affairs *forgotten the lyrics,* and only then the negative state of affairs (e.g., Carpenter & Just, 1975; Dale & Duran, 2011; Dudschig & Kaup, 2018; Fischler, Bloom, Childers, Roucos, & Perry, 1983; Hasson & Glucksberg, 2006; Kaup, Lüdtke, & Zwaan, 2006; Kaup, Yaxley, Madden, Zwaan, & Lüdtke, 2007; Lüdtke, Friedrich, Filippis, & Kaup, 2008; Tian, Breheny, & Ferguson, 2010; Tian, Ferguson, & Breheny, 2016; L. Zhang & Li, 2011). This processing route is referred to as the *two-step model* (Du, Liu, Zhang, Hitchman, & Lin, 2014) or the schema-plus-tag model (Mayo, Schul, & Burnstein, 2004). However, recent empirical evidence showed that the negative state of affairs can be directly processed without having to first process the positive state of affairs, which is known as the *fusion model* (Dudschig & Kaup, 2018; Mayo et al., 2004). Support for the fusion model was reported in a bipolar context (Du et al., 2014; Mayo et al., 2004; Orenes, Beltrán, & Santamaría, 2014). The bipolar context refers to negative expressions for which the positive/negative state of affairs can be expressed by available lexical opposites (*remembered/forgotten*), whereas in a unipolar context such opposites are not available (*sing/not sing*). Unlike for the processing route in a bipolar context, reported evidence suggests that negation processing follows the two-step model in a unipolar context (Du et al., 2014; Mayo et al., 2004; Orenes et al., 2014).

In contrast to extensive research on negation processing in monolingual speakers, the investigation on negation processing in bilinguals is scarce and with mixed results. Manning, Sabourin, and Farshchi (2018) observed greater difficulty in processing negation in L2 than L1. However, Wen and Schwartz (2014) reported that processing the interaction between aspect and negation in Chinese (e.g., *Ta bu lai* 'He doesn't/won't come' vs. *Ta mei lai* 'He didn't/hasn't come') is not more demanding for L2 learners of Chinese than for native users. Similarly, Ćoso and Bogunović (2019) found that changing from L1 to L2 did not affect the cost of processing negation. When processing negation in negative questions, using an L2 can even be easier than using an L1 (Zhang & Vanek, 2021). Besides the variations reported regarding the processing demand, the language of operation may also affect processing routes. This idea was advocated in Mayo et al. (2004). They found in their study that Hebrew speakers showed a general preference for following the two-step model. This may be accounted for by the fact that there is no negation affix in Hebrew, which limits access to available opposites. Unlike Hebrew speakers, when people of a language with abundant available opposites (such as English) process a negative expression, they might process states of affairs "according to what they are *not* rather than what they are" (Mayo et al., 2004, p.448), which could lead to a habituation of directly accessing the negative conceptual representations. Given the scarcity and contrasting findings on negation processing in bilinguals, as well as the barely explored first vs. second language influence on negation processing, the aim of this study is to provide new evidence on negation processing in bilinguals' L1 and L2. In doing so, we build on extant research in which different processing was reported in bipolar/unipolar contexts in monolingual speakers, and for the first time examine negation processing in bilinguals in these two contexts.

1.1 Monolingual speakers: The fusion model vs. the two-step model in the bipolar context vs. the unipolar context

Different explanations have been proposed for using two steps in processing negative sentences (Carpenter & Just, 1975; Kaup et al., 2007; Tian et al., 2010, 2016), converging on that negation is not processed by accessing the target negative state of affairs directly, but via the competing positive state of affairs. Clark and Chase (1972) asked English speakers to verify positive/negative sentences. They found that it took English speakers shorter to verify a positive sentence when it was true than when it was false. However, it took them longer to verify a negative sentence when it was true than when it was false. According to the authors, to verify a negative sentence as true means to perform two negations. To illustrate, if *A plus isn't above a star* is true, then the first negation would be over the positive statement, followed by the second negation over the truth value of the positive statement (see Tian et al., 2016 for a discussion). Similar claim was proposed by Kaup et al. (2007) who instructed participants to verify sentence-picture pairs. The results showed that it took the participants significantly shorter to react to mismatching than matching pictures, suggesting that the positive state of affairs is processed faster than the negative state of affairs during negation processing.

Some scholars proposed that negation processing routes depend on specific expressions. Mayo et al. (2004) instructed Hebrew speakers to verify sentences against preceding descriptions in a bipolar context (expressions with lexical opposites) and a unipolar context (expressions without lexical opposites). The results showed that negative descriptions facilitated the verification of mismatching sentences more than matching sentences whereas the opposite was found for positive descriptions. Critically, the asymmetry was limited to the unipolar context. In the bipolar context, both positive and negative descriptions facilitated the verification of matching sentences more than mismatching sentences, aligning with the fusion model. The results were corroborated by Orenes et al. (2014) and Du et al. (2014). However, if negation processing follows the fusion model in the bipolar context, why did it take the participants longer to match *not closed* than *open* with an open umbrella (Du et al., 2014)? This RT gap is unlikely to be attributable to representing the available opposite for negative sentences since the authors noted that the 1500ms reading time is "more than long enough to process the negation" (p.467).

Unlike Mayo et al. (2004), Orenes et al. (2014) and Du et al. (2014), some studies showed that negation appearing in a bipolar context still follows the two-step model. Kaup et al. (2006) designed short (750 ms) and long (1500 ms) intervals between the given sentences and the pictorial probes. If negative sentences are processed immediately, the effect of negation should be the same on RTs regardless of the duration of the intervals. However, they found a matching effect for negative sentences only with long intervals. The researchers interpreted the interval effects as evidence for the two-step model in negation processing. Furthermore, the researchers suggested that negation cannot be conceptually replaced by its available opposite immediately because the matching effect observed for *closed* took place with short intervals, while that for *not open* occurred with long intervals. That is, *not open* was not conceptually represented as *closed* and negation in *not open* was only processed in the second step. The design and argument by Kaup et al. (2006) also inspire the methodological choices in this study to examine both the processing routes and the conceptual representation of the negated statement in the line of inquiry. Similarly, Dudschig and Kaup (2018) found that the negative stimuli *not left* which required a right response activated the ipsilateral motor cortex (the right hemisphere), the contralateral to the positive state of affairs 'left'; Analogously, *not right* requiring a left response activated the left motor cortex, the contralateral to the positive state of affairs 'right'. The results suggest that the target negative conceptual representation is not directly activated during negation processing. This finding challenges the fusion model that negation can be processed immediately in one step in a binary context.

1.2 Mixed findings on the effects of language on negation processing in bilinguals

Unlike negation processing in monolinguals, it is only recently that researchers began to explore this topic in bilinguals. Wen and Schwartz (2014) tested whether English learners of Chinese process negation combined with grammatical aspect in Chinese like native Chinese speakers do. They instructed the participants to read positive/negative sentences in a word-by-word fashion. Similar RTs were found between advanced Chinese learners and Chinese native speakers, indicating that the bilingual participants can process negation like native users when processing the target language. Wen and Schwartz (2014) did not include the variable of bipolar/unipolar context in their study though.

Ćoso and Bogunović (2019) examined the performance when Croatian learners of English verified negative sentences in L2 English and L1 Croatian, and found comparable response speed in the bilingual participants. Based on the comparable performance of the bilingual participants regardless of the language tested, the researchers argued that it is not more difficult for bilinguals to process negation in an L2 than L1. Even though Ćoso and Bogunović (2019) did not specify the distinction between the bipolar/unipolar context, their results could be taken as evidence for negation processing by bilinguals in a bipolar context because their experimental stimuli were spatial opposites *above* vs. *below*.

However, Manning, Sabourin, and Farshchi (2018) reached a different conclusion from Wen and Schwartz (2014) and Ćoso and Bogunović (2019). They investigated whether negation processing is similar or not for L1 and L2 by examining ERPs of French learners of English and simultaneous French–English bilinguals when reading true/false positive/negative sentences. The results showed that, while the N400 was similar in simultaneous bilinguals when they processed positive and negative sentences, a greater N400 effect was found when L2 learners processed true-negative sentences than true-positive sentences. The researchers argued that there is an additional processing cost for L2 learners compared with native speakers when they process negative sentences, which may be accounted for by a stronger tendency to represent the positive state of affairs. Manning et al., (2018) did not take the bipolar/unipolar context distinction into consideration when investigating negation processing by bilinguals.

Centring on negation processing in bilinguals, while some researchers reported increased difficulty in L2 compared with L1 (Manning et al., 2018), others found comparable cognitive load in L1 and L2 (Wen & Schwartz, 2014; Ćoso & Bogunović, 2019). One plausible reason for the inconsistency in this field is that the bipolar/unipolar context was underexplored and thus poorly understood in studies on negation processing by bilingual speakers. The present study might help to address the issue by controlling for context type in the experimental design, allowing us to directly compare negation processing by bilingual speakers in the bipolar vs. unipolar context. Building on such mixed findings on negation processing in monolingual and bilingual speakers, the current study aims to address the following research questions:

RQ1: To what extent does negation processing differ in bipolar/unipolar contexts in the L1 vs. L2 of Chinese-English bilinguals?

H1: The different processing cost and route of negation in bilinguals' L1 and L2 are expected to manifest themselves as variations in response speed to negative stimuli. If it is more difficult for bilinguals to process negation in their L2 than in L1, then we would expect a significant interaction between *Language* and *Polarity*, and it would take the bilingual participants significantly longer to respond to the negative stimuli in their L2 than L1. Alternatively, if language is irrelevant to the difficulty of negation processing, then Chinese-English bilinguals would show comparable RTs when responding to negative stimuli in the L1 and L2. In terms of processing routes, if bilinguals take varied routes when processing negation in the bipolar /unipolar contexts in the L1 vs. L2, we would expect to observe a significant interaction between *Language*, *Context* and *Polarity.*

RQ2: To what extent does the conceptual representation of the negated statement differ in bipolar/unipolar contexts when bilinguals use their L1 vs. L2?
H2: On the between-language level, if language plays a role in the conceptual representation of negation, then we would observe *Language* to be a significant factor. On the within-language level, if the available opposite is conceptually represented when processing negation in a bipolar context, we should observe comparable RTs on the within-language level across the positive and negative stimuli. If negation in a bipolar context is not conceptually represented as the available opposite, we should observe longer RTs in response to the negative stimuli compared with positive controls.

Methodology

Experiment 1: Negative Stroop task

The use of a negative Stroop task to investigate negation processing in bilinguals was motivated by Orenes et al. (2014), who examined eye fixations when Spanish participants compared negative sentences (e.g., The figure was not red) against colour blocks. Their experiment was set in a bipolar context, in which the colour blocks were either red or green, or a unipolar context, in which the colour blocks could be red/green/blue/yellow. We combined context variation with the traditional Stroop task (Stroop, 1935). In a typical Stroop task, participants first see a colour block and then name the colour as soon as possible. In our modified Stroop task, we followed Orenes et al. (2014) in the design of the colour stimuli, and embedded these stimuli in a Stroop task to serve for the investigation of negation processing.

Participants

40 Chinese learners of English (35 females) were recruited from a university in China (M_{AGE} =20, max. 22, min. 18). All the participants confirmed that they had normal colour vision. Following Athanasopoulos, Damjanovic, Krajciova and Sasaki (2011), Vanek and Selinker (2017), and Wang and Li (2019, 2021), the bilingual participants

were asked before the experiments to self-assess their language background through a questionnaire and take the Oxford Placement Test (OPT, 2001) to assess their proficiency in English. This step was also taken to check if the samples in Expt. 1 and Expt. 2 were comparable in terms of their language background. The bilinguals started to learn English at the age of 7.30 (SD = 2.58) on average. Their average score of the OPT (out of 60) was 41.30 (SD = 8.01). Their average English use was 6.23 hours (SD = 4.67) per day.

Material

Language settings. The experiment was set up in 2 languages, English and Chinese. The two versions only differed in the language in which the colour expressions were presented. The verb *is* was added in English negative colour expressions with the aim to keep the number of words in English and Chinese the same. To illustrate, for the Chinese expression *bu shi hei* 'is not black', the English counterpart is *is not black* (Figures 1-4).

Contexts. The experiment was conducted in a bipolar and a unipolar context. The bipolar context (Figures 1 & 2) consisted of two antonymic colour items *white* and *black*, while the unipolar context (i.e., there is no lexical opposite for any of the colour items) (Figures 3 & 4) included four colour items *red/yellow/blue/green*. Following Du et al. (2014) and Dudschig and Kaup (2018), the criterion used to classify the bipolar context was that the bipolar context subsumes a pair of binary opposite predicates only, which are mutually exclusive and complementary to one another i.e., 'not Predicate A' implies 'Predicate B', in the same way as 'not close' implies 'open' in Du et al. (2014) and 'not left' implies 'right' in Dudschig and Kaup (2018). In contrast, the unipolar context involves the target predicate as a singular pole that could have three alternatives in the current design i.e., 'not Predicate A' can imply 'Predicate B' or 'Predicate C' or 'Predicate D'. To avoid the possibility that participants would associate the binary predicates in the bipolar context with other possible alternatives (e.g., left-right-up-down), and better distinguish the bipolar/unipolar contexts, participants were explicitly informed of all the predicates in the instructions at the beginning of the experiment, i.e., "You will see some colour expressions in white/black ink" for the bipolar context, and "You will see some colour expressions in red or yellow or blue or green ink" for the unipolar context.

Stimuli in the bipolar/unipolar context were presented in two blocks. The experiment was set up using Psychopy version 3.

Conditions. In each context, there were four conditions which were labelled based on the polarity of the colour expressions and the congruency between the colour expressions and the coloured inks, i.e., positive-congruent, positive-incongruent, negative-congruent, negative-incongruent respectively (Figure 1 & Figure 2). 8 trials were designed for each condition in each experimental block.

Altogether, there were 256 trials for each participant, i.e., 8 trials × 4 conditions × 2 blocks × 2 contexts × 2 language settings. The sequence of context × language setting was counterbalanced.

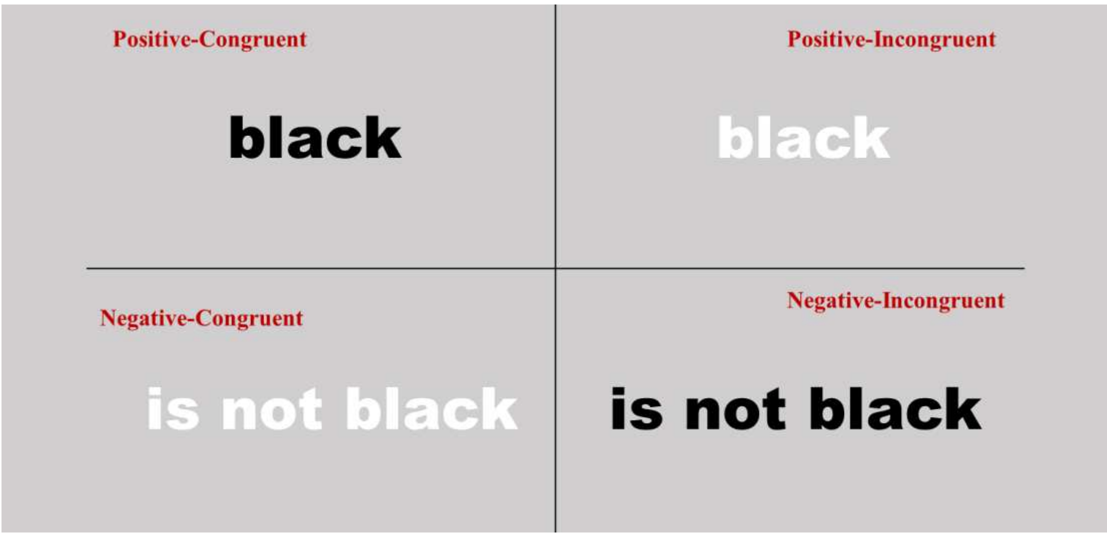

Figure 1 Stimuli for 'black' for each condition in bipolar context in English in Expt. 1.

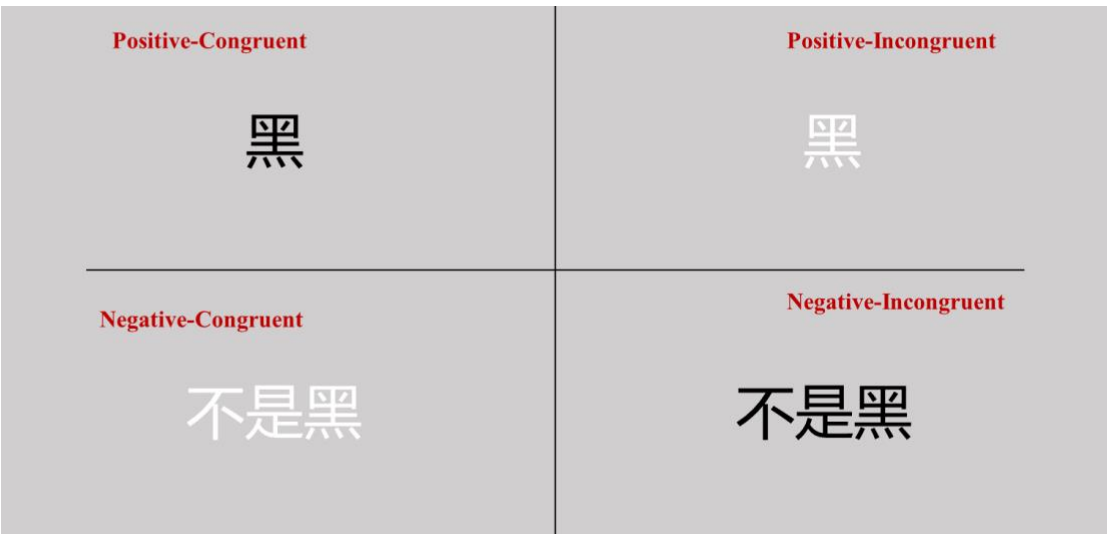

Figure 2 Stimuli for 'black' for each condition in bipolar context in Chinese in Expt.

1.

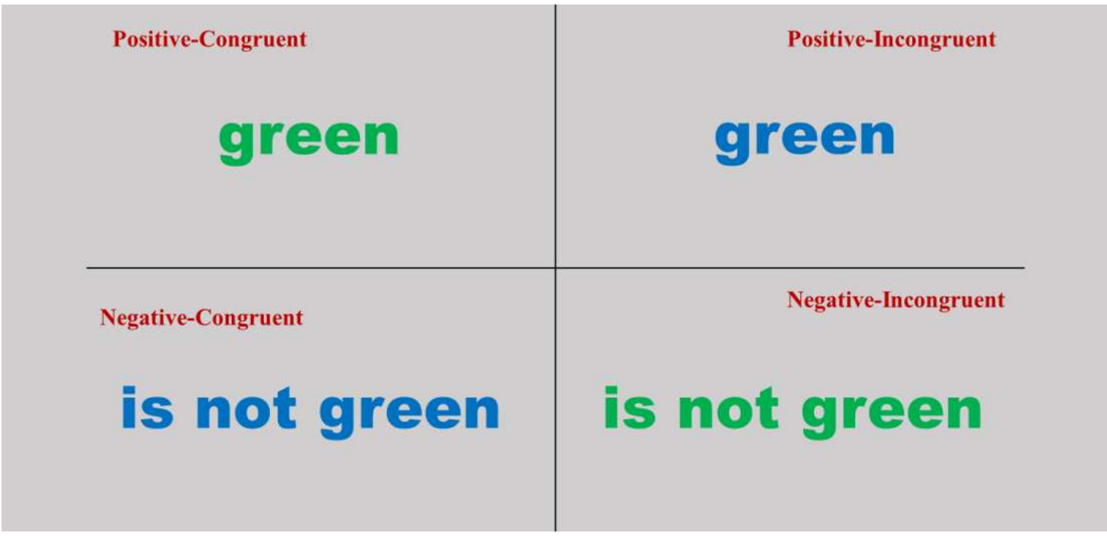

Figure 3 Stimuli for 'green' for each condition in unipolar context in English in Expt. 1.

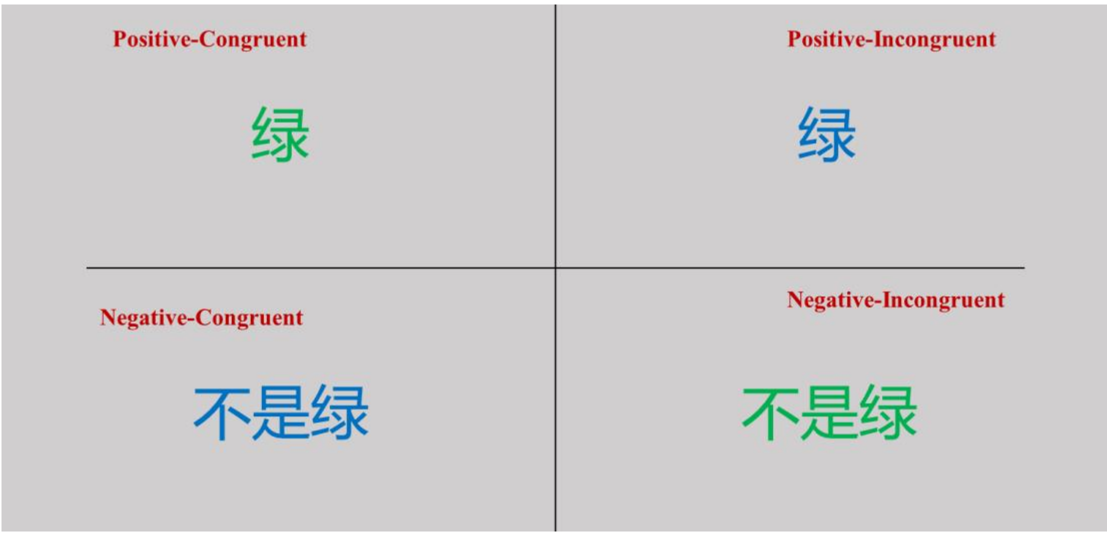

Figure 4 Stimuli for 'green' for each condition in unipolar context in Chinese in Expt. 1.

Procedure

First, the participants were provided with a consent form with guarantees of ethical matters including, anonymity, confidentiality, and the task details. The experiment was presented in four sections differing in the combinations of the contexts and the language settings. In each section, the presentation of trials was arranged in two blocks with a short break in-between. Each section started with instructions tailored for the corresponding context and language setting. Following each of the four versions of instruction, there were four trials for practice, each from one of the four conditions. After completing each practice trial, participants received feedback on their answers.

The procedure of the experimental trials was analogous to that of the practice trials. The only difference was that the participants would not receive any feedback during the experimental trials. In each trial, the participants first saw a fixation cross (0.5×0.5 cm, 500 ms). Then the participants saw one positive/negative colour expression in a coloured ink that matches/mismatches the given expression. The task was to verify whether the colour expression matches the colour of the ink accurately and as quickly as possible. The participants pressed '↑' on the keyboard when they chose 'match' and pressed '↓' when they chose 'mismatch'. The order of the trials was semi-randomized to ensure that items from the same condition would not appear consecutively.

Results

Inclusion criteria

Altogether we tested 40 Chinese-English bilingual participants and collected RTs of 10240 answers. Every participant's accuracy rate (M= 96%; SD= 4%) was above 75% (min. 79%, max. 100%). RTs of incorrect answers (4% of the total) were excluded. Following Keating & Jegerski (2015), the outliers were identified (3%) and replaced by the cut-offs (group mean per condition +/− 2.5 SDs). RTs of the correct responses are illustrated in Figures 5-6. The full dataset is available on the project website https://osf.io/avux7/?view_only=384a32efe630427c9f0187ed1d3d8297. To determine whether to include both the measure of accuracy and RT in our analysis, we tested the relationship between the two variables using Spearman's rank correlation coefficients. A significant moderate positive correlation r (10238) = .04, p <.001 was found between accuracies and RTs, indicating that the participants who took longer to respond to the stimuli were also more accurate. As all participants' accuracy rates in this experiment were relatively high, our analyses focused on the more time-sensitive measure of RT.

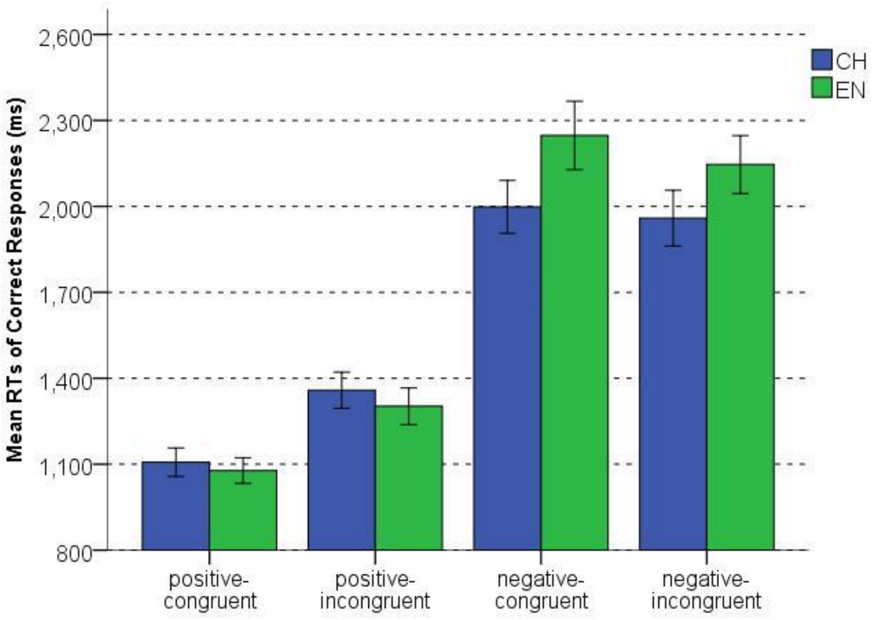

Figure 5 Mean RTs of correct answers in bipolar context (black/white) of Expt. 1.

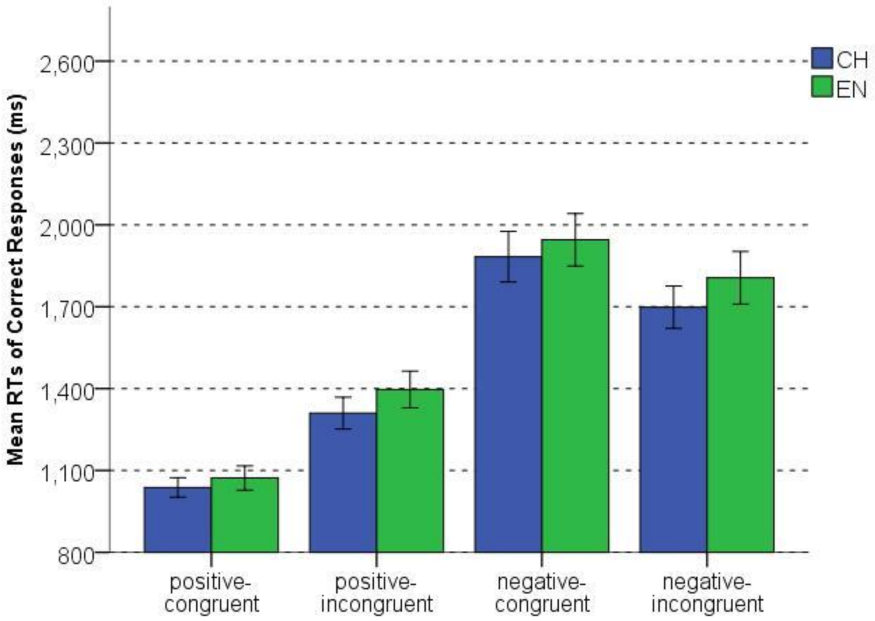

Figure 6 Mean RTs of correct answers in unipolar context (green/not green) of Expt. 1.

Analyses

Mixed-effects models were built using lme4 package (Baayen et al., 2008) in R (Version 3.5.1; R Development Core Team 2018) to test a) if language affects negation processing and b) negation processing across contexts and conditions.

Effect of language on negation processing. We specified Language

(English/Chinese), Context (bipolar/unipolar), Polarity (positive/negative) and congruency (congruent/incongruent) as fixed effect factors and Participant and Item as random effect factors (Table 1).

Table 1 Coefficients for bilinguals' RTs in Expt. 1

Fixed effects	*Estimate*	*SE*	*Z value*	*p*
Intercept	2010.83	79.93	25.16	< .001**
Language	242.31	53.39	4.54	< .001**
Context	-140.86	54.70	-2.58	.010*
Polarity	-901.67	66.99	-13.46	< .001**
Congruency	-51.39	52.94	-0.97	.332
Language × Context	-171.25	76.08	-2.25	.024*
Language × Polarity	-268.28	74.59	-3.60	< .001**
Context × Polarity	67.53	75.12	0.90	.369
Language × Congruency	-46.68	74.90	-0.62	.533
Context × Congruency	-127.03	75.19	-1.69	.091
Polarity × Congruency	304.83	74.34	4.10	< .001**
Language × Context × Polarity	232.98	105.82	2.20	.028*
Language × Context × Congruency	85.64	106.49	0.80	.421
Language × Polarity × Congruency	13.30	105.20	0.13	.899
Context × Polarity × Congruency	146.42	105.23	1.39	.164
Language × Context × Polarity × Congruency	-2.17	148.96	-0.02	.988

To statistically test whether participants' RTs significantly differed in processing negations in L1 and L2, we compared a full model including *Language* with a reduced model excluding *Language*. This comparison showed that the model fit was significantly improved with the presence of *Language*, $\chi2(8) = 45.15$, $p < .001$., confirming that language drives changes in participants' processing time in Expt.1. A significant interaction was found between *Language* and *Polarity*, indicating that it was more difficult for the bilingual participants to process negation in L2 (M=2037; SD=1305) than L1 (M=1884; SD=1133)[1]. However, their RTs to positive stimuli in L1 (M=1203, SD=686) and L2 (M=1212, SD=730) were comparable. Furthermore,

[1] In general, the standard deviations of the response time of the two experiments are large. One possible interpretation might be attributed to the variation in bilinguals' language learning trajectories. For example, previous studies have suggested that language proficiency and frequency of language use seem to be important modulators in the interaction between bilingual acquisition and cognitive processing (e.g., Bialystok, 2012; Vanek & Selinker, 2017). These individual differences may lead to a large dispersion of data, especially for time-sensitive measures.

there was a significant three-way interaction among *Language, Polarity* and *Context,* indicating that language influence was different on negation processing in the bipolar and the unipolar contexts. While negation processing was similar in L1 (M=1788, SD=1064) and L2 (M=1874, SD=1195) in the unipolar context, it was more difficult for the bilingual participants to process negation in L2 (M=2196, SD=1387) than L1 (M=1978, SD=1190) in the bipolar context.

Negation processing across contexts and conditions. To further explore the influence of *Context* on negation processing, we ran a separate model without *Language* factor. We examined whether the RT patterns were significantly different in the bipolar context and the unipolar context by comparing models with and without the fixed factor *Context*. The results showed that adding *Context* significantly increased the model fit, $\chi 2(4) = 90.73$, $p < .001$, confirming that *Context* affects bilinguals' negation processing (Figure 7).

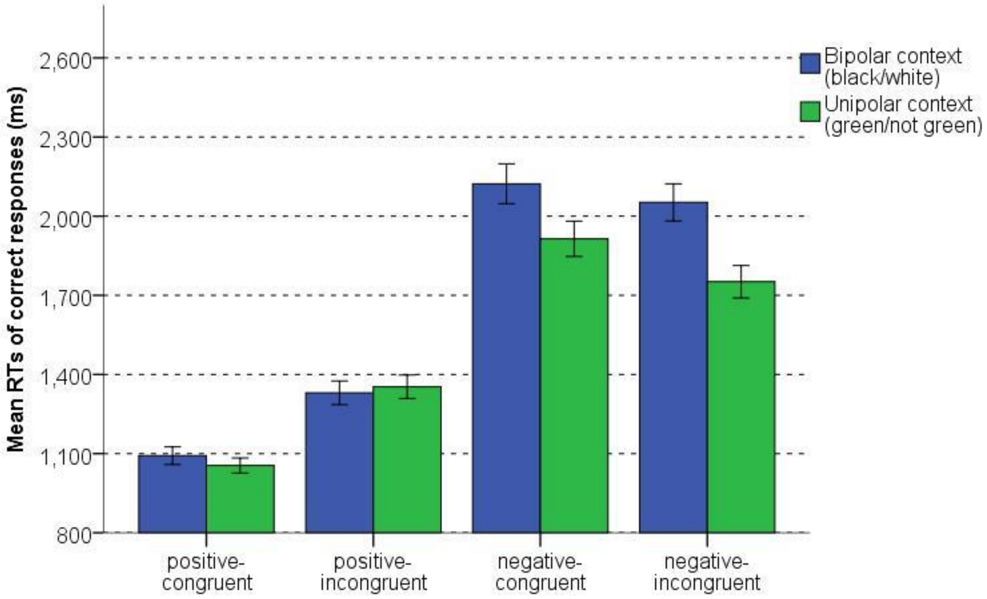

Figure 7 Mean RTs of correct answers in Expt. 1 when *Language* was removed from analysis.

Table 2 Coefficients for bilinguals' RTs in Expt. 1 when *Language* was removed from analysis.

Fixed effects	*Estimate*	*SE*	*Z value*	*p*
Intercept	2131.10	75.24	28.33	< .001**
Context	-225.71	39.38	-5.73	< .001**
Polarity	-1035.09	55.58	-18.62	< .001**

Congruency	-74.78	37.55	-1.99	.046*
Context × Polarity	183.38	53.46	3.43	< .001**
Context × Congruency	-84.41	53.37	-1.58	.114
Polarity × Congruency	311.63	52.73	5.91	< .001**
Context × Polarity × Congruency	145.46	74.65	1.95	.051

As shown in Table 2, participants' RTs were significantly different between the positive and the negative polarities as well as between the bipolar and the unipolar contexts. Critically, there was a significant interaction between *Context* and *Polarity*, indicating that while the participants showed comparable RTs in the two contexts when responding to the positive stimuli, their RTs were significantly different when responding to the negative stimuli. To further examine the effect of *Context* on the RTs to the negative stimuli, we ran a Tukey-adjusted pairwise comparison. In the bipolar context, the RTs were similar in the negative-congruent and the negative-incongruent conditions (estimate = 51.97, SE= 54.99, t ratio= .95, p = .379); however, in the unipolar context, the RTs were significantly slower in the negative-congruent condition compared with the negative-incongruent condition (estimate = 158.54, SE= 53.02, t ratio= 2.99, p = .011). This contrast suggests that the participants may have processed the negative stimuli in the bipolar and the unipolar contexts differently.

Discussion

In Expt. 1, bilingual participants took longer to respond to negative stimuli in L2 than L1, suggesting that L2 adds difficulty to negation processing compared with the L1. This finding collaborates Manning et al., (2018). Moreover, we found that the added difficulty in negation processing in L2 was linked to the bipolar context but not the unipolar context. Our explanation is that the Chinese negator *bu shi* 'is not' in the bipolar context may not be processed like its translation equivalent *is not* in English. Rather, the Chinese negator *bu shi* 'is not' in the bipolar context is likely to have been processed like a negation with a smaller scope compared with *is not* in English. This argument is based on the view that negation with a smaller scope entails less processing difficulty (Carpenter & Just, 1975; Sherman, 1973, 1976). Moreover, our explanation gives support to the claim that the Chinese negator *bu* 'not' is similar to a clitic in English, in line with the more traditional syntactic analyses of Chinese (Ernst, 1995; Huang, 1988; Yuan, 2004). However, this phenomenon is only observed in the bipolar context. In the unipolar context, Chinese-English bilinguals process negators in a similar manner, which aligns with the view that the Chinese negator *bu* 'not' can be processed like *not* in English (Zhang & Li, 2011). When we focused on the effect of *Context,* eliminating the language influence, significant RT differences were observed between the bipolar and the unipolar contexts. Regarding the unipolar context, while it took the bilingual participants longer to respond to the stimuli in the positive-incongruent than the positive-congruent condition, the opposite was observed for the negative stimuli. Unlike the unipolar context, in the bipolar context, they showed similar RTs in the negative-congruent condition and the negative-incongruent condition. The asymmetric RT pattern found in the unipolar context matches the two-step model (Clark & Chase, 1972; Fischler, Bloom, Childers, Roucos, & Perry, 1983; Kaup et al., 2007). However, RTs in the bipolar context do not clearly gear towards the fusion model (Du et al., 2014; Mayo et al., 2004), which predicts that it should have taken participants shorter to respond to the congruent than the incongruent conditions regardless of the positive/negative polarities. The current results, however, suggest that negation processing in the bipolar context does not follow the two-step model. Still, the RT variances observed between the bipolar and the unipolar contexts give support to the claim that negation processing can be influenced by the availability of lexical opposites (Du et al., 2014; Mayo et al., 2004; Orenes et al., 2014).

Bilinguals are prone to following the two-step model when processing negation in the unipolar context. The asymmetric RT pattern found between the positive and negative polarities in the unipolar context has traditionally been attributed to the use of the two-step model. That is, to verify a negative sentence as true means to perform two negations and it therefore takes longer (see Tian et al., 2016 for a discussion). Following this mechanism, verifying a negative-true sentence rests on two negations, which incurs an additional processing cost than verifying a negative-false sentence resting on only one negation. Not only can processing route affect difficulty, but also the way in which negation is represented in the mind. We further designed Expt.2 to explore the conceptual representation of negation in the bipolar and the unipolar contexts.

There is one issue regarding the experimental design that we feel the need to clarify. One may aruge that negation processing was found associated with longer

RTs, but how can we eliminate likely influence of the different number of words? It is apparent that 不是黑 'is not black' consists of more words than 黑 *'black'*, and that *is not black* has more words than *black*. Are they comparable? In response to the question, we first would like to acknowledge that the additional number of words in the negation conditions than the positive conditions could have contributed longer RTs in the processing of the former. However, word/character length differences play a marginal role for this study's analyses because our key comparison is within negation across contexts and languages. We examine the extent to which negation processing differs in bipolar/unipolar contexts in the L1 vs. L2 of Chinese-English bilinguals, rather than the extent to which processing a negative sentence is more difficult than its positive counterpart. To ensure the comparability of negation processing in L1 and L2, we kept the number of additional words in the negation condition than the positive condition the same in English (i.e., there were two more words in *is not black* than *black*) as well as that in Chinese (i.e., two more words/characters in *不是黑 'is not black'* than *黑 'black'*).

Experiment 2: Orientation task

The rationale for designing Expt. 2 on the basis of Expt. 1 was to zoom in on the conceptual representation of the negated statement in the bipolar and the unipolar contexts. We built Expt. 2 on Expt. 1, changing a critical point, namely that in Expt. 2 the program would not start timing until a participant finished reading a given sentence in their own pace. Whereas in Expt. 1, the timing started as soon as a participant saw a colour expression. That is, the data from Expt. 2 can more directly reflect the conceptual representation of the negated statement since the RTs do not include the reading time or negation integration time, whereas the reaction time data from Expt. 1 include both of these processes. This manipulation was motivated by the short/long interval distinction introduced in Kaup et al. (2006) as well as the eye-tracking paradigm used in Orenes et al. (2014), both allowing the researchers to discern the processing routes and the conceptual representation of the negated statement.

Participants

Another group of 40 bilingual participants (25 females) were recruited from the same university in China for Expt. 2 (M_{AGE} =20, max. 24, min. 17). comparable to the sample in Expt. 1. The bilinguals started to learn English at the age of 7.48 (SD = 2.72) on average. Their average score of the OPT (out of 60) was 41.10 (SD = 5.66). Their average English use was 5.81 hours (SD = 4.49) per day.

Materials

The materials for Expt. 2 were analogous to those used for Expt. 1 except that the colour items were changed to spatial expressions (e.g., English: *The star is/is not on the left;* Chinese: *Xingxing zai/bu zai zuobian* 'The star is/is not on the left').

Procedure

First, the participants were provided with a consent form with guarantees of ethical matters including, anonymity, confidentiality, and the task details. Expt. 2 was presented in four sections, the bipolar-Chinese section, the bipolar-English section, the unipolar-Chinese section, the unipolar-English section. In each section, the presentation of trials was arranged in two blocks with a short interval in-between. At the beginning of each section, the participants saw an instruction specifically designed for the corresponding context and language setting that would immediately follow. Then they received four trials of practice, each corresponds to one of the four conditions. After responding to each practice trial, the participants received feedback on their answers.

The procedure of the experimental trials and practice trials were similar (Figures 8 & 9), except that the participants would not receive any feedback during the experimental trials. In each of the practice and experimental trials, the participants first saw a fixation cross (0.5×0.5 cm, 500 ms). Participants then saw one positive/negative sentence indicating the location of a star. They were instructed to press the space bar on the keyboard once they finished reading a given sentence to proceed to the picture that depicted the location of the star mentioned in the preceding sentence. Their task was to verify whether the picture matches the description of the preceding sentence or not accurately and as quickly as possible. Participants needed to press '↑' on the keyboard to indicate 'match', and '↓' to indicate 'mismatch'. The order of the trials was semi-randomized to ensure that items from the same condition would not appear consecutively.

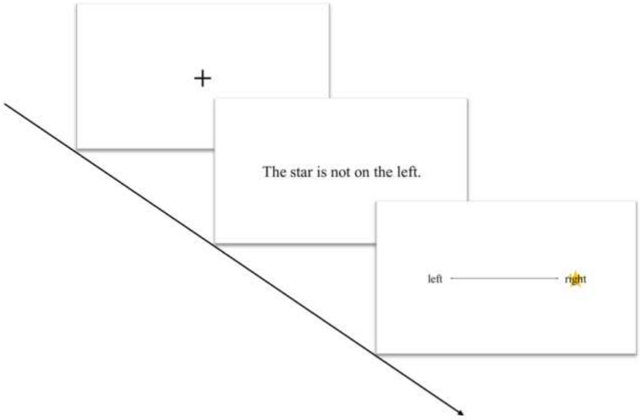

Figure 8 Procedure of bipolar context in Expt. 2.

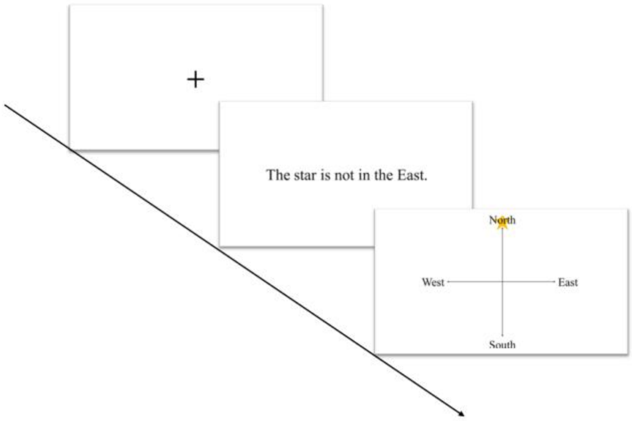

Figure 9 Procedure of unipolar context in Expt. 2.

Results

Inclusion criteria

Altogether 10240 answers were collected. Every participant's accuracy rate (M=97%, SD=2%) was above 75% (min. 91%, max.100%). We first excluded the RTs of incorrect answers (3% of total) from the analyses. Then, the outliers were identified (3%) and were replaced by the cut-offs (group mean per condition +/− 2.5 SDs). RTs of the correct responses are illustrated in Figures 10. The full dataset is available on the project website https://osf.io/avux7/?view_only=384a32efe630427c9f0187ed1d3d8297. Using Spearman's rank correlation coefficients, we found a significant moderate negative correlation r (10238) = -.05, p <.001 between accuracies and RTs in Expt. 2. The result illustrates that the participants who took shorter to recall given information were also more accurate. As all participants' accuracy rates in this experiment too were high, our analyses focused on the more time-sensitive measure of RT.

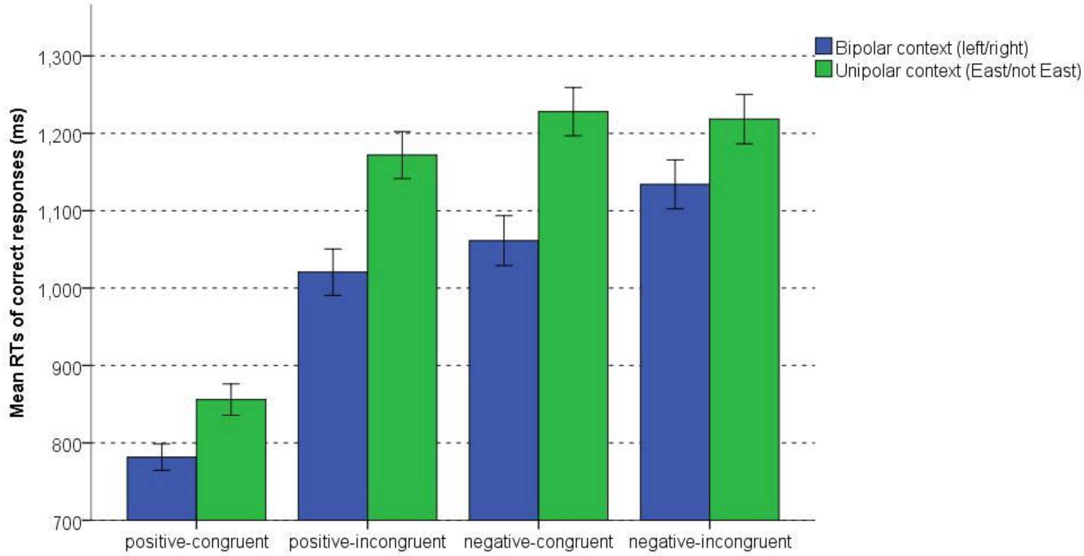

Figure 10 Mean RTs of correct answers in Expt. 2.

Analyses

Effect of language on conceptual representation during negation processing. We specified Language (English/Chinese), Context (bipolar/unipolar), Polarity (positive/negative) and congruency (congruent/incongruent) as fixed effect factors and Participant and Item as random effect factors (Table 3).

Table 3 Coefficients for bilinguals' RTs in Expt. 2

Fixed effects	*Estimate*	*SE*	*Z value*	*p*
Intercept	1088.62	36.66	29.69	< .001**
Language	-68.99	27.49	-2.51	.012*
Context	138.42	27.88	4.97	< .001**
Polarity	-304.65	34.10	-8.94	< .001**
Congruency	66.74	27.44	2.43	.015*
Language × Context	62.88	38.92	1.62	.106
Language × Polarity	22.63	38.72	0.59	.559
Context × Polarity	-59.14	39.48	-1.50	.134
Language × Congruency	14.29	38.78	0.37	.712

Context × Congruency	-94.52	38.77	-2.44	.015*
Polarity × Congruency	162.75	38.75	4.20	< .001**
Language × Context × Polarity	-26.52	54.90	-0.48	.629
Language × Context × Congruency	27.95	54.83	0.51	.610
Language × Polarity × Congruency	10.44	54.74	0.19	.849
Context × Polarity × Congruency	164.19	54.78	3.00	.003*
Language × Context × Polarity × Congruency	-26.85	77.44	-0.35	.729

We compared a full model including *Language* with a null model to test whether participants' RTs significantly differed in processing negations in L1 and L2. This comparison showed that the model fit was significantly improved with the presence of *Language*, $\chi 2(8) = 16.08$, $p = .041$, indicating that there is a language effect during negation processing. This result indicates that bilinguals responded faster to the English stimuli (M=1049, SD=538) than Chinese stimuli (M=1069, SD=534).

Conceptual representation during negation processing across contexts and conditions. Given no significant interaction was found between *Language* and other fixed factors, we merged the RTs in the two language settings to further analyse them across contexts and conditions. We compared a full model with the fixed factor *Context* with a reduced model without *Context*. The results showed that adding *Context* significantly increased the model fit, $\chi 2(4) = 141.86$, $p < .001$, indicating that *Context* affects negation processing. The results were summarised in Table 4 and Figure 10. *Context* was found significant, and so was its interaction with *Polarity* and *Congruency,* revealing that it took the participants significantly shorter to respond in the bipolar context compared with the unipolar context in each condition. To further analyse the critical negative polarity, we ran a Tukey-adjusted pairwise comparison. In the bipolar context, the RTs were similar in the negative-congruent (M=1061, SD=577) and negative-incongruent (M=1134, SD=568) conditions (estimate = -78.21, SE= 41.5, *t* ratio= 6.01, $p = .109$); comparably, similar patterns were found in the negative-congruent (M= 1228, SD=555) and negative-incongruent (M=1218, SD=574) conditions (estimate = 6.92, SE= 38.6, *t* ratio= .18, $p = .864$) in the unipolar context. These results suggest that negation processing in the bipolar and unipolar contexts became similar once the conceptual representation of the negated statement has been accessed.

Table 4 Coefficients for bilinguals' RTs in Expt. 2 when *Language* was removed from analysis.

Fixed effects	*Estimate*	*SE*	*Z value*	*p*
Intercept	1054.18	34.02	30.99	< .001**
Context	169.80	20.01	8.49	< .001**
Polarity	-293.42	28.04	-10.46	< .001**
Congruency	73.65	19.41	3.80	< .001**
Context × Polarity	-72.30	28.42	-2.54	.011*
Context × Congruency	-80.34	27.44	-2.93	.003*
Polarity × Congruency	168.23	27.39	6.14	< .001**
Context × Polarity × Congruency	150.54	38.75	3.88	< .001**

Discussion

A significant main effect of *Language* was found, indicating that overall, bilinguals responded faster to English stimuli than to Chinese stimuli. This finding could be explained as a result of bilinguals' increased cognitive control when suppressing their L1 in the L2 environment (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004; Hilchey & Klein, 2011). Critically, there was no interaction between *Language* and any other parameters, revealing that linguistic influence is unlikely to affect negation processing (Wen & Schwartz, 2014; Ćoso & Bogunović, 2019).

Negation processing did not differ in the bipolar and the unipolar contexts once the conceptual representation of the negated statement has been accessed. Regardless of polarities, the bilingual participants showed comparable RTs in the critical negative-congruent and negative-incongruent conditions. This finding is disparate from that in Expt. 1 where the participants showed context-specific RT patterns. Should negation processing differ in the bipolar and the unipolar contexts, we would have observed distinct RT patterns aligning with the fusion model or the two-step model respectively in the negative conditions of the two contexts. Instead, what we found was similar RT patterns in the negative conditions for the two contexts, indicating that negation processing becomes similar in the two contexts when the negated statement has been accessed.

General discussion

The study set off to examine the extent to which first and second language influences negation processing in Chinese-English bilinguals. In Expt.1, bilinguals were slowed down more by L2 English than L1 Chinese when processing negation in the bipolar context (black/white). This discovery gives support to Manning et al., (2018) by revealing that it could be more demanding to process negation in the L2 than in the L1. Regarding this finding, we propose that the translation equivalents of negators in English (i.e., *not*) and Chinese (*bu* 'not') could be processed in a language-specific manner. In a binary condition, Chinese-English bilinguals may tend to process the Chinese negator *bu* 'not' as a clitic *n't*. We build this claim considering a) negation with a smaller scope entails less processing difficulty such that a sentential negation *she is not happy* is more demanding to process than a lexical negation *she is unhappy* (Carpenter & Just, 1975; Sherman, 1973, 1976); and b) the Chinese negator *bu* 'not' has been argued to function like a clitic in English in traditional syntax analyses (Ernst, 1995; Huang, 1988; Yuan, 2004). However, bilinguals showed comparable performance in their L1 and L2 when processing the negative stimuli in the unipolar context. This finding supports Ćoso and Bogunović (2019) and Wen and Schwartz (2014) who showed similar difficulty in negation processing in L1 and L2. It suggests that, in the unipolar context, the Chinese negator *bu* 'not' and the English negator *not* can be processed in a similar way by Chinese-English bilinguals, which is in line with Zhang & Li (2011). Following Du et al. (2014), Kaup et al., (2006) and Orenes et al. (2014), Expt. 2 further examined the extent to which language influences the conceptual representation of the negated statement when bilinguals use their L1 vs. L2. The bilingual participants showed a general RT advantage when using their L2 than L1. Given the observed advantage in both the positive and negative conditions, and the lack of an interaction between *Language* and any other fixed factors, we interpret it as bilinguals' increased cognitive control when suppressing their L1 in the L2 environment (Bialystok et al., 2004; Hilchey & Klein, 2011). We thus conclude that language barely affects the conceptual representation of the negated statement in Chinese-English bilinguals.

The existence of available opposites can affect negation processing. In Expt. 1, we found distinct RT patterns from the bipolar and the unipolar contexts suggesting variances in processing routes. However, processing becomes similar in both contexts once the conceptual representation of the negated statement has been accessed. Diverging from the design of Expt. 1 in which the participants were timed as soon as they were presented with a colour stimuli, participants in Expt. 2 were not timed until they finished reading a given spatial sentence. The design of Expt. 2 allows the participants enough time to process negation and access the conceptual representation of the negated statement. Thus we found that in Expt. 1, the RTs in all the negative conditions were above 1500 ms, the minimum processing time of negation (Giora, Fin, Metuki & Stern, 2010) whereas in Expt.2, the RTs were below 1500 ms.

Negation might not be conceptually represented as its lexical opposite in the bipolar context. The comparable processing of negative stimuli once the conceptual representation of the negated statement has been accessed in the bipolar and the unipolar contexts leads to the idea that negating an expression in the bipolar context is not conceptually represented as its available lexical opposite by default. If it were the case, we would have observed varied RT patterns between the bipolar and the unipolar context since only in the bipolar context could the available lexical opposite replace the negated expression. However, what we found is a shared latency mismatch in these two contexts. To illustrate the mismatching latency, in the bipolar context, it took the participants longer to respond to '*not on the left*' than '*on the right*' for a star on the right after the conceptual representation of the negated statement had been accessed. It suggests that there is a mismatch between the conceptual representation for '*not left*' and the actual state of affairs 'right', otherwise it should have taken the participants a similar amount of time to respond to the lexical alternatives '*not left*' and '*right*' after they have processed the expressions. Nonetheless, it took the participants a similar amount of time to respond to '*not left*' and '*left*' for a star on the right, giving further support to the argument that negation might not be conceptually represented as its lexical opposite in the bipolar context (Du et al., 2014). Analogous to the bipolar context, the mismatching latency observed in the negative-congruent condition also holds true for the unipolar context. To sum up, regardless of the availability of lexical opposites, the conceptual representation of the negated statement is not the corresponding positive state of affairs (Dudschig & Kaup, 2018; Kaup et al., 2007).

This research also sheds light on L2 acquisition and pedagogy by showing that language can affect bilinguals' negation processing but in varied ways. Comparing the linguistic influence on bilinguals' negation processing across Expt.1 and Expt.2, we found language-specific processing in Chinese-English bilinguals when they responded to Chinese and English stimuli in Expt. 1 while general cognitive advantage was observed when using L2 than L1 after the Chinese-English bilinguals had processed the negated statement whilst matching the conceptual representations to given stimuli in Expt.2. In particular, the language-specific processing of negation reflected in Expt.1 could be indicative of language and conceptual transfer which has been reported in Chinese-English bilinguals processing negation in English negative yes-no questions (Zhang & Vanek, 2021). Future studies can suitably extend current study to recruit native English speakers with the aim to compare the performance of English speakers in L1 and that of English L2ers, which could shed more light on the extent of linguistic or possibly conceptual transfer in bilinguals' negation processing, and bilingual cognition in general.

Although this study contributes new knowledge to negation processing in bilinguals, it invites more questions. First, would bilinguals show similar sensitivity to negation with and without the presence of context compared with monolingual speakers? We raise this question considering the contrasting results on bilinguals' processing of negation. Context (i.e., background information), reported a significant factor in negation processing (Nieuwland &Kuperberg, 2008; Wang, Sun, Tian, & Breheny, 2021), is more complex in Manning et al., (2018) compared with Ćoso and Bogunović (2019). Even though the current study experimentally supports Manning et al. (2018), Ćoso and Bogunović (2019) and Wen and Schwartz (2014) in Expt.1 and Expt.2 respectively, we did not test the potential influence of complexity of background information. Further research can benefit from designing comparable experiments, manipulating the presence/absence of context, and comparing the performance of bilingual participants with L1 controls. Second, current findings showed that the conceptual representation of the negated statement is not through its available lexical opposite. Still, we cannot conclude that the conceptual representations of negation are similar in the bipolar and the unipolar contexts. Future studies can examine bilinguals' eye movements against pictural stimuli after the conceptual representation of the negated statement has been accessed by bilinguals.

References

Athanasopoulos, P., Damjanovic, L., Krajciova, A., & Sasaki, M. (2011). Representation of colour concepts in bilingual cognition: The case of Japanese blues. *Bilingualism: Language and Cognition*, *14*(1), 9–17.

Bialystok, E., Craik, F. I., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: evidence from the Simon task. *Psychology and aging*, *19*(2), 290.

Bialystok, E., Craik, F.I.M., & Luk, G. (2008). Cognitive control and lexical access in younger and older bilinguals. Journal ofExperimen- tal Psychology: Learning, Memory, and Cognition, 34, 859–873.

Ćoso, B., & Bogunović, I. (2019). The role of linguistic cues in bilingual negation processing. *International Journal of Bilingualism*, *23*(1), 21–36.

Dale, R., & Duran, N. D. (2011). The Cognitive Dynamics of Negated Sentence Verification. *Cognitive Science*, *35*(5), 983–996.

Du, P., Liu, D., Zhang, L., Hitchman, G., & Lin, C. (2014). The processing of contradictory and non-contradictory negative sentences. *Journal of Cognitive Psychology*, *26*(4), 461–472.

Dudschig, C., & Kaup, B. (2018). How does “not left” become “right”? Electrophysiological evidence for a dynamic conflict-bound negation processing account. *Journal of Experimental Psychology: Human Perception and Performance*, *44*(5), 716–728.

Ernst, T. (1995). Negation in mandarin Chinese. *Natural Language & Linguistic Theory*, *13*(4), 665-707.

Fischler, I., Bloom, P. A., Childers, D. G., Roucos, S. E., & Perry, N. W. (1983). Brain potentials related to stages of sentence verification. *Psychophysiology*, *20*(4), 400–409.

Hilchey, M. D., & Klein, R. M. (2011). Are there bilingual advantages on nonlinguistic interference tasks? Implications for the plasticity of executive control processes. *Psychonomic bulletin & review*, *18*(4), 625-658.

Huang, C. T. J. (1988). 'Wo Pao De Kuai' and Chinese Phrase Structure. *Language*, *64*, 274-311.

Giora, R., Fein, O., Metuki, N., & Stern, P. (2010). Negation as a metaphor-inducing operator. In *The expression of negation* (pp. 225-256). De Gruyter Mouton.

Kaup, B., Lüdtke, J., & Zwaan, R. A. (2006). Processing negated sentences with contradictory predicates: Is a door that is not open mentally closed? *Journal of Pragmatics*, *38*(7), 1033–1050.

Kaup, B., Yaxley, R. H., Madden, C. J., Zwaan, R. A., & Lüdtke, J. (2007). Experiential simulations of negated text information. *Quarterly Journal of Experimental Psychology*, *60*(7), 976–990.

Keating, G. D., & Jegerski, J. (2015). Experimental designs in sentence processing reseach: A Methodological review and user's Guide. *Studies in Second Language Acquisition*, *37*(1), 1–32.

Lüdtke, J., Friedrich, C. K., Filippis, M. De, & Kaup, B. (2008). Event-related potential correlates of negation in a sentence-picture verification paradigm. *Journal of Cognitive Neuroscience*, *20*(8), 1355–1370.

Mayo, R., Schul, Y., & Burnstein, E. (2004). "I am not guilty" vs "I am innocent": Successful negation may depend on the schema used for its encoding. *Journal of Experimental Social Psychology*, *40*(4), 433–449. Orenes, I., Beltrán, D., & Santamaría, C. (2014). How negation is understood: Evidence from the visual world paradigm. *Journal of Memory and Language*, *74*, 36–45.

Quick Placement Test. (2001). Oxford: Oxford University Press.

Sherman, M. A. (1973). Bound to be easier? The negative prefix and sentence comprehension. *Journal of Verbal Learning and Verbal Behavior*, *12*(1), 76–84.

Sherman, M. A. (1976). Adjectival negation and the comprehension of multiply negated sentences. *Journal of Verbal Learning and Verbal Behavior*, *15*(2), 143–157

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. Journal of Experimental Psychology, 18, 643–662.

Tian, Y., Breheny, R., & Ferguson, H. J. (2010). Why we simulate negated information: A dynamic pragmatic account. *Quarterly Jounal of Experimental Psychology*, *63*(12), 2305–2312.

Vanek, N., & Selinker, L. (2017). Covariation between temporal interlanguage features and nonverbal event categorisation. *IRAL – International Review of*

Applied Linguistics in Language Teaching, *55*, 223–243.

Wang, S., Sun, C., Tian, Y., & Breheny, R. (2021). Verifying Negative Sentences. *Journal of Psycholinguistic Research*, *50*(6), 1511-1534.

Wang, Y., & Li, W. (2019). Cognitive restructuring in the bilingual mind: Motion event construal in early Cantonese- English bilinguals. *Language and Cognition, 11*(4), 527- 554.

Wang, Y., & Li, W. (2021). Cognitive restructuring in the multilingual mind: Language-specific effects on processing efficiency of caused motion events in Cantonese-English-Japanese speakers. *Bilingualism: Language and Cognition, 24*(4), 1-16.

Wen, Z., & Schwartz, B. D. (2014). Fully-specified L2 processing of negation-aspect interactions in Chinese. In C. Chu (Ed.), *Selected proceedings of the 5th conference on generative approaches to language acquisition North America* (pp. 128–239). Somerville, MA: Cascadilla Proceedings Project.

Yuan, B. (2004). Negation in French–Chinese, German–Chinese and English–Chinese interlanguages. *Transactions of the Philological Society*, *102*(2), 169-197.

Zhang, H., & Vanek, N. (2021). From “No, she does” to “Yes, she does”: Negation processing in negative yes–no questions by Mandarin speakers of English. *Applied Psycholinguistics*, *42*(4), 937 - 967.

Zhang, L., & Li, H. (2011). An ERP Study on the processing of negation in the category verification task. *Scientia Sinica Vitae*, *41*(12), 1203-1211.