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Eye Movements Reveal Delayed Use of Construction-Based Pragmatic Information During Online Sentence Reading: A Case of Chinese *Lian. . .dou* Construction

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An event-related potential (ERP) study demonstrated that construction-based pragmatic constraints in Chinese (e.g., *lian. . .dou* that constrains a low-likelihood event and is similar to *even* in English) can rapidly influence sentence comprehension and the mismatch of such constraints would lead to increased neural activity on the mismatching word. Here we examine to what extent readers' eye movements can instantly reveal the difficulties of mismatching constraints when participants read sentences with the structure *lian* + *determiner phrase* + *object noun* + *subject noun* + *dou* + *verb phrase (VP)* + *final commenting clause*. By embedding high-likelihood or neutral events in the construction, we created incongruent and underspecified sentences and compared such sentences with congruent ones describing events of low expectedness. Relative to congruent sentences, the VP region of incongruent sentences showed no significant differences on first-pass reading time measures, but the total fixation duration was reliably longer. Moreover, readers made more regressions from the VP and the sentence-final region to previous regions in the incongruent than the congruent condition. These findings suggest that the effect of pragmatic constraints is observable during naturalistic sentence reading, reflecting the activation of the construction-based pragmatic information for the late integration of linguistic and extra-linguistic information at sentential level.

Keywords: eye movements, sentence construction, pragmatic constraint, Chinese reading, pragmatic inference

INTRODUCTION

To make sense of linguistic inputs in different communicative contexts, readers need to incrementally build linguistic representations based on local semantic constraint, and integrate this local representation with extra-linguistic (e.g., pragmatic) information in real time (Zhou et al., 2009, 2010; Jiang and Zhou, 2012; Jiang et al., 2013a,b; Clifton et al., 2016).

The negotiation of meanings derived at different representation levels determines when and how the pragmatic meaning is activated and used during sentence comprehension (Politzer-Ahles et al., 2013). In this sentence, *Even a rich person cannot a ord such an expensive house,* a less likely event *a rich person cannot a ord an expensive house* is constrained by the *even* construction, denoting the unexpectedness of what is described in the construction, and implying that any event which is more likely to happen than the embedded event must occur. If the event does not rank at the lowest end of the scale, embedding such event in the construction can result in infelicitousness (Fauconnier, 1975; Yuan, 2006). However, it remains unclear whether such construction-based pragmatic constraint can exert an immediate impact on local linguistic representation building and at what stage the detection of anomaly of such pragmatic constraint affects the relevant processes (Filik et al., 2009; Jiang et al., 2013a; Jiang and Zhou, 2014).

Extensive evidence from ERPs (event-related brain potentials) has suggested that readers can immediately detect when an upcoming word is pragmatically incongruent with the prior sentential/discourse/communicative context (such as the prediction generated from the discourse representation, reader's world knowledge, or even the speaker identity), as indicated by an increased N400 response on the word that indexes an increased effort of integrating the word into the pragmatic context (e.g., Van Berkum et al., 1999, 2003, 2008; Hagoort et al., 2004; Jiang et al., 2013a,b; Nieuwland, 2013; Li et al., 2014). Some studies showed a relatively late starting (~400 ms) but prolonged negativity effect on the words (e.g., sentence-initial scalar quantifiers *some kids were riding bicycles*) preceded by a context mismatching the pragmatic meaning of the quantifier (e.g., a picture showing all kids were riding bicycles). This negative response indexes a process of canceling or inhibiting initially built pragmatic representation, implicitly indicating that pragmatic information is instantly used for online sentence processing (Politzer-Ahles et al., 2013). In contrast, research using the eye-tracking technique has observed plenty inconsistent findings (e.g., Rayner et al., 2004; see also Warren, 2011 for a review). It is evident that ERP research typically adopts rapid serial visual presentation (RSVP) paradigm in which one word at a certain time is presented in the screen and participants are required to fixate the target and avoid making eye movements. Therefore, the word-by-word presentation prevents natural eye movement behavior that usually occurs during normal reading such as parafoveal processing (i.e., information about a word in the parafovea is available before the word is directly fixated), word skipping, refixation, and regression. In the present study we used the same stimuli from an ERP study conducted by Jiang et al. (2013a) and employed an eye movement tracking technique to examine the precise time course of processing Chinese construction-based pragmatic information during normal sentence reading.

Previous eye-tracking studies on pragmatic processing are inconclusive about how early the pragmatic constraints can impact the eye-movement measures during on-line sentence reading. The case of *pragmatic implausibility* (the use of language is still plausible if one's world knowledge permits the language use in rare cases, similar to the label "pragmatic anomaly") showed mixed evidence. For example, Murray and colleagues (Murray, 1998; Murray and Rowan, 1998; Kennedy et al., 2004) investigated whether readers could immediately detect the incongruence when a word was pragmatically incongruent with the context in a task where they were not explicitly reminded of the incongruent word in the sentence (i.e., when matching a probe sentence with the target sentence). Such incongruence arose given the low probabilistic expectancy of the linguistic input (the noun) in the given or inferred contextual information (the verb, e.g., *the savages/uranium smacked the child*). The authors reported very early *parafoveal-on-foveal* effects of pragmatic plausibility (although this effect appeared marginal in statistical significance), such that the pragmatically implausibility of the critical word inflated first pass reading times on its preceding regions (*uranium*), thus can be detected parafoveally before that word was directly fixated (see Drieghe, 2011; Clifton et al., 2016; for reviews).

The very early pragmatic effects reported in Murray and colleagues seem to be restricted to local adjacent linguistic combination, and such parafoveal effect disappeared when the noun and verb were separated by other adjunctive phrases (such as *the princess with blonde hair delivered the packages;* Murray, 2006). Ni et al. (1998) and Braze et al. (2002) used similar materials and asked participants to read sentences like *The wall will surely crack$_{baseline}$/bite$_{pragmaticanomaly}$ after a few years in this harsh climate*. They found that participants immediately detected the anomaly just at the critical regions "*bite after*" relative to "*cracking after,*" whereas the pragmatic anomaly did not manifest its effect until the word after the verb "*bite.*" In Ni et al. (1998), pragmatic anomaly and baseline condition did not differ until the final region of the sentence (*this harsh climate),* with the first pass reading time being increased for the former rather than for the latter condition. Furthermore, Rayner et al. (2004) investigated the time course of implausibility effect in the sentence frame (e.g., *John used a knife$_{baseline}$/an axe$_{implausible}$ to chop the large carrots for dinner last night*), and found no effect of implausibility during first pass reading of *carrots*. The potential effect was further delayed in the condition in which the world-knowledge permits no way out (the impossible condition, e.g., *John used a pump to inflate the large carrots for dinner*). The *go-past* measure of eye movement, which includes the amount of time readers spent on the target word as well as the one spent on constituents preceding the target before moving forward to new portions of the sentence, was influenced by implausibility; but the effect size of this measure was fairly small, indicating that the impact of context has no immediate effect on eye movements during reading (see also Warren, 2011 for a review).

The pragmatic implausibility seems to be affected by the discourse-level contextual information (Ferguson and Sanford, 2008; Xu et al., 2017). For example, although there was no use in rarelinfor

context (*Evolution dictates that cats are carnivores and cows are vegetarians. Families could feed their cat a bowl of carrots and*

TABLE 1 | An example of a set of sentences used in the experiment.

Condition	Sentences							
	Lian	Scalar adjective	Adjective phrase (AP)	Objective noun	Subject noun	Model verb (MV)	Main VP	Commenting clause (CC)
Affirmative sentences								
Congruent	连	这么	**危险的**	大桥	成超	**都能**	**走过去**	**真是勇敢**
	Even such a **dangerous** bridge Chengchao **can come across, he is so brave**							
Underspecified	连		**这样的**	大桥	成超	**都能**	**走过去**	**?**
	Even **such a** bridge Chengchao **can come across, he is so brave**							
Incongruent	连	这么	**安全的**	大桥	成超	**都能**	**走过去**	**真是勇敢**
	Even such a **secure** bridge Chengchao **can come across, he is so brave**							
Negative sentences								
Congruent	连	这么	**安全的**	大桥	成超	**都不能**	**走过去**	**真是胆小**
	Even such a **secure** bridge Chengchao **cannot come across, he is so timid**.							
Underspecified	连		**这样的**	大桥	成超	**都不能**	**走过去**	**真是胆小**
	Even **such a** bridge Chengchao **cannot come across, he is so timid**							
Incongruent	连	这么	**危险的**	大桥	成超	**都不能**	**走过去**	**真是胆小**
	Even such a **dangerous** bridge Chengchao **cannot come across, he is so timid**							

Regions of interest were bolded.

relocates the object noun to an earlier position in the sentence. The *Lian. . .dou. . .* construction in different experimental sets constrained a different event.

The main VP consisted of an action verb and a verb complement. The embedded event was manipulated by varying the DP, such that the DP was either a scalar adjective phrase "zheme/name/ruci [so] + adjective" to specify the likelihood of the event in the congruent and incongruent conditions or a demonstrative modifier "zheyangde/nayangde/rucide [such]" in the underspecified condition. In each set, the MV was in either affirmative or negative form, with a negation marker *bu* (not) either absent or present immediately before the main VP, creating the affirmative and the negative version of the sentences. Specifically, we replaced the affirmative modal verb with a negative counterpart and switched the adjectives in the congruent and incongruent conditions in the affirmative version to the opposite counterparts in the negative version. The purpose of using the negation form of the stimuli was to prevent readers from expecting the congruence of the sentence based on contextual information preceding the main VP.[1] Consequently, six sentences were constructed for each set of stimuli.

Both the global sentence comprehensibility (with *lian. . .dou* construction) and the likelihood of an embedded event happening in daily life (without *lian. . .dou* construction) were rated on 7-point scales for each sentence by two independent groups of readers in two off-line tests (see Jiang et al., 2013a for details). Among the stimuli selected for the current experiment, the comprehensibility score was the highest for the congruent sentences (Mean = 6.19, *SD* = 1.45 out of 5, 1- least comprehensible, 7- most comprehensible), lower for the underspecified sentences (Mean = 5.72, *SD* = 1.71), and the lowest for the incongruent sentences (Mean = 2.62, *SD* = 1.82). Reversely, the event likelihood was the highest for the incongruent sentences (Mean = 5.76, *SD* = 0.92 out of 5, 1- least likely, 5- most likely), lower for the underspecified sentences (Mean = 4.46, *SD* = 0.83) and the lowest for the congruent sentences (Mean = 2.48, *SD* = 1.13).

All stimuli were divided into six lists, with each containing 114 formal sentences. Conditions were rotated across lists according to a Latin-square procedure, such that a sentence within a given set appeared only once in each list, and there were equal numbers of sentences per condition per list. In addition, ninety narrative sentences with a canonical structure "Subject noun + Verb + Object noun" were added to each list as fillers to prevent readers from using specific reading strategies generated from certain constructions. In total, each participant was shown a total of 204 sentences which were randomized within the list. Each participant was randomly assigned a list. Ten practice sentences were included at the beginning of each testing session. Among the practice sentences, six had the *lian. . .dou. . .* structure, and the other four were narrative sentences without the *lian. . .dou. . .* structure.

In each list, seventy sentences, including 40 critical sentences with the *lian. . .dou. . .* structure and 30 filler sentences, were randomly selected and followed by a verification statement which required the reader to respond with a yes/no answer. In the 40 verification statements corresponding to the critical sentences, 25 required integrative comprehension of sentential meaning in order for a participant to provide a correct answer. The remaining 15 required information from a specific sentence constituents of the critical sentences, with 9 statements related to adjective phrases, 3 to VP, and 3 to object nouns. Statements concerning the filler sentences were also targeted the meanings

[1]To examine whether the form of sentence (affirmative vs. negative) could module the key effects of sentence type, we conducted a set of LMM analyses in which the sentence form was included as a fixed factor in addition to the sentence type. These analyses did not produce any reliable interactions between the sentence form and the sentence type for any measures over the two pre-critical regions, critical and post-critical regions (all $ts < 1.75$), indicating that this variable did not contribute significantly to our key findings.

of either the whole sentences or specific sentence constituents in different sentential positions. In this way, we made sure that the participants should have read and comprehended the whole sentences before they responded to the verification statements.

Data Analysis

Several regions-of-interest were predefined for the analysis (see **Table 1** for exemplar sentence). The main VP area (e.g., 走过去, meaning *come across*) was defined as the critical region, where the congruency of the sentence became apparent. The adjective phrase (AP, e.g., 危险的/这样的/安全的, meaning *dangerous/such/secure*) and the model verb (MV, e.g., 都能/都不能, meaning *can/cannot*) were defined as the two pre-critical regions. The MV was defined to detect any possible parafoveal effect on VP that is modulated by the congruency of the sentence. The AP was defined to examine possible regressive saccades into this region due to pragmatic inferences about the likelihood of an unspecified event against the constraints of the *lian…dou…* and the integration of specified event into the construction that take place on critical VP. Lexical features of AP were measured and controlled across the three conditions. The number of strokes of AP region was similar across the three conditions (all $M = 16$, $ps > 0.05$), and mean frequencies of this region were higher in the underspecified condition (1072/million) than those in the other two conditions (collapsing congruent and incongruent condition: 146/million, $p < 0.001$). The remainder of the sentence that follows the critical region – the commenting clause (e.g., ㄱ , meaning *he is so brave*) was defined as the post-critical region, making the "unexpectedness" meaning explicit.

We computed different eye movement measures that represent different processing stages. The measures for early processing include *first fixation duration* (FFD, the duration of the first fixation on a region during the first pass reading) and *gaze duration* (GD, the sum of all fixations on a region before moving to another region). The measures for late processing include *total fixation duration* (TFD, the sum of all fixations that take place on a region). Moreover, to investigate how participants attempted saccadic movement to deal with processing difficulty due to incongruence or under-specification, the probability of making a *regression in* (REG-IN, regressive saccades from the following regions land into the current region) was reported for pre-critical regions and the probability of making a *regression out* (REG-OUT, saccades departing out of the current region and landing in a previous region, i.e., the interested area at a previous region) was reported for critical and post-critical regions. These two measures indicated the proportion of trials in which a participant made a regressive saccade into/out of a region.

All statistical analysis was performed with linear mixed models (LMM), using the *lme4* package (version 1.1-7) in R (R Core Team, 2014). For all measures per region, we fitted LMM with the maximal random effects structure (Barr et al., 2013), which included both random intercepts and random slopes for the fixed effects over both participants and items. Given that our hypothesis was centered on the effect of pragmatic incongruence and underspecification on eye-movement measures, two contrasts were programed: the first contrast compared the incongruent with the congruent condition to test the "incongruence" effect, and the second contrast compared the underspecified with the congruent condition to test the "underspecification" effect. The congruent condition was treated as baseline in both contrasts to estimate statistical parameters. To reduce the impact of data skewness and facilitate interpretation, all fixation duration measures were analyzed using log-transformed data, and probabilities of regressions were analyzed using logit-link function.

Procedure

Participants were instructed to read sentences in a normal way that ensured comprehension. They were informed that a simple statement would occasionally appear after a sentence, and they should verify whether the statement was consistent with the message conveyed in the critical sentence by pressing a button on the response box. Prior to the experiment, participants were required to complete a three-point horizontal calibration procedure, with an average calibration error below 0.30 degrees. Prior to the start of each trial, a fixation point was presented on the 457 Td [(on)-550(t)-4-4(80(li-11.4(prid(t)-4-4-531([(on)-550(t)-4-4

TABLE 2 | Eye movement measures for regions of interest, including adjective phrase (AP), dou + modal verb (MV), the main VP and commenting clause (CC) areas.

Measure	Congruent	Underspecified	Incongruent
Pre-critical region 1 – Adjective phrase (AP)			
FFD (ms)	224(79)	233(83)	222(78)
GD (ms)	288(151)	337(183)	279(146)
TFD (ms)	558(339)	635(388)	643(423)
REG-IN (probability)	0.57(0.50)	0.70(0.46)	0.63(0.48)
Pre-critical region 2 – Dou + modal verb (MV)			
FFD (ms)	252(88)	244(82)	249(88)
GD (ms)	324(168)	319(167)	325(172)
TFD (ms)	491(285)	513(316)	553(334)
REG-IN (probability)	0.32(0.47)	0.32(0.47)	0.38(0.49)
Critical region – Main VP			
REG-OUT (probability)	0.25(0.43)	0.24(0.43)	0.29(0.45)
FFD (ms)	255(95)	256(96)	256(94)
GD (ms)	354(193)	354(196)	349(191)
TFD (ms)	512(317)	524(343)	548(348)
Post-critical region – Commenting clause (CC)			
REG-OUT (probability)	0.78(0.42)	0.81(0.39)	0.84(0.37)
FFD (ms)	284(123)	285(127)	291(126)
GD (ms)	436(235)	436(250)	440(230)
TFD (ms)	547(307)	559(327)	608(323)

FFD, first fixation duration (ms); GD, gaze duration (ms); TFD, total fixation duration (ms); REG-OUT (probability). Probability of regressions-in, i.e., the proportion of regressive saccades on a region from a region with higher index; REG-OUT (probability), Probability of regressions-out, i.e., the proportion of regressing out of a region, limited to the first pass reading of that region.

increased cost for the incongruent sentences during the first-pass reading.

However, for the total fixation duration, readers spent longer time fixating on the AP region when reading the underspecified and incongruent sentences, as compared to reading the congruent sentences (Underspecified vs. Congruent, b = 0.13, SE = 0.04, t = 3.19; Incongruent vs. Congruent, b = 0.12, SE = 0.03, t = 3.70). Furthermore, with more linguistic information accumulated for the underspecified and incongruent conditions, the readers were more likely to make regressions back to the pre-critical region (Underspecified vs. Congruent, b = 0.82, SE = 0.20, z = 4.21; Incongruent vs. Congruent, b = 0.28, SE = 0.11, z = 2.55).

Pre-critical Region 2 – Model Verb (MV)

The measures on MV may reflect parafoveal congruency effect on the critical VP prior to the fixation. Readers spent shorter first fixations on the MV region in the underspecified sentences than in the congruent ones (FFD: $b = -0.03$, $SE = 0.01$, $t = -2.14$). This reduced FFD on the MV in the underspecified condition might be due to the increased FFD in the same condition on the earlier AP region. The readers may initiate the inference of missing scalar adjectives based on their knowledge or pragmatic constraints of the *lian. . .dou. . .* construction to deal with the uncertainty of event likelihood in the underspecified sentences. With the initial missing scalar adjectives filled, it may cost less to process the upcoming MV during the first pass reading.

However, later measures showed longer TFD and more REG-IN in the incongruent relative to the congruent sentences (TFD: b = 0.10, SE = 0.02, t = 4.31; REG-IN: b = 0.30, SE = 0.10, z = 2.87). These results suggest that the processing difficulty for the incongruent condition did not appear as an early parafoveal processing mechanism prior to the fixation. The incongruent condition did not affect the initial processing of MV, but the later measures, probably involving re-checking linguistic information of event likelihood at earlier regions after the incongruency, has been detected in the later regions.

Critical Region – Verb Phrase (VP)

None of the first-pass reading time measures (including FFD and GD) showed any significant effects of incongruency or underspecification (all $ps > 0.05$). However, readers spent longer total fixations on and made more regressive saccades out of VP in the incongruent condition than they did in the congruent condition (TFD: b = 0.06, SE = 0.03, t = 2.07; REG-OUT: b = 0.32, SE = 0.16, z = 2.01). This suggested that readers did not encounter any difficulties or initiate any effort to deal with the difficulties immediately after detecting the infelicitous nature of the main clause. The incongruent sentence exhibited prolonged reading time in the later measure of main VP of incongruent sentences.

Post-critical Region – Commenting Clause (CC)

Similar to the findings on VP, readers spent longer TFDs on CC in the incongruent condition than in the congruent condition (b = 0.10, SE = 0.03, t = 3.22). Furthermore, there were significantly more regressive saccades out of the CC region back to previous regions in the incongruent and underspecified conditions than in the congruent condition (Incongruent vs. Congruent, b = 0.68, SE = 0.20, z = 3.32; Underspecified vs. Congruent, b = 0.37, SE = 0.16, z = 2.38). These data suggested that the incongruent pragmatic information did not result in the lengthening of the initial reading time but only prolonged the global reading time at the sentence-final clause. No other effects were significant for FFD and GD on CC (all $ps > 0.05$).

DISCUSSION

Using the same set of sentence stimuli as the previous study (Jiang et al., 2013a) and taking advantage of the eye-tracking technique, we re-visited the temporal course of processing the construction-based pragmatic constraint (i.e., the event likelihood) during natural Chinese sentence reading. We obtained novel evidence on sentences with *lian. . .dou. . .*construction (similar to *even* in English) in which the likelihood of the embedded event to occur was manipulated. By embedding a highly likely or an underspecified event in the sentence, we created the incongruent and the underspecified conditions, and compared each with congruent sentences in which an unexpected event was embedded.

TABLE 3 | Fixed effect estimates for the eye movement measures across pre-critical regions including adjective phrase (AP) and modal verbs (MV).

Effect	FFD			GD			TFD			REG-IN		
	b	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*z*
Pre-critical region 1 – Adjective phrase (AP)												
Congruent vs. Underspecified	0.03	0.02	1.39	0.12	0.04	**3.34**	0.13	0.04	**3.19**	0.82	0.20	**4.21**
Congruent vs. Incongruent	−0.01	0.01	−0.68	−0.03	0.02	−1.49	0.12	0.03	**3.70**	0.28	0.11	**2.55**
Pre-critical region 2 – Dou + modal verb (MV)												
Congruent vs. Underspecified	−0.03	0.01	**−2.14**	−0.02	0.02	−0.79	0.03	0.02	1.17	0.01	0.10	0.08
Congruent vs. Incongruent	−0.01	0.01	−0.83	0.00	0.02	0.06	0.10	0.02	**4.31**	0.30	0.10	**2.87**

Significant terms are marked in bold. b, regression coefficient.

TABLE 4 | Fixed effect estimates for the eye movement measures across critical and post-critical regions including main VP and commenting clause (CC).

Effect	REG-OUT			FFD			GD			TFD		
	b	*SE*	*z*	*b*	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*
Critical region – Main VP												
Congruent vs. Underspecified	0.07	0.14	0.50	0.00	0.02	0.05	0.00	0.02	0.08	0.01	0.03	0.24
Congruent vs. Incongruent	0.32	0.16	**2.01**	0.01	0.02	0.34	−0.01	0.02	−0.35	0.06	0.32	0.35

pre-critical regions

extended the findings of Filik et al. (2009), that the effect of incongruence in sentences with the *even* construction was not evident until a post critical region, to a language other than English. Presumably, these measures suggest that the increased difficulty is initiated by some sort of second-pass processing in search of more information to resolve the incongruence between the current event and pragmatic constraints. When processing *lian. . .dou,* to check whether the event indeed fits the lowest end of the pragmatic scale, readers need to contrast a particular event against a set of alternatives on the event likelihood scale, and decide whether this event can be an unexpected candidate or sits at the bottom of the scale. This difficulty was increased given the mismatch of the linguistic input and the prediction of the *lian. . .dou* constraint. Therefore, readers spent more time to recover from this mismatch and probably recheck any further information to resolve such mismatch (Jiang et al., 2013a), resulting in more regression-in on the pre-critical region and regression-outs on the critical/post-critical regions. Increased regressive saccades were reported for sentences with long distance dependencies which demand higher working memory load (e.g., in *who does Mary think that John calls?* Nicenboim et al., 2015). Here the AP, the key linguistic information that defines the event likelihood, is possibly reactivated on regions following AP and may demand higher working memory load as reflected by more regressive looks to reconfigure the event likelihood in the incongruent condition. The increased reading time on the sentence-final commenting phrase suggested a continued difficulty that arose earlier from the critical VP. This sentence wrap-up effect was consistent with the observation of an increased sustained negativity on that phrase in Jiang et al. (2013a). The pragmatically implausible word increased the rereading time (i.e., total reading time minus gaze duration) and probability of regression-out when it was located at the sentence-final position (Camblin et al., 2007a). It should be noted that the underspecified condition did not show any effect on VP but showed more regression out of the sentence-final position, possibly due to an effort to wrap up the sentence by rechecking previous AP (as reflected by increased regression-ins on AP) against the possibility of specifying the meaning of the event (Zhou et al., 2010; Jiang and Zhou, 2012; Jiang et al., 2013a).

Implications to Models of Pragmatic Processing

Our findings appear to contradict the ERP results (Jiang et al., 2013a) which argue for a "one-step" model of pragmatic processing (Hagoort and Van Berkum, 2007). The eye-tracking data cannot be accommodated easily by the "one-step" but may fit into a "two-step" language processing model. According to the latter model, in the first step, the local, context-independent meaning of a local structure is computed; only when this step is completed, the meaning is computed against the wider sentential, discourse and communicative context or against an individual's pragmatic knowledge (Grice, 1975; Fodor, 1983; Sperber and Wilson, 1995; Cutler and Clifton, 1999; Lattner and Friederici, 2003). This model is in contrast with the "one-step" model which assumes that different levels of meanings are activated simultaneously in the context, resulting in a unified N400 on words in ERPs that mismatched a diverse set of contextual information (Hagoort and Van Berkum, 2007), including the N400 effect on VP in the incongruent condition in Jiang et al. (2013a). Given that N400 typically indexes the immediate impact of pragmatic constraint during online linguistic processing (Kutas and Federmeier, 2011), it was concluded that the pragmatic information is rapidly used in online sentence reading.

The current data that tracked readers' eye-movement do not fully agree with the conclusion above. In the *lian. . .dou* construction, the reader has to form the representation of the event based on the local structure "determiner phrase + object noun + subject noun + VP," of which the likelihood is reversed by *lian. . .dou* in the global context. The "one-step" model would predict that pragmatic constraints of *lian. . .dou* is used in an immediate manner; this prediction was rejected by the lack of early modulation of congruency manipulation. In contrast, the specification of local event likelihood was manifested as an increased first-pass fixation duration in the underspecified condition, suggesting that the buildup of a local semantic meaning *can* be early. The *lian. . .dou* constraints are taken into account only when local representation is partially built and may be reanalyzed through initiating regressive saccades to the preceding sentential constituents whenever necessary.

The two-stage processing is consistent with recently proposed eye movement control models. For example, the E-Z Reader 10 (Reichle et al., 2009; see Reichle, 2011 for a review) specifies when the higher-level, post-lexical information affects eye movements during language comprehension. The model assumes that integration of a word into its syntactic and semantic context comes after the process of word identification, which is therefore post-lexical. Staub and colleagues (Staub, 2011; Abbott and Staub, 2015) provided evidence supporting this assumption as they observed that the integration difficulty of an implausible word (e.g., *the professor repaired the writer with a trusty old wrench*) does not appear on the early measures on the critical word (e.g., the skipping rate of *writer*) but appears downstream of that word. Even though the plausibility effect can, in some cases, be manifested in the first-pass fixation measures on a target word (Staub et al., 2007; Matsuki et al., 2011), the plausibility and other lexical effects (e.g., word frequency) are typically additive, suggesting the pragmatic information may not impact local processing in the early time course during sentence reading (Abbott and Staub, 2015). These model-guided experimental findings suggest that computation of plausibility or higher-level pragmatic meaning affects post-lexical integration, instead of lexical identification itself, during sentence comprehension.

How can we reconcile the contradictory findings between Jiang et al. (2013a) and the current study? In Jiang et al.'s study, each word (or phrase) was presented serially for 400 ms followed by an inter-stimulus interval (ISI) of 400 ms. Previous studies have shown that the presentation rate may affect the manifestation of different cognitive processes: the contextual effect is more likely to emerge without delay in a prolonged presentation rate (Camblin et al., 2007b). Similarly, the comparatively slower RSVP rates of word presentation in Jiang et al. (2013a) may provide readers with sufficient time to integrate

the critical VP with the pragmatic information conveyed by *lian. . .dou*, allowing the effect of congruence-related N400 to appear on the VP.

In the current eye-tracking paradigm, sentences were presented as an entirety in one line, and the readers were allowed to preview information and initiate regressive saccades to reanalyze uncertain or incongruent linguistic input. In an ERP study when readers were allowed to read at their own pace, longer reading time was predicted by larger amplitudes of ERP on words mismatching pragmatic constraint (e.g., less plausible sentence: *at the breakfast the boy would plant toast and jam*, Ditman et al., 2007), indicating that the immediacy of pragmatic congruency is affected by presentation speed. Moreover, in a task that does not emphasize the verification of acceptability of the sentence (cf. Jiang et al., 2013a), it is likely that the reader may adopt a good-enough strategy (Ferreira et al., 2002; Ferreira and Patson, 2007) as the demand of recovering from the pragmatic incongruence during normal sentence reading is low; consequently the incongruence effect appears late.

In summary, by using the eye tracking technique, the present study reveals a relatively delayed time course of processing pragmatic constraints during on-line reading of Chinese sentences with *lian. . .dou. . .*construction. When reading incongruent sentences, as compared with congruent ones, the reader spends longer total fixations, made more regressive saccades out of the critical regions where pragmatic infelicitousness is initially detected. This finding is comparable to the observation of *even* construction in English (Filik et al., 2009) which showed a delayed processing cost and an effort of reanalysis for highly likely events used after *even*. The current study provides new evidence showing that the processing of pragmatic constraints of the Chinese *lian. . .dou. . .* construction may not interrupt the early stage of lexical processing during natural sentence reading, and offers a methodological perspective that promotes ecological studies of language processing.

DATA AVAILABILITY STATEMENT

Original data covered by this study can be obtained from the corresponding authors upon request.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Academic Committee of the Academy of Psychology and Behaviour, Tianjin Normal University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CZ, XB, GY, XJ, and XZ designed the research. CZ, LZ, and MZ performed the research and analyzed the data. CZ, XB, GY, XJ, ZH, and XZ wrote the manuscript.

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