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Causal connectives as indicators of source information: Evidence from the visual world paradigm

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ABSTRACT

Causal relations can be presented as subjective, involving someone's reasoning, or objective, depicting a real-world cause-consequence relation. Subjective relations require longer processing times than objective relations. We hypothesize that the extra time is due to the involvement of a *Subject of Consciousness* (SoC) in the mental representation of subjective information. To test this hypothesis, we conducted a Visual World Paradigm eye-tracking experiment on Dutch and Chinese connectives that differ in the degree of subjectivity they encode. In both languages, subjective connectives triggered an immediate increased attention to the SoC, compared to objective connectives. Only when the subjectivity information was not expressed by the connective, modal verbs presented later in the sentence induced an increase in looks at the SoC. This focus on the SoC due to the linguistic cues can be explained as the tracking of the information source in the situation models, which continues throughout the sentence.

1. Introduction

The processing of discourse involves constructing mental representations of the input (Graesser, Millis, & Zwaan, 1997; Zwaan & Rapp, 2006). In line with previous research, we will use the term *situation model* for these mental representations of characters, actions, events, states etc. in discourse (Bower, 1989; Glenberg, Meyer, & Lindem, 1987; Johnson-Laird, 1983; Kintsch, 1988; Morrow, Greenspan, & Bower, 1987; van Dijk & Kintsch, 1983; Zwaan, Magliano, & Graesser, 1995; Zwaan & Radvansky, 1998). It has been shown that language users keep track of all kinds of information of a story, such as temporal/spatial links among entities and causal relations between events, and also of the source of that information (Graesser et al., 1997; Graesser, Bowers, Olde, & Pomeroy, 1999; Zwaan et al., 1995; Zwaan & Rapp, 2006). The source of information overlaps with the subjects/characters/agents who "are capable of speaking, perceiving and knowing" in discourse (Graesser et al., 1997: 172). In linguistic theories, the degree of involvement of such a locutionary agent or someone's intentional mind is termed "subjectivity" (Finegan, 1995; Lyons, 1977; Sanders, Sanders, & Sweetser, 2009). In this paper, we investigate the construction of subjectivity in mental representations (specifically in the context of causal relations) from an empirical perspective, using the visual world paradigm. We seek to answer the question how subjectivity is processed in real time, and whether that online process indeed involves tracking the source of information.

Information in a text can vary in its degree of subjectivity. It can be a description of a situation in the real world, as in (1a). In that case, we speak of an objective utterance. Alternatively, information can be presented as an opinion or belief presented from the point-of-view of an author or speaker, as in (1b). In that case, the utterance is subjective.

(1)

a. There is a tree in the garden.
b. I think there is a tree in the garden.

Classifying items as subjective or objective is not only possible for individual clauses, but also for relations between clauses. This holds true, for instance, for causal relations between segments, which constitute one type of information represented in the situation model. The person who is responsible for the reasoning is often termed the *Subject of Consciousness* (SoC) (Pander Maat & Sanders, 2001; Sanders et al., 2009; Sanders & Spooren, 2015). A conceptual distinction is drawn between "causes that are crucially located in a *Subject of Consciousness* and those that are located in the inanimate, outside world" (Pander Maat & Sanders, 2001: 251; cf., Lyons, 1977; Sanders et al., 2009; Verhagen, 2005). The former type of relation is termed *subjective relation* (example 2b), and the latter one is termed *objective relation*

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(example 2a).

(2)

a. The factory has been polluting the water, ***so*** the local water supply is contaminated.
b. The factory has been polluting the water, ***so*** it has a very irresponsible owner.

In the situation model built for subjective relations such as (2b), an SoC is responsible for the reasoning. In the case of (2b), the SoC is the speaker. In the objective relation (2a), however, the speaker is not responsible for the relation. Therefore, a higher degree of subjectivity is expressed in (2b) compared to (2a). The degree of subjectivity of the relation can be encoded by linguistic cues that function as processing instructions on how to construct the situation model (Gernsbacher, 1990; Givón, 1992; Kintsch, 1992; Zwaan & Radvansky, 1998; Zwaan & Rapp, 2006). These linguistic cues can be explicit references to the SoC, or the remaining content of the utterance. For instance, in (3a), readers know from the linguistic cue *I think* that the relation should be constructed as subjective. However, in (3b), the degree of subjectivity of the relation is not clear until a later point in the second clause, probably at the modal verb *may*. In such cases, readers rely on the content of the second clause to construct a subjective mental representation.

(3)

a. The Intercity Express is delayed for more than one hour, so ***I think*** the railway system has encountered a problem.
b. The Intercity Express is delayed for more than one hour, so the railway system ***may*** have encountered a problem.
c. The Intercity Express is delayed for more than one hour, ***so*** the railway system has encountered a problem.

The degree of subjectivity of a relation can also be marked by connectives. Some connectives are prototypically used for objective relations, such as French *parce que* 'because', German *weil* 'because', Chinese *yin'er* 'as a result', Dutch *omdat* 'because', *doordat* 'because of the fact that' and *daardoor* 'as a result'. Other connectives are prototypical markers of subjective relations, such as French *puisque* 'because' and *car* 'because', German *denn* 'because', Chinese *kejian* 'so', Dutch *want* 'because' and *dus* 'so' (Degand & Pander Maat, 2003; Li, Evers-Vermeul, & Sanders, 2013; Pander Maat & Sanders, 2000; Pit, 2003; Stukker & Sanders, 2012; Zufferey, 2012). The information encoded in connectives helps readers to interpret the subjectivity information as in (3c) (Canestrelli, Mak, & Sanders, 2013; Li, Mak, Evers-Vermeul, & Sanders, 2017). Finally, there are connectives that are underspecified in terms of the degree of subjectivity, such as English *because* and *so* and Chinese *yinwei* 'because' and *suoyi* 'so', i.e. they can be used to mark subjective as well as objective relations (Andersson, 2016; Li et al., 2013). If clauses are connected by such underspecified connectives, readers/hearers can only rely on other elements in the utterances to establish the degree of subjectivity of the relations, such as *may* in (3b).

The processing effects of different connectives marking causal relations have been examined in on-line reading studies. Canestrelli et al. (2013) have shown that the Dutch subjective connective *want* 'because' leads to an immediate processing delay in the region directly after the connective as in example (4b), in comparison to the objective connective *omdat* 'because' as in example (4a). According to Canestrelli et al., the processing delay after *want* can be attributed to the effect of subjectivity because the subjective connective *want* triggers a subjective interpretation of the relation, which requires longer processing time compared to the objective connective *omdat*. According to the authors, the subjective connective triggers "the representation of someone's belief or opinion, be it from the author, speaker, or other person whose reasoning is presented in the text" (Canestrelli et al., 2013: 1410). In accordance with this interpretation, the processing delay is cancelled by the presence of an indicator of the SoC, such as v*olgens Peter* 'according to Peter' in (4c) (see also Traxler, Sanford, Aked, & Moxey, 1997).

(4)

a. Hanneke was buiten adem, ***omdat*** ze vier trappen was afgerend om de post te halen.
   Hanneke was out of breath, ***because*** she ran down four stairs to get the mail.
b. Hanneke had haast, ***want*** ze was vier trappen afgerend om de post te halen.
   Hanneke was in a hurry, ***because*** she ran down four stairs to get the mail.
c. Volgens Peter had Hanneke haast, ***want*** ze was vier trappen afgerend om de post te halen.
   According to Peter, Hanneke was in a hurry, ***because*** she ran down four stairs to get the mail.
   (Adapted from Canestrelli et al., 2013: 1403)

Thus, there are longer reading times after the subjective connective *want* than after the objective connective *omdat*. How can this extra processing time be explained? Although on-line reading times give an indication of the cognitive load in processing language, they do not directly show the content of the mental representation that comprehenders construct while processing the linguistic input. We hypothesize that this extra processing time is due to the construction of subjectivity in situation models. This process requires, first of all, recognizing the SoC. Hence, readers are expected to focus more on the SoC in the situation model when the linguistic input indicates that the utterance is subjective than when it is objective. In order to examine the attention devoted to the SoC in processing in detail, we conducted two Visual World Paradigm (VWP) eye-tracking experiments in which we measured the proportion of looks at the speaker in the picture. Evidence from the VWP may reveal the process of focusing on the SoC in situation models.

This hypothesis is illustrated in Fig. 1. The left panel in Fig. 1 represents the situation model that is created when objective information is processed; in (1a), the statement that "there is a tree in the garden" is presented as rooted in the objective world. The picture on the right represents the mental state that results from subjective information. In (1b), for example, the speaker presents the idea or claim that there is a tree in the garden, and the addressee will process the sentence with a source of information involved. If these situation models are indeed created by the language user, the subjective information might require longer processing time, because the discourse model that is constructed is more complex.

The VWP method has been widely used in language studies to

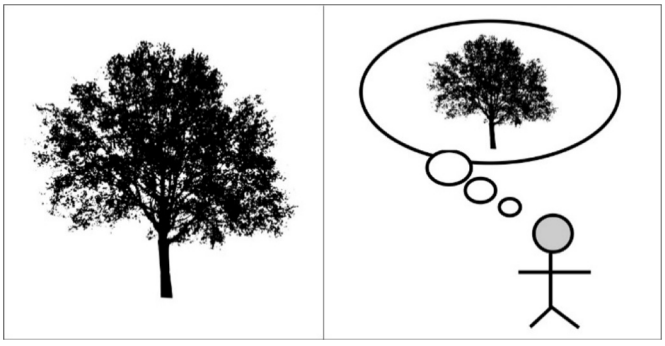

Fig. 1. Possible mental representations of objective information and subjective information. (The image of the tree was created by Chrisdesign (acquired from OCAL Website) with the title: *Illustration of a tree silhouette*. The file is licensed under a free license (public domain). Link to the source: http://www.freestockphotos.biz/stockphoto/15118).

investigate comprehension issues, such as predictions of incoming words (DeLong, Urbach, & Kutas, 2005; Kamide, Altmann, & Haywood, 2003) and pronoun resolution (Cozijn, Commandeur, Vonk, & Noordman, 2011; Pyykkönen & Järvikivi, 2010), In VWP eye-tracking studies, people exhibit a tendency to look at an object or person when they hear a reference to this object or person. For instance, previous VWP studies on pronoun resolution have shown that pronouns direct attention to the subject that is preferred on the basis of the context (Järvikivi, Van Gompel, Hyönä, & Bertram, 2005; Knoeferle, Crocker, Pickering, & Scheepers, 2005; Pyykkönen & Järvikivi, 2010). Pronouns refer to entities in the discourse model, and as a result of hearing the pronoun, people look at the picture of the entity that is referred to. Connectives do not refer to entities in the discourse model the way pronouns do. However, Koring, Mak, and Reuland (2012) have shown that looks at a picture do not only occur based on direct references. In their experiment, verbs induced an increase in eye gazes to pictures that were closely related to the subject of the verb (e.g. verb: *fell*; subject: *wood*; target in the picture: a saw). The reactivation of the subject, as the argument of the verb, is considered to be "the result of integrating the verb and its argument into one representation" (Koring et al., 2012: 361). In the same vein, we expect subjective connectives to activate the process of focusing on the SoC, which is essential in the processing of subjectivity.

Apart from giving insight in the way subjectivity is processed, this study will bring new insights into language comprehension in two respects. First, it extends the link between linguistic signals and attention to real world entities – not only for words with clear reference, but also for function words such as connectives, which do not directly refer to any entities. Second, this VWP study explores changes of looks in processing discourse relations across clauses, which is beyond merely measuring reactions in VWP to semantic and syntactic information within a sentence.

2. Experiment 1: Subjectivity in Dutch connectives

In Experiment 1, we compared the processing of two specific Dutch connectives: the objective connective *daardoor* 'as a result' and the subjective connective *dus* 'so' – based on theoretical and corpus-based work underpinning these semantic-pragmatic profiles (Pander Maat & Degand, 2001; Pander Maat & Sanders, 2000, 2001). The participants heard auditory linguistic input while they were presented with two contrastive scenes that were presented on the same screen. The participants saw a scene with an SoC and a scene without an SoC (see Fig. 2). They heard Dutch sentences either connected by the subjective connective *dus* 'so' (subjective condition) or by the objective connective *daardoor* 'as a result' (objective condition). We measured the changes in the proportion of fixations on the SoCs caused by the introduction of the connectives.

We predicted an increase in looks at the SoC when the participants heard the subjective connective, compared to when they heard the objective connective. This prediction is based on the assumption that when people hear the subjective connective *dus*, they will automatically infer that the causal relation arises from someone's mind instead of reality, and will represent this information in the situation model. In the case of the connective *daardoor*, which indicates that the causal relation can be observed in the outside world, this process does not take place.

2.1. Method

2.1.1. Participants

Twenty native Dutch speakers participated in the experiment: sixteen women and four men. The average age was 23 (range 18–26). The educational level of the participants was college level or above. All participants were recruited from an adult participant database of the UiL-OTS lab, Utrecht University. Their vision was normal or corrected to normal and no hearing problems were reported. Participants were paid five euro for their participation. Informed consent was obtained from all participants.

Fig. 2. Example of a visual stimulus. Left: without-SoC scene (This image was created by Frank J. Aleksandrowicz with the title: *Harshaw chemical company discharges waste water into the Cuyahoga river*, and recorded by the Environmental Protection Agency. The image is licensed under a free license (public domain). Link to the source: https://commons.wikimedia.org/wiki/File:HARSHAW_CHEMICAL_COMPANY_DISCHARGES_WASTE_WATER_INTO_THE_CUYAHOGA_RIVER_-_NARA_-_550193.jpg); Right: with-SoC scene (There is a tree in the gardenThis image was created by Alfred Pertl with the title: *Interviews für ORF Seitenblicke - Armin Assinger bei Buchpräsentation bei Thalia in Wien*. The file is licensed under the Creative Commons Attribution-Share Alike 4.0 International license. The size of the picture had been adjusted to fit the computer screen for the purpose of the experiment. Link to the source: https://commons.wikimedia.org/wiki/File:Interviews_f%C3%BCr_ORF_Seitenblicke_-_Armin_Assinger_bei_Buchpr%C3%A4sentation_bei_Thalia_in_Wien.jpg).

2.1.2. Materials

Twenty items were used in the experiment. Each item consisted of a display with two scenes about the same event: a scene with an SoC on one side and a scene without SoC on the other side. An example item is provided in Fig. 2. An example of auditory input that came along with the visual stimulus is presented in Table 1.

The left picture (without-SoC scene) depicts a scene of an objective situation. In the right picture (with-SoC scene), however, the salient part is a speaker making a statement. The objective scene presented in the with-SoC scene stays in a small speech bubble to suggest that the depicted person is speaking about that scene. The positions of the with-SoC scene and the without-SoC scene were counterbalanced: half of the pictures had the with-SoC scene on the left and without-SoC scene on the right, for the other half it was the other way around.

Along with the twenty visual items, we created twenty auditory items as the linguistic input. Two versions of each auditory item were made with a manipulation of connectives. The sentences of both versions were composed of two clauses connected by either the subjective Dutch connective *dus* 'so' (subjective condition) or the objective connective *daardoor* 'as a result' (objective condition). The contents of the first clauses of the input sentences were kept identical across conditions: this was a description of the event depicted in the without-SoC scene. The actual recordings of these first clauses differed between conditions, because the objective and subjective condition were recorded separately. Table 1 shows an example of the auditory input corresponding to Fig. 2.

The Dutch sentences were uttered by a young female native speaker and recorded in a soundproof room. By adding silence before the first clause, the sound files were manipulated in such a way that the connective started 3.5 s after the onset of the trial: depending on the duration of the first clause, the auditory input started between one and

Table 1
Example Sentences in Dutch.

Subjective condition connected by ***dus***	
Dutch	Het bedrijf heeft het water vervuild, ***dus***/heeft het/een heel onverantwoordelijke eigenaar.
English translation	Lit. The company has the water polluted, so has it a very irresponsible owner.
	'The company polluted the water, ***so*** it has a very irresponsible owner.'
Objective condition connected by ***daardoor***	
Dutch	Het bedrijf heeft het water vervuild, **daardoor**/heeft het/de watervoorzieningen verontreinigd.
English translation	Lit. The company has the water polluted, as a result has it the water supplies contaminated.
	'The company polluted the water, ***as a result*** it contaminated the water supplies.'

two seconds after the presentation of the visual item. The preview time was included for two reasons: First, we wanted to make sure that the participants were familiar with the scenes before they heard the connective, and second, given the fact that faces attract much attention, we wanted to give the participants time to become familiar with the faces. If the connective would start too early, the participants might all be looking at the face in the picture, and consequently it would be difficult to detect an increase in attention to the with-SoC scene.

The average duration of the objective connective *daardoor* 'as a result' was 0.56 s; and the average duration of the subjective connective *dus* 'so' was 0.43 s. Post-conjunctional silence was added after the connectives so that the second clause started 1 s after the onset of the connective. The inserted silence time did not affect the naturalness of the speech because pauses at clause boundaries (i.e. in this case around the connectives) are common in spoken language (Hawkins, 1971; Schilperoord, 1996; Swerts, 1998). By adding the silence after the connectives, we ensured that the critical region – the processing periods of connectives did not differ between the two conditions. Two words following the connectives were kept identical across conditions.

We expected participants to exhibit different responses to the two conditions at the connective region, and that such responses would be reflected in their fixations on the displayed scenes (Fig. 2). For each item, participants under different conditions heard the same utterance except the connective before the diverging point in the second clause. During the connective region, the content of the second clause is not known yet. Therefore, in terms of the longitudinal changes in fixations on the SoC, any differences between the two conditions before the diverging point should be due to the effect of the connective instead of any other linguistic elements, because these were identical across conditions up till that time point.

2.1.3. Apparatus

The experiment was conducted using an EyeLink-1000 eye tracker (SR Research), sampling at 500 Hz (every 2 ms). A high-speed camera was affixed to a Desktop Mount to measure the eye movements. The items were presented on a 36.4 * 27.2 cm (screen size) monitor via a host computer with the *real time Linux* system. The experiment was controlled by the software *ZEP* (version 1.6.3, Veenker, 2013).

2.1.4. Procedure

The experiment was performed in a sound-treated lab booth. Participants first received an instruction on the procedure of the eye-tracking experiment. They did not have any task apart from looking at the pictures while listening to the sentences. The participants were seated on a medical chair with about 40–70 cm distance to the display computer screen. The experiment started with a calibration procedure and a validation of the calibration. When both the calibration and validation were successful, the experimenter left the booth and the experiment began. The experiment was machine-paced, i.e. the participants were directed to the next test item automatically after a set period (5 s after the sentences ended). A drift check was performed by means of a point in the center of the screen before the picture of a stimulus was presented. The whole experiment took about 10 min per participant.

2.1.5. Analysis

We specified three areas of interest for each item in the software Fixation: the image of the objective scene, the speech bubble with the objective scene, and the image of the speaker.

In the original dataset, the position of the eye was captured every 2 ms. From this record, we sampled the position of the eye with 20 ms steps relative to connective onset. The eye-tracking data were analyzed in a multilevel logistic regression model (Goldstein, 2003; Mirman, Dixon, & Magnuson, 2008) in R (R Core Team, 2015), using the lme4 package (Bates, Maechler, Bolker, & Walker, 2015). With this analytical model, the eye-tracking data were treated as longitudinal data with time as a predictor. The time variable was centered for each time frame to ease the effort for R to converge the models. The dependent variable in the analysis was whether the participant looked at the SoC (i.e., the image of the speaker). The multilevel modeling approach we applied took into account the random intercepts of item and subject.

The probability of fixation on the SoC was modeled as a function of two factors: *Time* and *Connective* (subjective vs objective). The critical region (the connective time frame) for analysis was from the onset of the connective (3.5 s after the beginning of the sentence) to 200 ms after the onset of the second clause (4.7 s after the beginning of the sentence). The extra 200 ms were included because that is approximately the time period needed for initiating and computing a saccade in reaction to the input (Matin, Shao, & Boff, 1993). Thus, until the time point 4.7 s, participants were supposed to be still processing the information before the second clause. During that time frame, the only difference between the conditions that could influence the proportion of looks at the picture was the connective itself.

2.2. Results

Figs. 3 and 4 show the growth of the proportion of fixations on the SoC over time under the two conditions. The proportion of looks started from a similar level in both conditions. Then there was an increase of

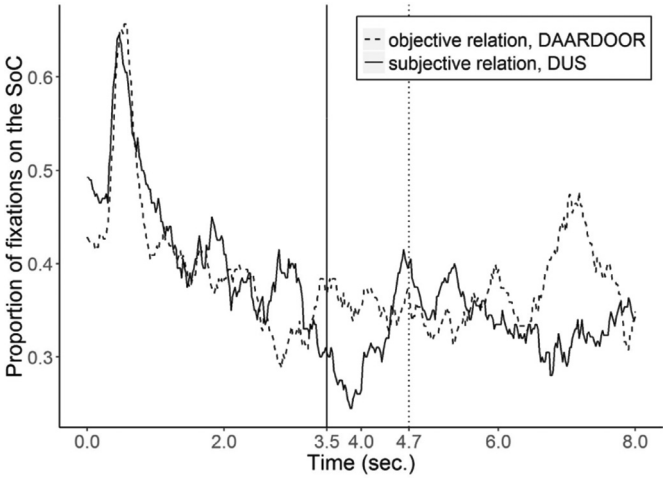

Fig. 3. Proportion of fixations on the SoC throughout the trial.

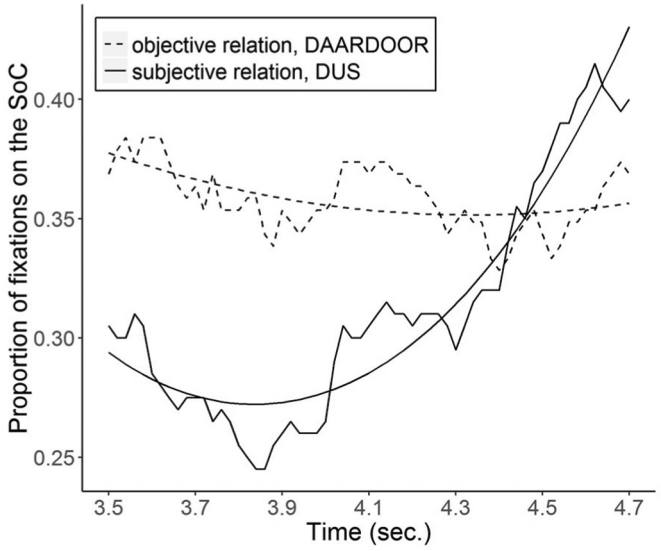

Fig. 4. Proportion of fixations on the SoC during the connective time frame (3.5–4.7 s, with regression lines estimated by the model) – subjective relation + *dus* vs objective relation + *daardoor*.

looks at the SoC under both conditions. This increase of looks was probably due to the fact that a picture of a person naturally attracts more attention. After the initial sharp increase of fixations on the scene with an SoC, both lines returned to a lower level before the connective was introduced.

The proportion of fixations on the SoC was modeled for the connective time frame (3.5 s–4.7 s). We started with a base model with the random effects of items and subjects on the intercept, and the main effects of *Time*, *Time*^{2} and *Connective*. By including *Time* as a predictor, the change of fixation proportions over time was captured. *Time*^{2} was included because we anticipated a curved trajectory in the development of fixation proportions over time (Mirman et al., 2008). The fit of the model improved when the interaction effect of *Time* and *Connective* was added (χ^2 (1) = 63.041, $p < .001$). Moreover, adding the interaction of *Time*^{2} and *Connective* also significantly increased the fit of the model (χ^2 (1) = 11.465, $p = .001$). Thus, the model with the random effects of subject and item, the main effects of *Time*, *Connective* and *Time*^{2}, the interaction effects of *Time* and *Connective*, and the interaction effects of *Time*^{2} and *Connective* was used as the final model.

A summary of the parameter estimates is presented in Table 2. The main effect of *Connective* shows the influence of connective on the average proportion of fixations on the SoC over the entire region (Table 2, ID.4). The significant main effect means that during the entire connective time frame, the subjective condition had a lower mean proportion of looks at the SoC than the objective condition, which is unexpected and will be discussed in detail in Section 2.3. There were no effects of *Time* or *Time*^{2} in the objective condition (Table 2, ID.2, ID.3), indicating a more or less straight flat line for the objective condition. The proportion of looks at the SoC remained stable after the objective connective *daardoor* was introduced.

However, there were also significant interaction effects of *Connective* and *Time* (Table 2, ID.5), as well as *Connective* and *Time*^{2} (Table 2, ID.6). A significant increase in the proportion of looks at the SoC under the subjective condition compared to the objective condition was observed. The significant interaction effect of *Time*^{2} and *Connective* indicated that the subjective connective led to an increasing concave upward curve.

In sum, the statistical tests showed a different development in the proportion of looks at the SoC under two connective conditions (as shown in Fig. 4): during the connective time frame, attention to the SoC stayed around the same level under the objective condition. In the subjective condition right after the introduction of the connective *dus* 'so', there was an increase of looks at the SoC in comparison to the objective connective *daardoor* 'as a result'.

Table 2
Dutch experiment: Parameter estimates for the best-fitting multilevel logistic regression of the connective time frame (reference level: objective connective daardoor).

ID	*Parameters*	*Estimate*	*SE*	*z*	*p*
Fixed factors					
1	Intercept	−0.668	0.171	−3.895	< 0.001
2	Time	−0.084	0.057	−1.487	0.137
3	Time^2	0.180	0.180	0.998	0.318
4	Subjective *dus*	−0.370	0.044	−8.466	< 0.001
5	Subjective *dus* * Time	0.640	0.081	7.865	< 0.001
6	Subjective *dus* * Time^2	0.877	0.259	3.386	0.001
Random factors					
1	Subject	0.297	0.545		
2	Item	0.272	0.522		

2.3. Discussion

In previous Dutch online reading experiments, a processing delay was observed immediately after the Dutch subjective connective *want* 'because', compared to objective *omdat* 'because' (Canestrelli et al., 2013). According to Canestrelli et al., this processing delay is related to the fact that an SoC is added to the mental representation of the discourse. After all, the interpretation of subjective relations is associated with somebody who is thinking, reasoning or arguing – the SoC. Therefore, we expected subjective connectives to draw attention to the SoC.

The results for the critical time region in the current study has confirmed this prediction about the effects of connectives in the processing of subjectivity information. During the 1.2 s after the onset of the connectives, there is a difference in the change of looks at the SoC over time between the two connective conditions. In comparison to the objective connective *daardoor*, an increase in the proportion of looks at the SoC is found after the subjective connective *dus*. Apart from the interaction effects of *Connective* and *Time* respectively *Time*^{2}, there is a main effect of *Connective* suggesting a lower mean proportion of looks at the SoC in the subjective condition compared to the objective one. This main effect is probably due to the fact that there is a decline in looks at the SoC, which starts approximately 500 ms before the onset of the connective, and continues until 200–300 ms after connective onset. Note that this initial fall after connective onset cannot be a reaction to the connective, since it takes approximately that time to compute and initiate a saccade (e.g, Saslow, 1966). We have no explanation for the fall in looks at the target before connective onset. This fall coincides with the development of the first clause, a description of the situation in the alternative picture. Given the pattern in the first clause (initial looks at the SoC, followed by a fall), it may be the case that the proportion of looks at the SoC had not yet fallen to a stable level. This makes an alternative explanation possible, namely that the difference in slope of the lines is due to this initial difference, rather than to the difference in semantics between the connectives. Therefore, in Experiment 2 we used a longer time frame after item onset, in an attempt to give the participants time to switch from the SoC to the alternative picture.

The findings are consistent with prior studies in at least two respects. First, at the level of the cognitive representations, this VWP processing study gives credibility to previous theoretical hypotheses that the interpretation of a subjective relation involves the process of focusing on an SoC in the situation model. Second, the experiment shows that the process of focusing on the SoC can be instructed by the subjective connective *dus*. In other words, a subjective connective itself can function as a processing instruction which increases language users' attention to the responsible subject in the situation, i.e. the SoC, in

comparison to an objective connective. The effect of the subjective connective *dus* 'so' found here is in line with the processing delay detected immediately after the Dutch subjective connective *want* 'because' compared to the objective connective *omdat* 'because' (Canestrelli et al., 2013). Both the processing delay and the increased attention to the SoC are associated with the processing of subjectivity.

Two questions remain unanswered in the Dutch experiment. First, although we have observed a difference between the subjective connective *dus* and the objective connective *daardoor* in directing people's attention to the SoC, it is not clear whether this difference should be attributed to the characteristics of the subjective connective or those of the objective connective. That is, the difference can either be due to an effect of the subjective connective in directing attention to the SoC, or an effect of the objective connective of guiding attention away from the SoC, or both. Without a neutral connective condition as a reference, we cannot disentangle the effects of connectives marking different degrees of subjectivity. A comparison to a neutral connective can also shed more light on what we are measuring precisely with the VWP method.

Second, the growth patterns of fixations in the later period (i.e. after the connective time frame) were not comparable under the two conditions, because the contents of the second clause in the two conditions were partially different. In Dutch, the subjective connective *dus* is prototypically used for subjective causal relations, while the objective connective *daardoor* is used to express objective ones. Hence, it is impossible to create conditions with exactly the same second clause following *dus* and *daardoor*. In order to investigate the processing effect of the subjective connective at a later stage (i.e., in the second clause of the two clauses in the coherence relation), we need to compare this effect to the effect of a causal connective underspecified in the degree of subjectivity, similar to English *because*, used in identical second clauses. However, such underspecified connectives are not available in Dutch. Experiment 2 was therefore run in Chinese, which has both underspecified and specific causal connectives.

Mandarin Chinese has an underspecified causal connective *suoyi* 'so', which can be used in both subjective and objective relations, as well as an objective connective *yin'er* 'as a result' and a subjective connective *kejian* 'so' (Li et al., 2013). The rich profile of Chinese causal connectives is beneficial to our research in two respects. First, the underspecified connective *suoyi* can serve as a reference level for the two specific types of connectives. By comparing the two specific connectives to the underspecified connective as the neutral level, we can identify the exact processing effects of each type of connective. Second, both for the objective and for the subjective condition, items can be created that differ only in the specificity of the connective, and display identical second clauses. Thus, the effect of connectives in the later processing stages can be examined properly.

3. Experiment 2: Subjectivity in Chinese connectives

The two Dutch connectives in Experiment 1 are both marked for the level of subjectivity, either marking an objective relation or a subjective relation. In order to directly see the effect of the marking of the degree of subjectivity by connectives, the processing of specific connectives should be compared to the processing of underspecified connectives. Li et al. (2017) tested this on Chinese in a reading experiment. In clauses with a subjective causal relation (5a), readers slowed down at the end of the second clause in the condition with the underspecified connective *suoyi* 'so' compared to the condition with the subjective connective *kejian* 'so/therefore'. In objective relations, such as (5b), Li et al. did not find a late difference between relations marked with the objective connective *yin'er* 'as a result', compared to relations marked with the underspecified connective *suoyi*.

(5)

a. Meng Na na tiao kuzi xianzai xiande hen fei, ***suoyi/kejian*** ta bi yiqian shou le bu. shao.
That (old) pair of trousers now look very baggy on Meng Na, **so/therefore** she has become much thinner now than before.

b. Meng Na yi nian lai baoshou weibing de zhemo, ***suoyi/yin'er*** ta bi yiqian shou le bu. shao. Ta shi liang ge haizi de muqin.
For a year Meng Na has been suffering from stomach trouble, **so/as a result** she has become much thinner now than before.
(Li et al., 2017: 51)

Li et al. (2017) attributed the processing cost to the cognitive complexity of subjectivity. To be specific, in the *suoyi* condition, the subjectivity information is not explicitly marked by the connective. Therefore, people have to process the subjectivity at a later stage, after they find out that the relation is subjective on the basis of the propositional content. Compared to the *kejian* condition, this process leads to an increase in reading times in the *suoyi* condition. After the subjective connective *kejian*, readers do not need to process subjectivity at a later processing stage because the subjectivity is already encoded by the connective, and hence processed at an earlier stage. In an experiment using the Visual World Paradigm, this late effect should be reflected in an increase in looks at the target in subjective relations with *suoyi* at the point where readers can infer the subjectivity from the content of the sentence, compared to the proportion of fixations in the same relations marked with *kejian*.

In Experiment 2, the three causal connectives with different subjectivity profiles illustrated in (5a) and (5b) were used. There were four conditions: the two relation types (objective vs subjective) were expressed by either the underspecified connective *suoyi* or the specific connectives *yin'er* or *kejian*.

3.1. Method

3.1.1. Participants

48 native Chinese speakers were recruited for the experiment. Two participants failed the calibration test before the experiment and their data were not collected. The data from six other participants were dropped because of poor data quality. Thus, we analyzed the data from 40 participants (26 women and 14 men). The average age was 27 (range 20–31). The educational level of the participants was college level or above. All participants were recruited in Utrecht. Their vision was normal or corrected to normal and no hearing problems were reported. Participants received five euro for their participation. Informed consent was obtained from all participants.

3.1.2. Materials

Twenty items were used in the experiment. Each of the items was composed of a picture (presented on the screen) paired with a spoken sentence. The sentences were produced by a young female native speaker of Chinese. In this Chinese experiment, we adopted the same picture setting as in the Dutch experiment (Fig. 2). In addition to the experimental items, there were sixteen fillers. Filler sentences were temporal relations marked by temporal connectives. Filler pictures had the same properties as the experimental items.

Four conditions of sentences as auditory input were created according to a two-by-two design: relation type (subjective vs objective) and connective type (specific vs underspecified). Examples of the four conditions are presented in Table 3. Subjective relations were expressed either by the subjective connective *kejian* or the underspecified connective *suoyi*. Objective relations were expressed either by the objective connective *yin'er* or the underspecified connective *suoyi*.

In the two subjective conditions, a modal verb (either *keneng* 'may' or *yiding* 'must') was inserted about 3–4 characters after the connective. By including modal verbs, it was possible to measure the effects of *kejian* and *suoyi* on the proportion of looks at the SoC later in the sentence. The modal verbs *keneng* 'may' and *yiding* 'must' provide information to the participant that the relation is subjective since these

Table 3
Example sentences in Chinese.

Subjective relation + *suoyi* (underspecified):
Zhe jia siying de huagongchang yizhi zai paifang wushui, ***suoyi*** ta de changzhu **keneng** bing bu guanxin huanjing baohu.
Subjective relation + *kejian* (specific):
Zhe jia siying de huagongchang yizhi zai paifang wushui, ***kejian*** ta de changzhu **keneng** bing bu guanxin huanjing baohu.
English translation
The private chemistry factory has been polluting the water, ***so*** *its owner* ***may*** *not care about environment protection.*
Objective relation + *suoyi* (underspecified)
Zhe jia siying de huagongchang yizhi zai paifang wushui, ***suoyi*** fujin heliu li de yulei da mianji siwang.
Objective relation + *yin'er* (specific)
Zhe jia siying de huagongchang yizhi zai paifang wushui, ***yin'er*** fujin heliu li de yulei da mianji siwang.
English translation
The private chemistry factory has been polluting the water, ***so*** *fishes in the rivers nearby are dying at a large scale.*

modal verbs introduce an epistemic stance. In the *kejian* condition, hearers are supposed to know the relation is subjective at the connective, while in the *suoyi* condition, this degree of subjectivity is not clear until the modal verb is read.

The Chinese sentences were uttered by a native Mandarin Chinese speaker and recorded in a soundproof room. Silence was added to sentences in such a way that the connective started 6.0 s after the onset of each trial, and the second clause started 7.2 s after the onset of the trial. In the subjective conditions, the onset of modal verbs was the same across items: at 8.3 s from the onset of the item.

The average duration of connectives was 0.62 s (*suoyi*: 0.66 s; *kejian*: 0.60s; *yin'er*: 0.56 s). The average duration of pauses before the connective (the time period between the offset of the first clause and the onset of the connective) was 0.60s (pause before *suoyi*: 0.60s; pause before *kejian*: 0.60s; pause before *yin'er*: 0.60s). The post-connective pause (the time period between the offset of the connective and the onset of the second clause) was 0.58 s (pause after *suoyi*: 0.55 s; pause after *kejian*: 0.60s; pause after *yin'er*: 0.64 s).

In the Dutch experiment, the contents of the first clauses (S1) were identical, but we made different recordings per condition. In the Chinese experiment, all four conditions had exactly the same S1 auditory recording. The two subjective conditions had exactly the same S2 auditory recording except for the connective (*kejian* vs *suoyi*), as did the two objective conditions, again except for the connective (*yin'er* vs *suoyi*). Out of the four versions uttered by the same speaker, we selected the segment recordings with a comparatively better quality (clearer, slower, with less noise), irrespective of condition. These recordings came from all four conditions.

In each item, the first clause was identical in all four conditions. Therefore, in terms of the longitudinal changes in fixations on the SoC, any differences among the four conditions before the onset of the second clause should be attributed to the effect of connective instead of any other linguistic elements. Moreover, the second clauses were the same in the two subjective conditions, and so were the second clauses in the two objective conditions. Thus, during the processing of the second clause, any differences in fixation patterns between two conditions of the same relation type were due to the processing of the connectives, which varied in terms of whether they marked the level of subjectivity, or – in subjective relations – due to the effects of the modal verb.

3.1.3. Apparatus & procedure

The Chinese experiment was conducted with the same apparatus and the same procedure as the Dutch one. The Chinese experiment took 15 min per participant.

3.1.4. Analysis

A multilevel logistic regression analysis was performed (cf. Section 2.1). We measured the dependent variable (whether or not the participant looked at the image of the speaker) in two time intervals: the *Connective time frame* - from the onset of the connective (6.0 s) to 200 ms after the beginning of the second clause (7.4 s); and in the subjective condition, the *Modal verb time frame* - from the onset of the modal verb (8.3 s) till 1.2 s after the onset of the modal verb (9.5 s). As in Experiment 1, in the former time frame, 200 ms were added because it takes approximately that time to initiate a saccade in response to an external input. Therefore, the fixation patterns during the time period 6.0 s–7.4 s reflected the reaction to the connectives. In the later time frame we measured the effect of the modals on the processing of the subjective relations.

3.2. Results

Just as in the Dutch experiment, the fixations on the SoC increased to a high percentage at the very beginning. The picture with a speaking person attracted most of the attention. Then the proportion of fixations in the four conditions declined gradually to a low level, until the onset of the connectives (6.0 s). As clearly exhibited in Fig. 5, unlike in Experiment 1 the proportion of looks at the SoC under different conditions have declined to a similar stable level by the time the participants heard the connective. The proportion of looks at the SoC diverged after different connectives were introduced (as shown in Figs. 6, 7, and 8). At a later stage of the two subjective conditions, the modal verb time frame, the specific connective *kejian* and underspecified connective *suoyi* also showed different effects on the fixation proportion (see Fig. 9).

3.3. Connective time frame (6.0 s–7.4 s)

For the connective time frame, we modeled the proportion of fixations on the SoC as a function of four factors: *Connective type* (specified vs underspecified), *Relation type* (objective vs subjective), *Time* and *Time*^{2}. The interactions were also taken into account. We started with a base model with subjects and items included as random factors, and *Connective type*, *Relation* type, *Time* and *Time*^{2} as fixed factors. Then we added the two-way interactions of *Connective type* and *Time*, *Relation*

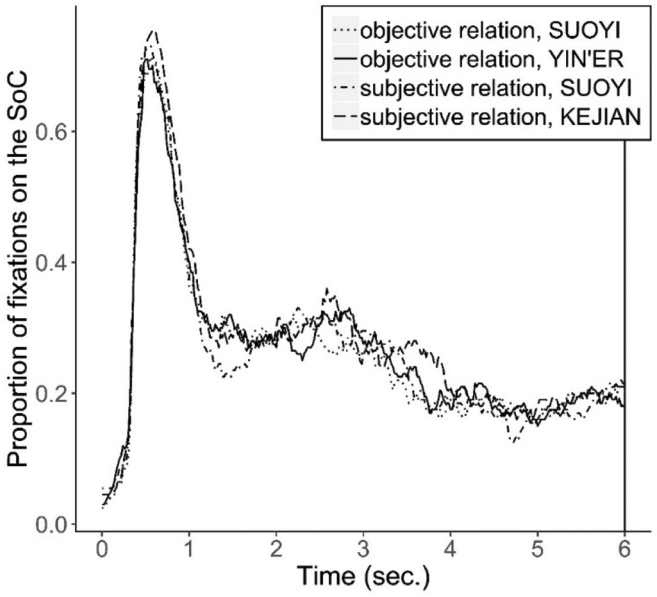

Fig. 5. Chinese experiment: Proportion of fixations on the SoC during the first clause.

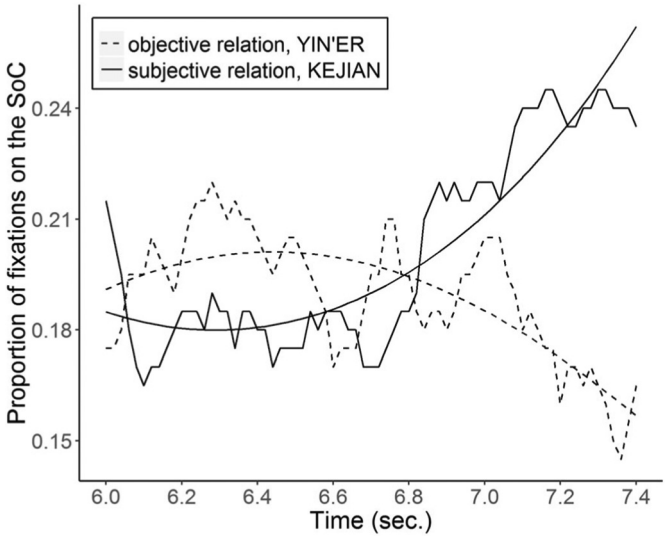

Fig. 6. Proportion of fixations on the SoC during the connective time frame (6.0 s–7.4 s, with regression lines estimated by the model) − subjective relation + *kejian* vs objective relation + *yin'er*.

type and *Time*, *Connective type* and *Relation type*, and the three-way interaction of *Connective type*, *Relation type* and *Time* to the model. The model fit significantly improved by adding the interaction effects (χ^2 (4) = 51.37, $p < .001$).

We also explored models with quadratic components: the two-way interactions of *Connective type* and *Time*^{2}, and *Relation type* and *Time*^{2}, and the three-way interaction of *Connective type*, *Relation type* and *Time*^{2}. Adding these quadratic components improved the model fit significantly (χ^2 (3) = 26.534, $p < .001$). Therefore, the final model contained the three-way interaction of *Connective type*, *Relation type* and *Time*, the three-way interaction of *Connective type*, *Relation type* and *Time*^{2}, as well as all the two-way interactions. Table 4 shows the parameter estimates of the final model.

There was a significant three-way interaction of *Connective type*, *Relation type* and *Time* (Table 4, ID.11). To disentangle this three-way interaction, a series of pairwise comparisons between different conditions were made. First, we tested whether the effect in Experiment 1 was replicated by comparing the subjective relation marked by the specific connective *kejian* with the objective relation marked by the specific connective *yin'er*. Second, the effect of objective marking was tested by comparing the objective relation marked by the underspecified connective *suoyi* with the objective relation marked by the specific connective *yin'er*. Finally, the effect of subjective marking was tested by comparing the subjective relation marked by the underspecified connective *suoyi* with the subjective relation marked by the specific connective *kejian*.

***Comparison 1**: subjective relation specific connective 'kejian'* versus *objective relation specific connective 'yin'er'*.

Fig. 6 shows the proportion of looks over time in the two specific connective conditions. The model with the interaction effect of *Connective* and *Time* increased the fit of the model compared to the base model with only the random effects and the main effects of *Connective*, *Time* and *Time*^{2} (χ^2 (1) = 54.081, $p < .001$). Adding the interaction between *Relation type* and *Time*^{2} also improved the model fit significantly (χ^2 (1) = 15.329, $p < .001$). Therefore, the model including all the main effects, the interaction effect of *Connective* and *Time*, the quadratic component of *Time*^{2} and its interaction effect with *Connective* was taken as the final model. The parameter estimates of this model are presented in Table 5.

The effect of *Time* in the reference condition (*yin'er* condition) showed that the proportion of fixations on the SoC declined after *yin'er* (specific connective for objective relations) over time (Table 5, ID.2). A negative effect of *Time*^{2} (Table 5, ID.3) was observed for the *yin'er* condition, i.e. a downward curve for the development of the proportion of looks at the SoC after *yin'er*.

The interaction effect of *Time* and *Connective* shows different tendencies under the two conditions. The growth of the proportion of looks in the *subjective relation* + *kejian* condition over time diverged considerably from the *objective relation* + *yin'er* condition (Table 5, ID.5). The interaction of *Connective* and *Time*^{2} was also significant (Table 5, ID.6), which implied an opposite trajectory of the proportion of looks over time after the two specific connectives expressing different types of relations.

By releveling the factor of *Connective* (with *kejian* as the reference level), we found a significant effect of time for the *kejian* condition. The proportion of looks increased in the *subjective relation* + *kejian* condition ($\beta = 0.382$, $SE = 0.055$, $z = 6.923$, $p < .001$). The *subjective relation* + *kejian* condition also had a positive quadratic effect of *Time*^{2}, i.e. an upward curve for the development of the proportion of looks at the SoC after *kejian* ($\beta = 0.465$, $SE = 0.151$, $z = 3.090$, $p = .002$).

***Comparison 2**: objective relation specific connective 'yin'er'* versus *objective relation underspecified connective 'suoyi'*.

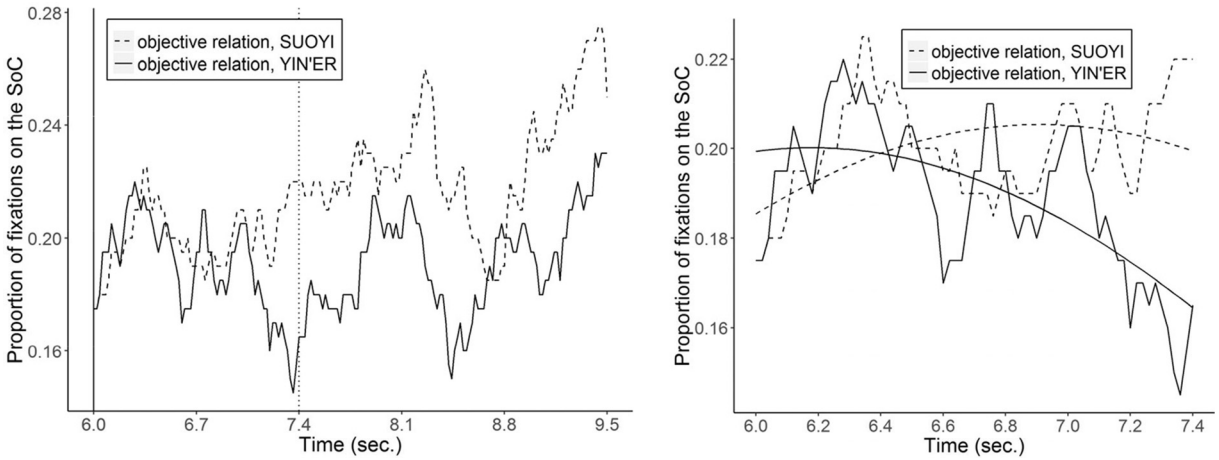

Fig. 7. *1.* Proportion of fixations on the SoC during the time frame 6.0 s – 9.5 s – objective relation + *suoyi* vs objective relation + *yin'er*.
2. Proportion of fixations on the SoC during the connective time frame (6.0 s–7.4 s, with regression lines estimated by the model) – objective relation + *suoyi* vs objective relation + *yin'er*.

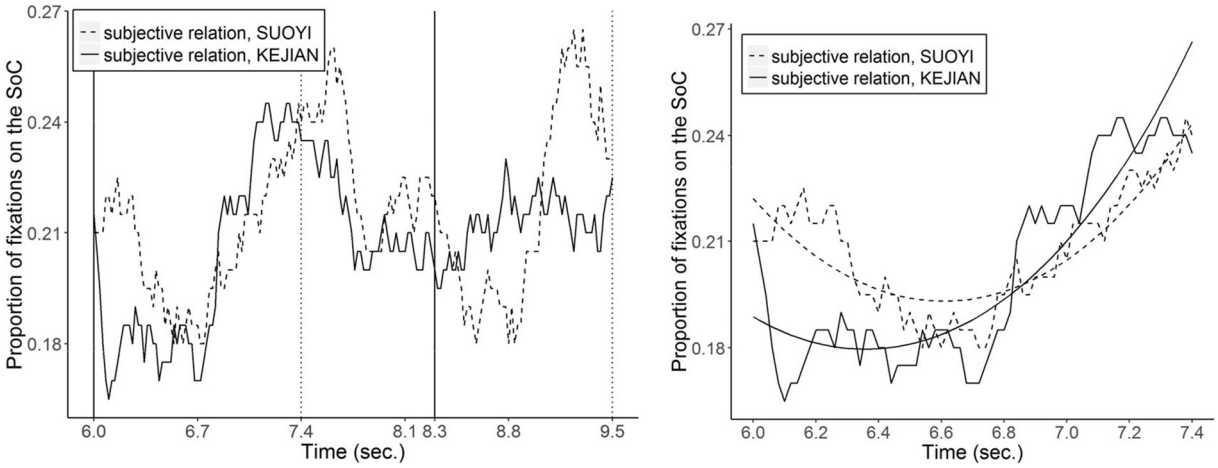

Fig. 8. *1.* Proportion of fixations on the SoC during the time frame 6.0 s – 9.5 s – subjective relation + *suoyi* vs subjective relation + *kejian*.
2. Proportion of fixations on the SoC during the connective time frame (6.0 s – 7.4 s, with regression lines estimated by the model) – subjective relation + *suoyi* vs subjective relation + *kejian*.

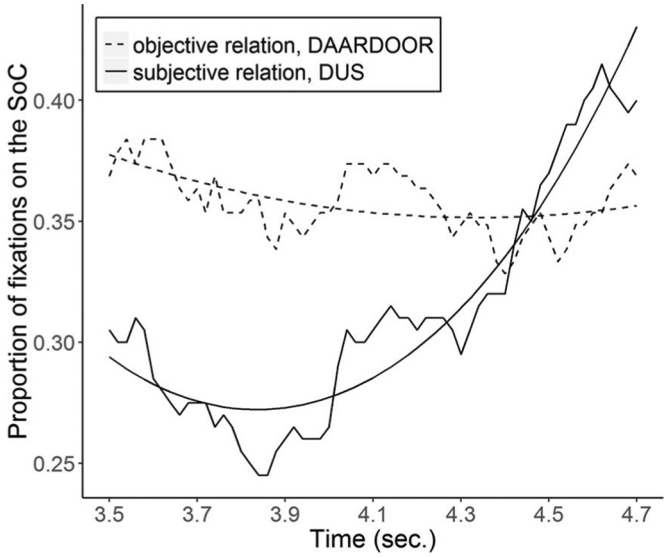

Fig. 9. Proportion of fixations on the SoC during the modal verb time frame (8.3 s – 9.5 s, with regression lines estimated by the model) – subjective relation + *kejian* vs subjective relation + *suoyi*.

The development of the fixation proportions in the two objective relation conditions is presented in Fig. 7. The model including the interaction effect of *Connective* and *Time* increased the fit of the model compared to the base model with the random effects and main fixed effects (χ^2 (1) = 11.782, $p < .001$). Adding the interaction between *Connective* and *Time*^{2}, however, did not improve the model fit significantly (χ^2 (1) = 3.238, $p = .072$). Therefore, the final model included the main effects of *Connective*, *Time* and *Time*^{2}, and the interaction effect of *Connective* and *Time* (see Table 6).

There was a significant interaction effect of *Connective* and *Time* (Table 6, ID.5). Under the *suoyi* condition, there was no development in the looks at the SoC over time (Table 6, ID.2 and ID.3). However, as revealed earlier in Comparison 1, the proportion of looks at the SoC decreased over time after *yin'er* (Table 5, ID.2).

***Comparison 3**: subjective relation specific connective 'kejian'* versus *subjective relation underspecified connective 'suoyi'.*

The data of the two subjective relation conditions are presented in Fig. 8. The model including the interaction effect of *Connective* and *Time* increased the fit of the model compared to the base model with only the main effects (χ^2 (1) = 12.931, $p < .001$). Adding the interaction between *Connective* and *Time*^{2} did not significantly improve the model fit (χ^2 (1) = 0.675, $p = .411$). Therefore, the model including the main

Table 4
Chinese Experiment: Parameter Estimates for the Best-Fitting Multilevel Logistic Regression of the Connective Time Frame – Relation Type * Connective Type * Time (reference level: Connective type – underspecified (suoyi); Relation type – objective).

ID	Parameters	Estimate	*SE*	*z*	*p*
Fixed factors					
1	Intercept	−1.641	0.173	−9.473	< 0.001
2	Time	0.071	0.054	1.315	0.189
3	Time^2	0.008	0.148	0.051	0.959
4	Connective type (specific)	0.001	0.047	0.024	0.981
5	Relation type (subjective)	−0.039	0.047	−0.823	0.410
6	Connective type (specific) * Relation type (subjective)	−0.035	0.067	−0.520	0.603
7	Connective type (specific) * Time	−0.260	0.078	−3.340	0.001
8	Relation type (subjective) * Time	0.025	0.076	0.333	0.739
9	Connective type (specific) * Time^2	−0.374	0.212	−1.763	0.078
10	Relation type (subjective) * Time^2	0.608	0.207	2.939	0.003
11	Connective type (specific) * Relation type (subjective) *Time	0.528	0.108	4.869	< 0.001
12	Connective type (specific) * Relation type (subjective) * Time^2	0.202	0.296	0.684	0.494
Random factors					
1	Subject	0.680	0.825		
2	Item	0.237	0.486		

Table 5
Chinese Experiment: Parameter Estimates for the Best-Fitting Multilevel Logistic Regression of the Connective Time Frame – Subjective Relation + kejian vs Objective Relation + yin'er (reference level).

ID	*Parameters*	*Estimate*	*SE*	*z*	*p*
Fixed factors					
1	Intercept	−1.834	0.245	−7.490	< 0.001
2	Time	−0.198	0.057	−3.454	0.001
3	Time^2	−0.383	0.156	−2.464	0.014
4	Subjective *kejian*	−0.061	0.049	−1.245	0.213
5	Subjective *kejian* * Time	0.579	0.079	7.288	< 0.001
6	Subjective *kejian* * Time^2	0.848	0.217	3.918	< 0.001
Random factors					
1	Subject	1.769	1.330		
2	Item	0.275	0.524		

Table 6
Chinese experiment: parameter estimates for the best-fitting multilevel logistic regression – Objective Relation + yin'er vs Subjective Relation + suoyi (reference level).

ID	Parameters	Estimate	SE	z	p
Fixed factors					
1	Intercept	−1.913	0.286	−6.696	< 0.001
2	Time	0.080	0.058	1.395	0.163
3	Time^2	−0.191	0.111	−1.723	0.085
4	Objective *yin'er*	0.038	0.035	1.095	0.274
5	Objective *yin'er* * Time	−0.279	0.081	−3.436	0.001
Random factors					
1	Subject	1.967	1.402		
2	Item	0.622	0.789		

Table 7
Chinese Experiment: Parameter Estimates for the Best-Fitting Multilevel Logistic Regression – Subjective Relation + kejian vs Subjective Relation + suoyi (reference level).

ID	Parameters	Estimate	SE	z	p
Fixed factors					
1	Intercept	−1.765	0.214	−8.257	< 0.001
2	Time	0.100	0.053	1.863	0.062
3	Time^2	0.547	0.105	5.226	< 0.001
4	Subjective *kejian*	−0.057	0.032	−1.791	0.073
5	Subjective *kejian* * Time	0.275	0.076	3.599	< 0.001
Random factors					
1	Subject	1.056	1.028		
2	Item	0.366	0.605		

effects of *Connective*, *Time* and *Time*^{2}, and the interaction effect of *Connective* and *Time* was taken as the final model. The parameter estimates of this model are presented in Table 7.

Table 7 shows no significant main effect of *Connective*: the mean fixation proportions on the SoC during the whole time frame were the same after the two connectives (Table 7, ID.4). As the quadratic effect of *Time*^{2} suggests, there was a change over time in the *suoyi* condition: an increase following a decrease at the beginning (Table 7, ID.3). In Comparison 1 we observed a main effect of *Time* in the *kejian* condition ($\beta = 0.382$, $SE = 0.055$, $z = 6.923$, $p < .001$), and *Time*^{2}, i.e., an increase of fixation proportions after *kejian* over time as well ($\beta = 0.465$, $SE = 0.151$, $z = 3.090$, $p = .002$).

However, the interaction effect of *Time* and *Connective* (Table 7, ID.5) indicated a difference in the form of changes under the *kejian* condition compared to the *suoyi* condition. What is this difference? Fig. 8-2 suggests a similar rise in both conditions, preceded by different patterns in the beginning.

To test this, the time frame was split into two periods: 6.0 s–6.62 s (the average duration time of the connectives), and 6.62 s–7.4 s. In the former time frame, the average proportion of fixations was lower under the *kejian* condition in comparison to the *suoyi* condition ($\beta = -0.181$, $SE = 0.049$, $z = -3.696$, $p < .001$). In the latter time frame, the average proportion of fixations did not differ across conditions ($\beta = 0.060$, $SE = 0.043$, $z = 1.390$, $p = .165$). Main effects of *Time* were found for both the *suoyi* condition and the *kejian* condition: the proportion of looks at the SoC increased over time after *kejian* ($\beta = 0.655$, $SE = 0.094$, $z = 7.002$, $p < .001$), and also increased after *suoyi* ($\beta = 0.655$, $SE = 0.094$, $z = 7.002$, $p < .001$). The absence of an interaction effect between *Connective* and *Time* (χ^2 (1) = 1.013, $p = .314$) indicated that the proportion of looks under the two conditions increased equally over time during the latter period. Therefore, the difference in fixation proportions observed at the connective time frame was mainly due to the differences at the connective itself. During the silence period after the average offset of the connective (6.62 s) and before the onset of the second clause (7.4 s), the growth of fixation proportions was the same for the *kejian* condition and the *suoyi* condition.

3.4. Modal verb time frame (8.3 s–9.5 s)

For the connective time frame, Comparison 3 shows no difference in the reactivation of the SoC after the underspecified connective *suoyi* compared to the subjective connective *kejian*. The question then is whether there were no processing differences at all between these two conditions. In order to investigate this, we looked at the processing of the modal verb, which gives explicit information on the subjectivity of the utterance.

The proportion of looks at the SoC were measured for the two subjective conditions during the modal verb time region. In Fig. 8-1 and Fig. 9, an S-curve with two bends can be observed under the *suoyi* condition. Therefore, the cube of *Time* was added to the base model. The base model with the main effects (*Connective*, *Time*, *Time*^{2}, *Time*^{3}) was improved by adding the interaction effect of *Connective* and *Time* (χ^2 (1) = 1.098, $p = .001$). Adding the interaction effect of *Connective* and *Time*^{2} also increased the model fit significantly (χ^2 (1) = 5.740, $p = .017$), and so did the interaction of *Connective* and *Time*^{3} (χ^2 (1) = 1.856, $p = .001$). The base model with the main effects and all of the interaction effects (linear, quadratic and cubic) is presented in Table 8.

No significant *Time* effects were observed for the *kejian* condition during the modal verb time frame (linear: Table 8, ID.2; quadratic: ID.3; cubic: ID.4). Those non-significant results indicated a more or less horizontal line for the *kejian* condition, i.e. the proportion of looks in the *kejian* condition stayed at the same level during this time frame after the modal verb was presented.

However, the interaction effects of *Connective* with the *Time* factors indicated diverging trajectories of the fixation proportions over time under the *suoyi* condition compared to the reference level *kejian*. Compared to the *kejian* condition, there was a temporary increase in the proportion of fixations at the SoC in the *suoyi* condition after the modal verb was presented.

3.5. Discussion

The Chinese experiment replicated the main result of the Dutch experiment: the proportion of looks at the SoC increased over time after the subjective connective *kejian* 'so' compared to the condition with the objective connective *yin'er* 'as a result', just as there was an increase after *dus* 'so' compared to *daardoor* 'as a result'. These results confirm that the processing of subjectivity is associated with an increased focus on the SoC. Connectives encoding a high degree of subjectivity lead to relatively more attention to the SoC compared to those encoding a low degree of subjectivity.

Table 8
Chinese Experiment: Parameter Estimates for the Best-Fitting Multilevel Logistic Regression of the Modal Verb Time Frame – Subjective Relation + 'kejian' (reference level) vs Subjective Relation + 'suoyi'.

ID	Parameters	Estimate	SE	z	p
Fixed factors					
1	Intercept	−1.737	0.289	−6.019	< 0.001
2	Time	0.011	0.177	0.064	0.949
3	Time^2	−0.284	0.224	−1.266	0.206
4	Time^3	0.351	0.730	0.480	0.631
5	Subjective *suoyi*	−0.076	0.053	−1.442	0.149
6	Subjective *suoyi* * Time	1.061	0.250	4.240	< 0.001
7	Subjective *suoyi* * Time^2	0.772	0.314	2.459	0.014
8	Subjective *suoyi* * Time^3	−3.354	1.028	−3.264	0.001
Random factors					
1	Subject	0.893	0.945		
2	Item	1.184	1.088		

Moreover, the Chinese experiment provides answers to the two questions left open by the Dutch experiment. The first question was whether the difference in the proportion of fixations is due to the effect of the subjective connective, the objective connective, or both. By comparing the subjective connective and the objective connective to the underspecified connective *suoyi*, we found that the increase of focus on the SoC is not unique for the subjective connective. The underspecified connective *suoyi* also leads to an increase in the proportion of fixations on the SoC. By contrast, the objective connective *yin'er* differs from the subjective connective and the underspecified connective by guiding attention away from the SoC.

The question then is whether this implies that readers in the *suoyi* condition also process the information as subjective. The answer to this question can be found in the pattern of fixations in the remainder of the second clause of the subjective relations. In the *suoyi* condition, the increase in the proportion of looks at the SoC in the modal verb frame indicates that readers at this point still need to reactivate the source of information in their mental representation. In the *kejian* condition they do not have to do this anymore, which is why there is no increase in looks during the modal verb frame. From this difference we derive that readers have already reactivated the SoC at the connective region in the *kejian* condition, but not in the *suoyi* condition. This pattern of results supports the hypothesis that the subjective connective *kejian*, but not the connective *suoyi*, instructs the listener to incorporate the SoC in the situation model of the input. The underspecified connective *suoyi* only marks the causal nature of the relation, and hence hearers need to incorporate the SoC in the situation model when they hear the modal verb. The question then remains what the increase in looks at the SoC after the underspecified connective *suoyi* means. Or, to put it in more general terms, what exactly are we measuring with this VWP method? These questions will be discussed in the general discussion.

The current VWP evidence in combination with the previous on-line reading results gives insight in the mental representation of subjective relations: in order to interpret subjective relations, people need to keep track of an SoC, who has to be reactivated when information is interpreted as originating from this subject/agent. This tracking and reactivation process is reflected in increased attention to the SoC in the VWP, and in longer reading times in reading experiments.

4. General discussion

The current visual world paradigm experiments set out to investigate the way in which people process subjectivity in causal coherence relations. Previous processing studies used online reading times to measure effects of subjectivity (Canestrelli et al., 2013; Li et al., 2017). Canestrelli et al. (2013) reported longer processing times immediately after subjective connectives compared to objective connectives. According to them, this difference in on-line reading times should be attributed to the fact that the interpretation of subjective relations requires the construction of a mental representation in which an SoC is involved. In other words, the reader or hearer needs to incorporate the source of information into the mental representation of subjective relations. This takes more time and effort compared to the processing of objective relations, in which no such SoC is involved.

In this study, we tested whether this explanation is on the right track, by looking at the way in which subjective and objective connectives affect the amount of attention devoted to the SoC. In the utterances in our study, this was always the speaker. The two VWP experiments provide evidence for the interpretation of the reading time effects in terms of the construction of a mental model in which an SoC is involved. A significant difference in attention to the speaker is found between the Dutch subjective connective *dus* 'so' and the objective connective *daardoor* 'as a result', as well as for the Chinese subjective connective *kejian* 'so' compared to the objective connective *yin'er* 'so'. As hypothesized, the subjective connectives, which encode a higher degree of subjectivity, lead to an increased attention to the SoC compared to the objective connectives. This effect is found in both languages, immediately at or after the connective, the region that corresponds to the region in which a processing delay was found in online reading experiments (Canestrelli et al., 2013). This indicates that subjective connectives indeed trigger a growing focus on the narrator as the SoC in the situation models, whereas objective connectives function as a linguistic cue for hearers to pay less attention to the SoC.

To further address the exact effect of connectives in directing attention to the SoC, we compared the Chinese underspecified connective *suoyi* 'so' to the subjective connective *kejian* and the objective connective *yin'er*. The change in attention to the SoC triggered by the underspecified connective *suoyi* patterns with the effects of the subjective connective *kejian* – both *suoyi* and *kejian* lead to an increased attention to the SoC. The objective connective *yin'er*, however, differs from these two connectives in that it guides people's attention away from instead of to the SoC. It explicitly specifies the relation to be an objective one, and more specifically a non-volitional content relation. This is a causal type of relation between events that do not involve any SoC (Sanders et al., 2009). From the VWP data we can derive that *yin'er* immediately signals that the interpretation of the relation does not involve an SoC.

The absence of a processing difference between the underspecified connective *suoyi* and the subjective connective *kejian* is unexpected. The question is whether this implies that the same mental model is constructed in both cases. For the answer to this question it is crucial to look at the behavior of the participants in response to the modal verb that occurs later on in the utterance. This modal verb is an unambiguous signal that the relation is to be interpreted as subjective. Only in the *suoyi* condition the modal verb led to an increase in looks at the SoC; in the *kejian* condition no change in the proportion of looks at the SoC was found at the modal verb region. Again, this difference can be related to the construction of a mental representation that involves an SoC. The underspecified connective *suoyi* leaves the hearer/reader uninformed about the degree of subjectivity, and therefore requires activation of the SoC at a later stage than in the *kejian* condition, which already specifies high subjectivity at the connective. And again, this VWP difference in attention to the SoC patterns with the results of previous online reading studies: in the predicate region of the connective clause – the region comparable to the modal verb region in our study – Li et al. (2017) found longer reading times in causal sentences connected by the underspecified connective *suoyi* compared to those connected by *kejian*.

Similar to the increase in looks at the SoC immediately after the subjective connective *kejian*, the activation of the SoC at the modal verb region in sentences with *suoyi* can be related to the tracking of source information. However, this leaves the question what the earlier increase in looks – at the region containing *suoyi* – exactly reflects, as this underspecified connective itself does not provide information that the relation involves an SoC. In order to understand this increase in looks, it is important to remember that the SoC in our experimental sentences was always the speaker. In other words, the picture containing the SoC always represented the person who reported his or her conclusion on the basis of an argument. One might argue that the speaker is somehow involved in the representation of all types of information: we often remember who has told us something, even if it is an objective fact. In addition, speakers usually do not convey information randomly, but present information they think is relevant or interesting, and they structure it in a specific way. As we might see connectives as processing instructions provided by the speaker on how to structure information, connectives in general may put the processing instructor, the speaker, in focus. Still, the degree to which they do this may vary with their degree of subjectivity. If this explanation is correct, all connectives may lead to a focus on the speaker to some extent, because this speaker – in his/her role of narrator – is involved in structuring the discourse and presenting links between utterances. This explanation implies that, in our experiment, there are at least two triggers for an increase or decrease in looks at the person depicted as the speaker in the Visual World

Paradigm. All connectives – underspecified, objective and subjective ones – activate the speaker in his role of narrator. On top of that, certain connectives activate the speaker in his/her role of SoC, as in the case of subjective connectives, or result in deactivation of the speaker, as in the case of objective connectives. Objective connectives indicate the speaker, but not in his/her role as SoC, but 'just' as the narrator. That is why the attention to the person in the picture is less than in the case of subjective connectives, which activate a speaker as both the narrator and the SoC.

If focusing on the speaker after connectives is a general tendency, we would expect to find a similar increase in looks at the speaker picture after other types of connectives. A first indication that this idea is on the right track comes from the processing effects of the connectives in the filler items in our experiment. In these fillers, sentences were connected by either of two temporal connectives: *erhou* 'and then' and *ranhou* 'then'. An analysis of these items indeed confirms the general tendency of connectives to generate an increase in looks at the speaker.[1] A follow-up question is how connectives marking other types of relations, and linguistic cues that provide other links to the speaker (e.g. perspective markers) may influence the attention to the speaker. More research is needed in order to further investigate how the attention to the speaker – either in his role of the narrator or in his role of SoC – comes and goes while people process language.

This paper connects visual attention in response to linguistic cues marking subjectivity with the effects of subjectivity on processing times in reading. We have constructed a method with which we can explore the nature of the extra processing time in subjective relations. This measure of looks at the SoC gives us insight into the development of situation models during processing: an intentional mind (the SoC) is attended to when a connective indicates the involvement of a narrator making subjective opinions or coherence connections between segments. However, if the connective specifies the relation to be objective, peoples' attention is guided away from the SoC and the objective scene gets more attention. The results support the proposal by Graesser et al. (1997, 1999); see also Sparks & Rapp, 2011; Strømsø, Bråten, & Britt, 2010) that comprehenders keep track of the source of information (*who said what*) in the situation models they build for comprehension. For causal relations, we have shown that the subjectivity of the information is tracked and immediately updated on the basis of linguistic cues such as connectives and modal verbs.

In our exploration of differences between connectives with varying degrees of subjectivity, we only selected one type of objective connectives. However, objective connectives and the relations they express can vary in terms of volitionality. It has repeatedly been argued (Pander Maat & Degand, 2001; Pander Maat & Sanders, 2000, 2001; Sanders et al., 2009) that non-volitional content relations such as (6a) – the objective type of relation we used in this study – differ from volitional content relations such as (6b) in terms of the involvement of an SoC.

(6)

a. The factory has been polluting the water, *daardoor/yin'er/**as a result*** the local water supply is contaminated.
b. The factory has been polluting the water, *daarom/yushi/**that is why*** the residents nearby decided to file a complaint to the local government.

The non-volitional content relation involves no SoC at all, while the volitional content relation involves a so-called character SoC, *the residents* in this case. Different from the speaker type of SoC (recall example (2a)) that is responsible for the subjective reasoning, a character SoC is the person responsible for a volitional act. In some languages, this distinction in volitionality is encoded by connectives as well. For instance, Dutch *omdat* 'because' and *daarom* 'that's why' as well as Chinese *yushi* 'that's why' explicitly mark causal relations as volitional content (Degand & Pander Maat, 2003; Li et al., 2013; Pit, 2003; Sanders et al., 2009), whereas Dutch *daardoor* 'as a result' and Chinese *yin'er* 'so' indicate non-volitionality. Future research could be done to investigate the role of connectives in the processing of volitional content relations and non-volitional content relations with the current experimental set-up in the VWP. The current study has shown that the degree of subjectivity encoded in connectives functions as a specific processing instruction for building mental representations, in two typologically totally different languages. Future research is needed to investigate how different types of SoC are constructed in situation models, and how connectives of other types may influence online reading times and the construction of situation models.

[1] In the analysis of fillers with the connectives *erhou* and *ranhou*, we observed main effects of *Time* ($\beta = 0.141$, $SE = 0.030$, $z = 4.762$, $p < .001$) and *Time*^{2} ($\beta = 0.203$, $SE = 0.081$, $z = 2.502$, $p = .012$) on the proportion of looks at the picture containing the speaker during the connective time frame (6.0 s–7.4 s). For these temporal connectives, the proportion of looks showed a curvilinear increase over time with a decline at the beginning.

Declarations of interests

None.

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