THE ANTICIPATORY EFFECTS OF FOCUS OPERATORS: A VISUAL-WORLD PARADIGM EYE-TRACKING STUDY OF "ONLY IF" AND "EVEN IF" CONDITIONALS

Likan Zhan, Stephen Crain, and Peng Zhou
Macquarie University

1. Introduction

This paper reports the findings of an experimental study on the interpretation of focus operators in sentence processing. Focus operators include words like English "only" and "even", and their Mandarin counterparts *zhiyou* "only" and *jiusuan* "even". It is generally acknowledged that these focus operators have two meaning components: One pertains to the element in focus, and the other pertains to a presupposed set of alternatives to the focus element (Rooth, 1985, 1992; von Fintel, 1994). Despite these commonalities, different focus operators introduce different semantic relationships between the focus element and the set of alternatives. These differences are the focus of our first topic.

"Only" is traditionally referred to as an "exclusive operator" (Rooth, 1985, 1992). Consider sentence (1). The element in focus in (1) is "Astroboy". The assertion being made is that the property being attributed to Astroboy – helping a camel – does not hold for any other individuals under consideration in the domain of discourse. So sentence (1) is true if two conditions are met: (1a) Astroboy helps a camel, and (1b) no one else does. The focus operator "even" can be contrasted with "only". Example (2) illustrates the different semantic contributions of "even". As in example (1), sentences with "even" have two meaning components (Bennett, 1982; Francescotti, 1995). In fact, (1) and (2) share one meaning component, namely the proposition that Astroboy helps a camel (2a). For (2) to be true, however, someone else must also help a camel (2b). Whereas "only" is an "exclusive", the focus operator "even" is "additive".

(1) Only Astroboy helps a camel.
   a. Astroboy helps a camel.
   b. No one else (except Astroboy) helps a camel.

(2) Even Astroboy helps a camel.
   a. Astroboy helps a camel.
   b. Someone else (besides Astroboy) also helps a camel.

In the sentences considered so far, the focus operators "only" and "even" are associated with an element within a statement. Focus operators can also be associated with the whole statements. For example, "only" and "even" can occur in bi-conditionals (i.e., only if) and in semi-factual conditionals (i.e., even if) (Bennett, 1982). Sentences (3) and (4) illustrate.

(3) Only if Astroboy helps a peacock, he gets a hamburger as a reward.
   a. If Astroboy helps a peacock, he gets a hamburger as a reward.
   b. If Astroboy helps another animal, he doesn't get a hamburger as a reward.

(4) Even if Astroboy helps a camel, he gets a carrot as a reward.

a. If Astroboy helps a camel, he gets a carrot as a reward.
b. If Astroboy helps another animal, he also gets a carrot.

We now have under our belts the basic meanings of the focus operators "only" and "even". The next step is to review the relevant experimental literature on people's comprehension of sentences that contain focus operators.

1.1. Literature Review

The previous studies on sentences containing focus operators have investigated how the alternatives to the focus element were activated by focus operators. We will briefly review the main conclusions that have been reached in these two areas of research.

Behavioral studies on the interpretation of the focus operator "only" (Crain, Ni, & Conway, 1994, Exp.2; Paterson, et al., 2007; Paterson, Liversedge, Rowland, & Filik, 2003; Paterson, Liversedge, White, Filik, & Jaz, 2005; Zhou & Crain, 2010) revealed that the set of alternatives introduced by "only" can be accessed by adults. The data obtained from adults was gathered as part of several experimental studies of child language acquisition. For present purposes, we limit our attention to the adult data. As we have seen, the sentences with focus operators can introduce different sets of alternatives, when its scopes are different. The correct assignment of different sets of alternatives to focus operators would advocate that participants successfully understand both semantic components of the focus operator. The following two sentences, for example, "only the cat is holding a flag", and "the cat is only holding a flag", introduce the same meaning component pertaining to the focus element, "the cat is holding a flag", but different meaning components pertaining to contrast sets of alternatives: the former one implies that "no other animal is holding a flag"; while the latter one suggests that "the cat is not holding anything other than that flag". In (Crain, et al., 1994, Exp.2)'s experiment, for example, participants' understanding of such differences were examined by asking them to decide whether or not the previous sentence was a correct description of the following image: a cat with a flag, a frog with a balloon, and a duck with a flag and a balloon. The findings were that adults gave a negative response to the first sentence, but they gave an affirmative response to the second, suggesting that both of the two semantic components of the focus operator "only" were accessed by adults.

Although children's behavioral responses are somehow controversial in literature, the online eye tracking studies (Höhle, Berger, Müller, Schmitz, & Weissenborn, 2009; Zhou, Su, Crain, Gao, & Zhan, 2011) suggest that children can also correctly grasp the different sets of alternatives elicited by the different scope of focus operators. In (Zhou, et al., 2011)'s eye tracking experiment, for example, children's eye movements on test scenes were recorded as they listened to auditorily presented test sentences. Each test scene contained two characters and four objects of two categories; the color of one object was different from the remaining three. In one scene, for example, there were a boy with a pair of green scissors and a yellow clock; and a girl with a pair of yellow scissors and a yellow clock. The auditorily presented test sentence was "Only Xiaoming's (i.e., the boy) clock is yellow". The alternatives of the focus operator "only" are ambiguous, depending on the scope of "only". Which alternative was associated with the focus operator was determined by the stress pattern of the sentences. If "Xiaoming" is accented, then the test sentence means that the boy's clock is yellow and no one else's clock is yellow. In this case, only the girl's clock was an alternative. If "clock" is stressed, however, the test sentence means that the boy's clock is yellow, and nothing else in the discourse is yellow. In this case, both the boy's scissors and his clock were alternatives. So if the contrast set of alternatives was correctly interpreted by participants, and the alternatives were activated by focus operators, then the girl's scissors were expected to be the

object of a greater proportion of fixations in the second condition. This is exactly what they found in their experiment.

A number of studies have included experiments on the focus operator "even." The findings from these studies have led researchers to conclude that both of the meaning components of this focus operator are mentally computed by adults (Gómez-Veiga, García-Madruga, & Moreno-Ríos, 2010; Handley & Feeney, 2004; Moreno-Ríos, García-Madruga, & Byrne, 2008; Santamaría, Espino, & Byrne, 2005). In an priming experiment, for example, (Santamaría, et al., 2005, Exp.2) found that people read a negative conjunction ("It had not rained, and the plants bloomed") faster when it was primed by the phrase "even-if" ("Even if it had not rained, the plants would have bloomed"), than when the same negative conjunction was preceded by "if" alone (e.g., If it had not rained, the plants would have bloomed"). The shorter reading time of the alternatives in the "even if" condition implies that the semantic contribution of "even" was included in the representation computed by the participants. That is, the participants had used the presence of "even" to generate a set of alternatives to the event of raining.

The conclusion that adults process both meaning components of the focus operator "even" was further supported in several studies investigating how people reason with conditional statements (Handley & Feeney, 2004; Moreno-Ríos, et al., 2008). Four kinds of inferences have been studied in the literature on conditional reasoning. We will focus on two of them. One involves affirmation of the consequent, so this is abbreviated as "AC". In the AC condition, we are permitted to make the following inference: Given that both a conditional statement and its consequent are true, we may infer that the antecedent clause is also true. The other kind of conditional involves the denial of the antecedent, so this is abbreviated "DA". In the case of DA, we are permitted to make the following inference: Given that a conditional statement is true, and its antecedent clause is false, we may infer that its consequent is also false. (Handley & Feeney, 2004), for example, found that participants made far fewer AC and DA inferences when the conditionals are "even if" conditionals, as compared to indicative conditionals (with "if" alone). The alternatives to the focus element that are involved in conditionals that are modified by the focus operator "even" require the consequent to remain true, despite the antecedent being false. So when the antecedent is false, it's unlikely to get that the consequent is also false. This means that DA is illegal. Similarly, when the consequent is true, the antecedent can either be true or false. So AC is also illegal. It is the illegality that reduces the inferences of DA and AC, in "even if" conditionals compared to that of indicative conditionals.

To summarize, despite some controversies involving children' behavioral data, all of the previous studies have reached consensus on the fact that adults can understand the relationship between the focus element and the set of alternatives, and can utilize this information in assisting them in understanding the intended interpretation of sentences, even eliminating garden path effects in some cases.

1.2. Predictions

In spite of the findings discussed in the previous section, the online processes involved in deriving the interpretation of focus operators is still unclear. Three innovations are made in this study to help illuminate these online processes. First, the visual-world paradigm is adopted as the experimental method (Cooper, 1974; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). This technique provides detailed temporal resolution. In a study using this technique, participants' eye movements are recorded as they listen to auditorily presented sentences and at the same time look at visually presented scenes. When the spoken sentence is presented, the incremental online interpretation of the sentence results in the construction of a syntactic and semantic representation. The featural overlap between these representations

activated by the spoken sentence and the cognitive representation activated by the visual scene are both activated. This leads to increased attention to, and therefore, increased fixations on those objects in the visual scene that match the conceptual representations activated by the spoken sentence (Altmann & Kamide, 2007; Crocker, Knoeferle, & Mayberry, 2010; but see, Salverda, Brown, & Tanenhaus, 2011). An anticipatory effect is one in which participants fixate on an object before they hear the word that denotes that object. Anticipatory effects are widely reported in studies using the visual-world paradigm (see, Huettig, Rommers, & Meyer, 2011; Kamide, 2008, for reviews). Altmann and Kamide (1999) first reported that the selectional information of a verb can elicit such effects. In their experiment, participants were instructed to judge whether the auditorily presented sentence could in principle apply to the associated image. One pair of sentences was the following: "The boy will move the cake" ("move" condition) versus "The boy will eat the cake" ("eat" condition). The picture showed a boy, a cake (the only edible object in the scene), and various distractor items corresponding to the sentences. The finding was that there were more fixations launched to the target object (i.e., the cake) even before the onset of the spoken word "cake" in the "eat" condition, as compared to the "move" condition. Subsequent studies found that such anticipatory effects are also triggered by the semantic properties of the subject (Kamide, Altmann, & Haywood, 2003), a case marker (Kamide, Scheepers, & Altmann, 2003), a gender marker (Van Berkum, Brown, Kooijman, & Hagoort, 2005), a tense marker (Altmann & Kamide, 2007), and by particles (Delong, Urbach, & Kutas, 2005). Anticipatory effects have proven to be a sensitive indicator of when and how abstract properties (such as case markers, tense, etc.) of natural languages are processed by the human sentence processing system, or parser.

Anticipatory effects are expected to arise in sentences with focus operators. The present study investigated anticipatory effects in "even if" and "only if" conditionals, rather than in simple sentences containing focus operators "even" and "only". As mentioned earlier, participants' visual attention to potential referents can either be attributed to the fact that these objects have been previously mentioned or because subjects anticipate that these objects will be mentioned later (Crocker, et al., 2010). So in a simple sentence such as "only/even Astroboy helps a camel", the fixation on "Astroboy" can be evoked by the meaning of focus operators, or due to the mention of Astroboy, or possibly from some combination of these two sources. Replacing the simple sentences by "even if" and "only if" conditionals will be used to tease apart such effects, to obtain a "pure" effect of the processing of focus operators. Consider a scene in which there are a camel with a carrot, a rooster with a carrot, and a peacock with a hamburger. When presented with this visual scene, some specific fixation patterns associated with sentences (3) and (4) (repeated below) are expected to arise only if the meanings of the focus operators are accessed.

(3) Only if Astroboy helps a peacock, he gets a hamburger as a reward.
   a. If Astroboy helps a peacock, he gets a hamburger as a reward.
   b. If Astroboy helps another animal, he doesn't get a hamburger as a reward.

(4) Even if Astroboy helps a camel, he gets a carrot as a reward.
   a. If Astroboy helps a camel, he gets a carrot as a reward.
   b. If Astroboy helps another animal, he also gets a carrot.

More specifically, two specific predictions are made: The first prediction is about the pattern of participants' fixations before the mention of the object of the antecedent ("peacock" or "camel"). Participants are expected to fixate more on the object "peacock" before the mention of "peacock" in the "only if" condition, e.g. (3), and to fixate more on the objects "camel" and "rooster" before the mention of "camel" in the "even if" condition, e.g., (4). The

first pattern is possible only when both (3a) and (3b) are accessed by the participants, based on the fact that the peacock is the animal with a unique reward that is different from other animals (i.e., "hamburger"). And the second pattern is possible only when both (4a) and (4b) are accessed, based on the fact that the camel and the rooster share the same rewards (i.e., "carrots"). So the predicted fixation patterns would imply that both meaning components of the focus operators are accessed. The second prediction is about the pattern of participants' fixations between the onset of the consequent and the onset of the object of the consequent. During this period, the access of the alternatives of focus operators is expected to elicit two fixation patterns. The first pattern is expected to occur when the object of its antecedent was "camel". This is because it shares the same reward, "carrot", with the camel, such that "rooster" is the potential alternative. And the rooster should receive more fixations in the "even/only if" condition, as compared to control condition, because the focus operator elicits more access to the alternatives. When the object of the antecedent is "peacock", there is no potential alternative. This is because peacock's reward is different from the other two animals (i.e., a hamburger versus a carrot). Nevertheless, participants' attention should be distributed to other animals to search possible alternatives, so participants should fixate less on peacock in "even/only if" conditions, as compared to that of the control condition.

2. The Experiment

2.1. Experimental Design and Stimulus

A typical trial in the visual world paradigm involved recording participants' fixations on the test image while they were exposed to the auditorily-presented test sentence. To familiarize the participants with the content of the test image, and to make the use of the test sentences more natural, the test images and test sentences were preceded with a short animation (the animations were created with Blender 2.57, a free software running on Mac system, with 24 frames per second.). Fig. 1 and fig. 2 illustrate the opening and closing scene of the animation. A trial encompasses a superhero (e.g., Astroboy), three animals (e.g. a camel, a peacock, and a rooster), and six rewards of two types (e.g. carrots and hamburgers). Initially, the superhero didn't have any reward, while each animal had two rewards (Fig. 1). Two of the three animals' rewards are of the same type (e.g., the camel and the rooster had two carrots each), while the third animal's rewards were different from the other two (e.g., the peacock had two hamburgers). In the animation, the superhero first moved to an animal, performed an action (e.g. offering help), and then brought back a reward with him. The superhero performed three actions in each animation, once on each animal (both the spatial positions of the four characters and the temporal order that the animals received the action from the superhero in the animation were counterbalanced between different trials). At the end of each animation, the superhero had obtained three rewards of two categories, and each animal had one reward left (Fig. 2). Then an auditorily presented test sentence was presented, accompanied by a test image that is the same as the closing scene of the animation.

Fig. 1. The initial scene of the animation. Astroboy doesn't have any object. Each animal has two objects.

Fig. 2. The closing scene of the animation, and the test scene. Astroboy has three objects and each animal has only one object left. This is because Astroboy helped the three animals three times, one time for each animal. And he got an object as a reward after each help.

A test sentence (fig. 3) was comprised of three parts: the connective, i.e., "only if", "even if", or "control" (no connective); the antecedent clause about the superhero performing an action on an animal, such as "Astroboy helps a camel"; and the consequent clause describing that the superhero got a reward from the animal, such as "he gets a carrot as a reward". This study was a 3*2*2 design. So, in addition to the three levels of the connectives, the objects of the test sentences' antecedent and consequent were also counterbalanced. As for the object of the test sentence' antecedent: half of the trials referred to one of the animals who shared the same rewards (e.g., "camel" in the example); and the other half referred to the animal with unique rewards (e.g., "peacock" in the example). To manipulate the truth-values of the test sentences, the object of its consequent was also counterbalanced: half of the trials referred to the correct reward that the animal gave to the superhero; and the other half referred to a wrong reward.

1)Control Sentence

有次	阿童木	帮助了	一只	孔雀 / 骆驼，	他	__	得到了	一个	汉堡	/ 萝卜。
youci	atongmu	bangzhule	yizhi	kongque / luotuo,	ta	__	dedaole	yige	hanbao	/ luobo.
one-time	Astroboy	help-Asp	one-Cl	peacock / camel,	he	__	get-Asp	one-Cl	hamburger/	carrot.

"Astroboy helps a peacock/camel, and he gets a hamburger/carrot as a reward."

2) Even if Sentence

就算	阿童木	帮助了	一只	孔雀/骆驼,	他	也	得到了	一个	汉堡	/ 萝卜。
jiusuan	atongmu	bangzhule	yizhi	kongque / luotuo,	ta	ye	dedaole	yige	hanbao	/ luobo
Even if	Astroboy	help-Asp	one-Cl	peacock / camel,	he	also	get-Asp	one-Cl	hamburger/	carrot

"Even if Astroboy helps a peacock/camel, he gets a hamburger/carrot as a reward."

3) Only if Sentence

只有	阿童木	帮助了	一只	孔雀 / 骆驼，	他	才	得到了	一个	汉堡	/ 萝卜。
zhiyou	atongmu	bangzhule	yizhi	kongque / luotuo,	ta	cai	dedao le	yige	hanbao	/ luobo
only if	Astroboy	help-Asp	one-Cl	peacock / camel,	he	then	get-Asp	one-Cl	hamburger/	carrot

"Only if Astroboy helps a peacock/camel, he gets a hamburger/carrot as a reward."

Fig. 3. An example of the complete list of the test sentences in this study. We have three connectives, with both the object of its antecedent and the object of its consequent counterbalanced. In the real experiment, only one test sentence was related to one contextual animation. And the counterbalance was carried out between different animations.

A female Mandarin-speaker from Beijing was recruited to record the test audios. Each test sentence was recorded in a word-by-word fashion. By doing this, we made the test sentences the same in length (i.e., 10,000ms each) and in intonation. We divided the experiment into two blocks: a practice block and an experimental block. 8 trials were included

as practice, to familiarize the participants with the experimental procedure. The experimental block consists of 24 experimental trials, with 8 trials in each connective, and 13 fillers like "Astroboy first helps a camel, and he then helps a peacock". Trials in each block were presented in pseudo-randomized sequence, and any two neighboring trials were from different connectives. The whole experiment lasts about 35 minutes.

2.2. Participants and Procedure

Forty-three students from the Beijing Language and Culture University took part in the experiment. All participants were native speakers of Mandarin Chinese and had normal or corrected normal visions. They were paid 30CNY (about $5) for their participation.

Participants were seated approximately 65cm from a 21 inch 4:3 color monitor with 1024*768 pixel resolution. 24 pixels equaled about 1° of visual angle. Participants wore a SR Research Eyelink II head-mounted eye-tracker running at a 500 Hz sampling rate. Viewing was binocular, but only the participant's dominant eye was tracked. Participants were instructed to avoid strong head movements throughout the experiment. The auditory stimuli were presented via a pair of external speakers situated to the left and right of the monitor. The recordings were played from the hard disk as 24 khz mono sound clips. Stimulus presentation and data recording were controlled by two PCs running software developed by SR research Ltd. The keyboard of data presentation PC was used to record participants' button responses. At the beginning of the experiment, participants saw a brief introduction of the experiment on the screen in Mandarin Chinese. The experimenter then helped the participant to wear the Eye-tracker and performed the standard Eyelink calibration routine, which involved participants looking at a grid of nine fixation targets in random succession. Then a validation phrase followed to test the accuracy of the calibration against the same targets. If the average error of validation was bigger than 1°, the routine would be repeated. This routine was carried at the beginning of each block, and whenever the experimenter noticed that the measurement accuracy was poor (e.g., after strong head movements or a change in the participant's posture). Each trial was structured as follows: participants first saw the trial number in the middle of the screen. 4 seconds later, or pressing SPACE key brought up a short animation. A black dot appeared at the center of the screen when the animation was finished. The participant was guided to press SPACE key while fixating at the dot. This was a drift correction process. This press brought up the test image. The auditorily presented test sentence was then played 1000ms after the onset of the test image. The test picture remained on the screen for 2000ms after the offset of the spoken sentence. A test sentence is 10000ms long, so a test picture was presented for about 12000ms. Participants' eye movements were recorded during this 12000ms.

Participants were instructed to view the animation and pictures, and to listen to the sentences attentively, so that they were able to decide whether or not the test sentence was an appropriate description of the story depicted in the animation. Pressing a key or 4000ms later brought up a new trial, with the trial number appearing in the middle of the screen.

2.3. Data Processing

In preparing the data, fixations shorter than 80ms were pooled with preceding or following fixations if they were within 0.5° of visual angle, otherwise they were deleted, since short fixations are considered to be a result of false saccade planning rather than meaningful information processing, and readers do not extract much information during such short fixations (Rayner & Pollatsek, 1989). One participant was deleted for further analysis, because of too many tracking losses. The test scene was then equally divided into four interest areas (Fig. 4): the superhero with the three rewards he received, i.e., IA1; the animal and the

reward left with this animal, i.e., IA2, IA3, and IA4. More specifically, the reward of the animal in IA4 is different from that of the other two animals. The animal in IA2 is the one that is sometimes mentioned in the object of the test sentence' antecedent.

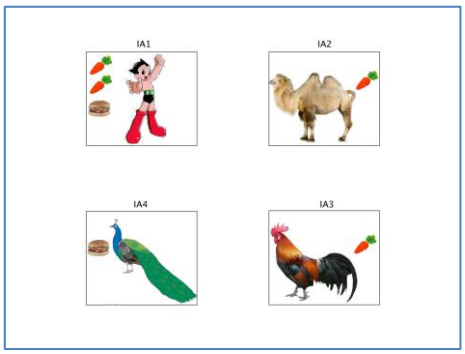

Fig. 4. The interest areas used in the study: "IA1" is a superhero, e.g., Astroboy; "IA2" and "IA3" are the two animals with the same rewards, e.g., camel and rooster; "A4" is the animal with unique reward, e.g., peacock.

As depicted in Fig. 5, the 1000ms long temporal period during the presentation of the test sentences was partitioned into 20 temporal frames (FR), 500ms long each. Two clusters of temporal frames were important to us, and are thus called interest periods (IP): "IP-1" and "IP-2". "IP-1" ranges from the onset of the test sentence to the onset of the object of the antecedents and consists of 7 temporal frames. "IP-2" consisted of 6 temporal frames, ranging from the onset of the test sentence' consequent to the onset of its object.

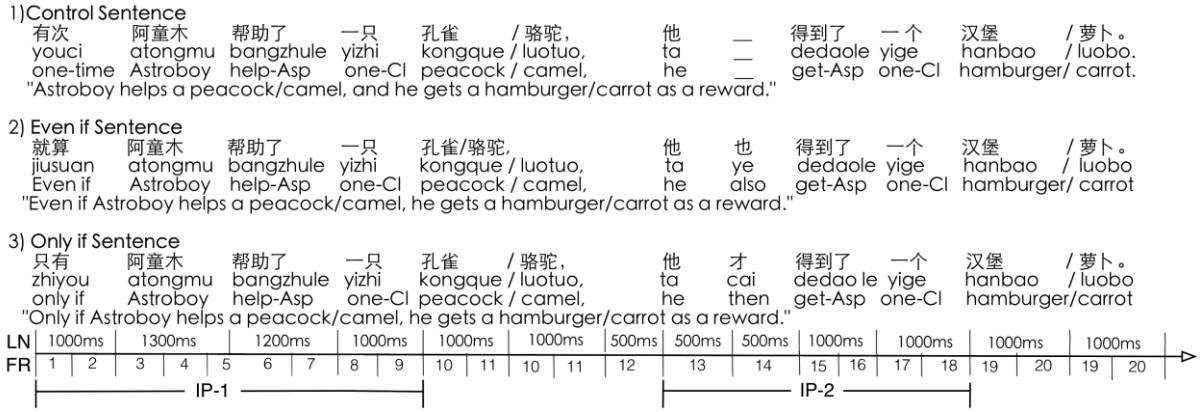

Fig. 5. Examples of the test sentences used in the study, their English translations, the length of relevant words (LN), the temporal frames (FR), and the interest periods (IP) defined in the experiment.

The dependent variable was the proportion of fixations to an object (i.e., an interest area) in a temporal frame divided by all fixations recorded in that temporal frame. For example, if there were 4 fixation points in a temporal period, with 1 point locating in the interest area, then the proportion is ¼. Because it is possible to record two different fixation points in one temporal frame, so the dependent variable is not strictly binary. It is possible that one fixate point locates in an interest area, and the other one locates in another interest area. Generalized linear mixed-effects models (GLMM) were used to fit our data with 2 fixed effects: "connective" and the temporal framers ("FR"). Predictor "connective" was a factor with three levels: "Control", "Even if" and "Only if". "FR" was treated as numeric. The levels of "FR" in "IP-1" and "IP-2" were "1, 2…9" and "13, 14… 18" respectively. Subjects and items were treated as random effects (Baayen, Davidson, & Bates, 2008). The fitting process was

conducted via functions "lmer" in package "lme4 (v0.999375-42)"(Bates, Maechler, & Bolker, 2011) of R software environment (v2.13.2) (R Development Core Teem, 2010). The significant level was calculated using the following formula in R: "*2*(1-pnorm(abs(data.frame(summary(FO)@coefs)$t.value)))*", where "FO" is the output of the fitting process. Analyses were carried out on the raw data with no aggregation, and every model used can be found at the bottom of the table reporting the results.

3. Results

To provide an overview of the eye-movement data, we first present the results with descriptive graphs, followed by more detailed statistical analysis.

3.1. IP-1

In the interest period IP-1, the object of the antecedent hasn't been uttered yet, and the only difference between the three conditions is the different operators used at the beginning of the test sentences. The difference between the focus operators is the only reason introducing different fixation patterns between different conditions. If and only if both semantic elements of the focus operators are processed, the camel and the rooster will then be more fixated in "even if" condition, but the peacock will be more fixated in "only if" condition, compared to that of the control condition. The analysis on the relevant interest areas was presented below.

First, the two animals with the same rewards cannot be distinguished from each other in this antecedent temporal period. Either of the animals can be the focus element of the focus operator "even". So the areas containing the two animals with the same rewards were combined together. Fig. 6 depicts participants' fixation patterns on the combined area of the camel and the rooster, i.e., IA2 and IA3. The x-axis is the time in seconds, and the y-axis is the proportions of fixations. The graph shows that the relationship between the temporal frames and participants' fixations is not linear, so the second and the third order polynomials of time were added in the model fitting analysis (the exact formula was given at the bottom of table 2). The graph also suggests that the camel and the rooster were more fixated in "even if" condition than in the control condition; but there was no clear difference between "only if" condition and the control condition.

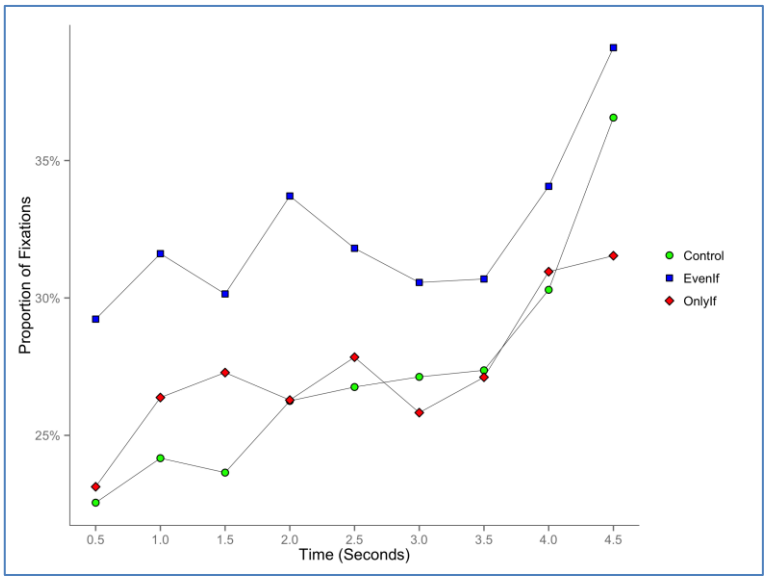

Fig. 6. Participants' fixation patterns on the combined interest area of camel and rooster, i.e., the two animals shared the same rewards, from the onset of the test

sentence to the onset of the object of the antecedent's object. The x-axis is the time in seconds, and the y-axis is the proportions of fixations.

The model fitting analysis confirmed these observations. The linear time (β=5.04E-02, SE=2.17E-02, t=2.46, p< .01), the quadratic time (β=-1.24E-02, SE=4.72E-03, t=-2.63, p< .01), and the cubic time (β=9.23E-04, SE=3.13E-04, t=2.95, p< .01) all have a significant influence on participants' fixation patterns. Furthermore, the two animals with the same rewards were more fixated in "even if" condition than in the control condition (β=4.83E-02, SE=2.45E-02, t=1.97, p< .05). No significant difference was found between "only if" and "control" conditions (β=1.78E-03, SE=2.48E-02, t=0.07, p> .05).

Second, Fig. 7 illustrates the fixation pattern on the animal "peacock", i.e., the animal with a unique reward. The graph shows that the peacock was more fixated in "only if" condition, compared to that of the control condition; and no clear difference was observed between "even if" condition and the control condition.

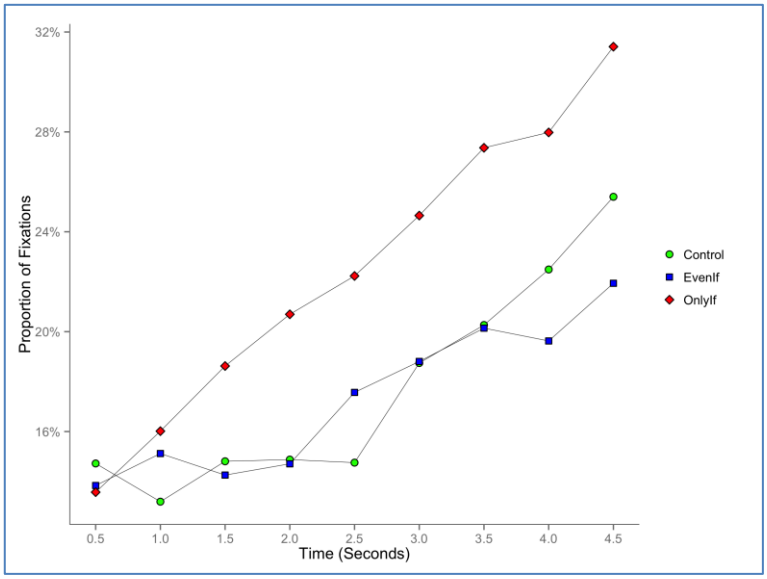

Fig. 7. Proportion of fixations on peacock, i.e., the animal with the unique reward, from the onset of the test sentence to the onset of the object of the antecedent. The x-axis is the time in seconds, and the y-axis is the proportions of fixations.

Model fitting analyses are summarized in table 2. Neither the linear time (β=-8.49E-05, SE=1.78E-02, t=-0.01, p> .05), the quadratic time (β=2.38E-03, SE=4.21E-03, t=0.57, p> .05), or the cubic time (β=9.65E-05, SE=2.85E-04, t=-0.34, p> .05) has a significant effect on participants' fixation pattern. Furthermore, the peacock was more fixated in "only if" condition, compared to that of the control condition (β=6.41E-02, SE=2.38E-02, t=2.70, p< .01). No significant difference was found between the "even if" condition and the control condition (β=3.43E-03, SE=2.07E-02, t=0.17, p> .05).

If we put the two diagrams together, it seems that the effects of the camel and rooster (fig. 6) occurred earlier than that of the peacock (fig. 7). This is in accordance with the model fitting analysis applied to each temporal frame (Formula: proportions of fixation ~ conditions + (1+ conditions |subject) + (1+conditions |trial)). The results revealed that the effects of "even if" mainly happened from temporal frame 2 to temporal frame 4 (p<. 05), i.e., from 1s to 2s; whereas the effect of "only if" emerged from temporal frame 5 to temporal frame 7 (p< .05), i.e., from 2.5s to 3.5s.

3.2. IP-2

"IP-2" comes after the offset of the object of the antecedent, and ranges from the onset of the consequent to the onset of the object of the consequent. The fixation patterns observed in this interest period were affected both by the connectives and by the objects of its antecedent.

When the object of its antecedent refers to one of the two animals that shared the same rewards, such as "camel" in the example, the test sentence is "__ if the Astroboy helps the camel, he gets a __ as a reward". Because the camel gave the Astroboy a carrot as a reward, the legitimate object of the consequent is "carrot", rather than "hamburger". The fact that the rooster also gave the Astroboy a carrot as a reward affirms the felicity of using the focus operator "even", while denying the felicity of using "only". Therefore, the animal "rooster" is critical in understanding the test sentence when the object of its antecedent is "camel". Similarly, when the object of its antecedent refers to the animal with the unique reward, such as "peacock" in the example, the test sentence is "__ if the Astroboy helps the peacock, he gets a __ as a reward". Since the peacock gave the Astroboy a hamburger as a reward, the legitimate object of the test sentence's consequent is "hamburger". The fact that no other animal gave the Astroboy a hamburger made it felicitous to use the focus operator "only", but infelicitous to use "even". Thus, the animal "peacock" is critical in determining the felicity of the test sentence when the object of its antecedent is "peacock".To differentiate the effect of the object of the test sentence's antecedent from that of the focus operators, we conducted two separate analyses, depending on the objects of the test sentence's antecedent. When the object of the test sentence's antecedent was one of the animals that shared the same rewards, such as the camel in the example, participants' fixation patterns on the other animal with the same rewards, such as the animal rooster, were analyzed. When the object of its antecedent was the animal with a unique reward, such as the peacock in the example, participants' fixation patterns on this animal, i.e., peacock, were analyzed. The results of the two analyses were given as follows.

First, figure 8 illustrates the fixation patterns on the animal whose reward is the same as the animal mentioned in the object of the test sentence's antecedent, such as the animal rooster in the example. The data depicted in the graph only contains the trials where the object of the test sentence's antecedent is the animal sharing the rewards with another animal, such as the animal camel. The graph suggests that the rooster was more fixated in both "only if" condition and "even if" condition, compared to that of the control condition, regardless of the felicity of the conditions. The data fitting process justified the validity of the observations. First, the effect of the focus operators is not influenced by the time, whether it is linear (β=-8.51E-01, SE=8.31E-01, t=-1.02, p> .05), quadratic (β=5.73E-02, SE=5.39E-02, t=1.06, p> .05), or cubic (β=-1.28E-03, SE=1.16E-03, t=-1.10, p> .05). However, participants' fixation patterns on the animal rooster were significantly affected by different focus operators. More specifically, the animal rooster was more fixated in "even if" (β=7.17E-02, SE=2.65E-02, t=2.70, p< .01) and "only if" (β=5.96E-02, SE=2.40E-02, t=2.49, p< .01) conditions than in the control condition.

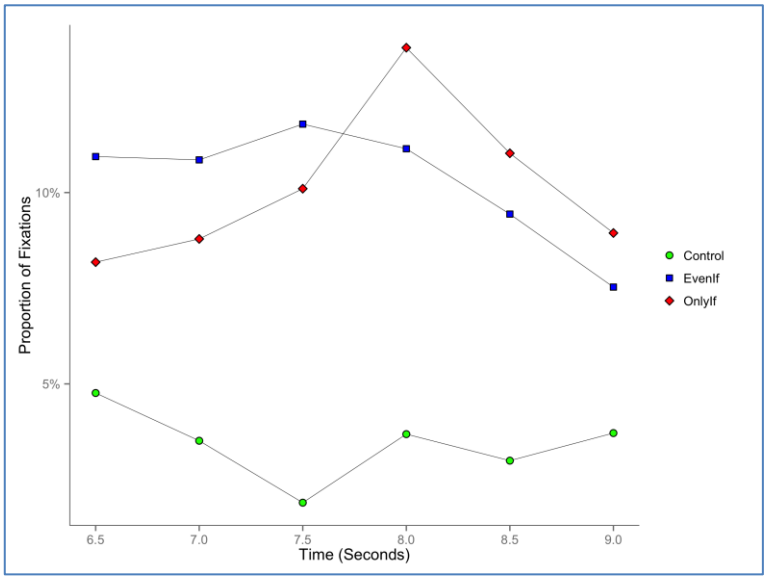

Fig. 8. The graph depicts participants' fixation patterns on the animal sharing the reward with the animal mentioned in the object of the test sentence's antecedent, such as the rooster in the example. The result contains only the trials where the object of the test sentence's antecedent is the animal that shared the reward with another animal, such as the camel.

Second, fig. 9 presents participants' fixation patterns on the animal peacock when the object of the test sentence's antecedent is peacock. The graph indicates that the peacock was less fixated in the experimental condition than in the control condition, regardless of the felicity of these conditions.

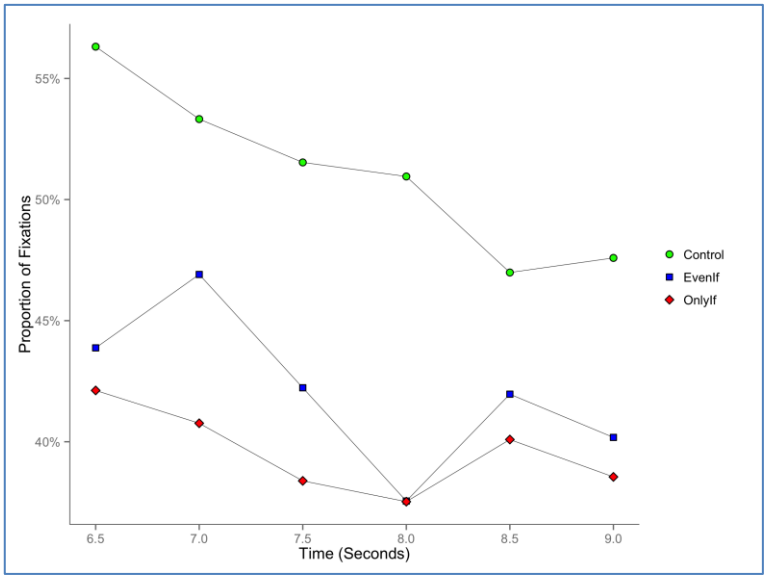

Fig. 9. The graph depicts participants' fixation patterns on the animal with a unique reward, such as the peacock in the example. The result contains only the trials where the object of the test sentence's antecedent is the animal with a reward that is different from other animals.

The fixed effects from the best fitting modal confirmed the validity of our observations. Both the focus operators "even if" (β=-9.25E-02, SE=3.56E-02, t=-2.60, p< .01) and "only if" (β=-1.24E-01, SE=3.89E-02, t=-3.18, p< .01) negatively affected participants' fixation on the animal peacock, regardless of their felicities. And this effect remained unchanged within this

temporal period; no matter it is linear (β=4.68E-02, SE=1.57E+00, t=0.30, p> .05), quadratic (β=-3.37E-02, SE=1.02E-01, t=-0.33, p> .05), or cubic (β=7.79E-04, SE=2.19E-03, t=-0.36, p> .05).

4. Conclusion

To conclude, the online processing of the auditorily presented sentences with focus operators is actually a combination of top-down and bottom-up processes (fig. 10). The two top-down processes consist of the two anticipatory effects initiated by the focus operators. And the bottom-up processes are launched by the utterance of relevant words. First, the onset of the focus operators activates participants' first anticipatory eye-movements on the most reasonable focus element in the visual field. Second, the onset of the object of the test sentence's antecedent initiates the second anticipatory eye-movements on the most reasonable alternatives to the focus element in the visual field. Third, the onset of the object of the test sentence' consequent confirms the felicity and/or the truth-values of the test sentence with focus operators.

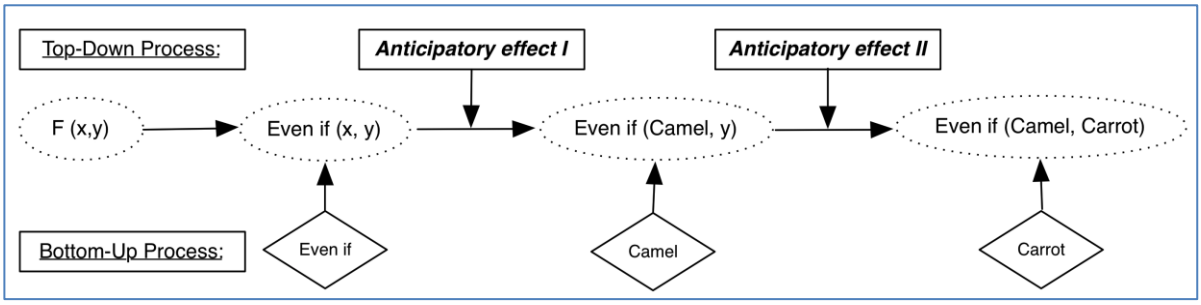

Fig. 10. A model of how the sentences containing focus operators are processed online. First, the onset of a focus operator initiated fixations to the most accessible focus element in the visual domain. When the focus element was no-longer task relevant (e.g., the focus elements had been explicitly mentioned), participants tended to fixate more on the alternatives to the focus element. Note: "even if" can be replaced by "only if".

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