Grammatical aspect and event recognition in children's online sentence comprehension

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A B S T R A C T

This study investigated whether or not the temporal information encoded in aspectual morphemes can be used immediately by young children to facilitate event recognition during online sentence comprehension. We focused on the contrast between two grammatical aspectual morphemes in Mandarin Chinese, the perfective morpheme –*le* and the (imperfective) durative morpheme –*zhe*. The perfective morpheme –*le* is often used to indicate that an event has been completed, whereas the durative morpheme –*zhe* indicates that an event is still in progress or continuing. We were interested to see whether young children are able to use the temporal reference encoded in the two aspectual morphemes (i.e., *completed* versus *ongoing*) as rapidly as adults to facilitate event recognition during online sentence comprehension. Using the visual world eye-tracking paradigm, we tested 34 Mandarin-speaking adults and 99 Mandarin-speaking children (35 three-year-olds, 32 four-year-olds and 32 five-year-olds). On each trial, participants were presented with spoken sentences containing either of the two aspectual morphemes while viewing a visual image containing two pictures, one representing a completed event and one representing an ongoing event. Participants' eye movements were recorded from the onset of the spoken sentences. The results show that both the adults and the three age groups of children exhibited a facilitatory effect trigged by the aspectual morpheme: hearing the perfective morpheme –*le* triggered more eye movements to the completed event area, whereas hearing the durative morpheme –*zhe* triggered more eye movements to the ongoing event area. This effect occurred immediately after the onset of the aspectual morpheme, both for the adults and the three groups of children. This is evidence that young children are able to use the temporal information encoded in aspectual morphemes as rapidly as adults to facilitate event recognition. Children's eye movement patterns reflect a rapid mapping of grammatical aspect onto the temporal structures of events depicted in the visual scene.

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1. Introduction

Language comprehension involves the rapid integration of different types of linguistic and non-linguistic information.

Understanding the mechanism underlying this rapid process is a central component of the study of language comprehension. Research on adult sentence processing has demonstrated that when interpreting a sentence, the human sentence processing mechanism (or the parser), incrementally computes the structural representation and possible meanings of the sentence while drawing on different sources of linguistic and non-linguistic information (e.g., Altmann & Kamide, 1999, 2007; DeLong, Urbach, & Kutas, 2005; Kamide, Altmann, & Haywood, 2003; Omaki,

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2010; Pickering, Traxler, & Crocker, 2000; Staub & Clifton, 2006; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005). Much research has examined this rapid and incremental nature of the processing mechanism, of which a key question that has been widely investigated is the role of event knowledge in sentence comprehension (Elman, 2009; Madden & Ferretti, 2009). Knowledge about events includes typical event participants, causal relationships between participants and objects, instruments, time course, and duration (McRae, Hare, Elman, & Ferretti, 2005; Zacks & Tversky, 2001; Zacks, Tversky, & Iyer, 2001). Verbs are an important source of information about events. Previous research found that event information associated with verbs can be used quickly by adults during online sentence comprehension (Altmann & Kamide, 1999; Ferretti, McRae, & Hatherell, 2001; McRae, Spivey-Knowlton, & Tanenhaus, 1998). For example, Altmann and Kamide (1999) found that when interpreting a sentence, the argument structure (i.e., typical event participants) associated with verbs was activated immediately to predict the upcoming object noun phrase, which resulted in anticipatory eye movements towards the most plausible object in the visual display (see also Altmann & Kamide, 2007; Boland, 2005). In the study, the participants heard sentences like (1) and (2) while viewing an image of a scene with a boy, a cake, and a few toys.

(1) The boy will eat the cake.
(2) The boy will move the cake.

In (1) the verb *eat* can take only one of the objects in the visual scene as its argument, namely the cake, whereas the verb *move* in (2) can take any of the objects as its argument. Altmann and Kamide found that the participants were more likely to fixate on the picture of a cake when hearing (1) *The boy will eat...* than when hearing (2) *The boy will move....* This effect occurred even before the onset of the object noun *cake*. This is evidence that event information associated with verbs can be used immediately by adults to facilitate sentence comprehension.

The immediate activation of event information during online sentence comprehension has also been found to be influenced by the morphology of verbs that signals tense and aspect (Altmann & Kamide, 2007; Becker, Ferretti, & Madden, 2013; Carreiras, Carriedo, Alonso, & Fernandez, 1997; Ferretti, Gagné, & McRae, 2003; Ferretti, Kutas, & McRae, 2007; Ferretti, Rohde, Kehler, & Crutchley, 2009; Ferretti et al., 2001; Madden & Zwaan, 2003; Magliano & Schleich, 2000). Human languages often use morphology to refer to the temporal structures of events (e.g., *ongoing* versus *completed*). In this paper, we focus on the contrast between the *imperfective* versus *perfective* aspect. Imperfective aspect makes specific reference to the internal structure of events by focusing on the ongoing process, but makes no reference to their completion. Perfective aspect refers to events as completed by focusing on the endpoint of the events rather than the ongoing process/internal structure (Comrie, 1976; Smith, 1991). English uses grammatical morphemes to mark aspect. Consider (3a) and (3b), for example. (3a) contains the

grammatical morpheme *–ing*, which makes it clear that the event of planting a flower is currently in progress. By contrast, (3b) contains the grammatical morpheme *–ed*, which indicates that the event of planting a flower has been completed.

(3) a. The old lady is planting a flower.
    b. The old lady has planted a flower.

The examples illustrate that the use of grammatical morphemes is closely related to the temporal structures of events, e.g., whether the event is ongoing or has been completed. Previous research found that the aspectual information encoded in grammatical morphemes can be used immediately by adults to construct representations of events during sentence comprehension. For example, using a picture verification task, Madden and Zwaan (2003) found that English-speaking adults were more likely to choose the picture depicting an completed event when reading a sentence containing a perfective morpheme (e.g., –ed), but they chose both pictures (e.g., one depicted a completed event and one described an ongoing event) equally often when reading a sentence containing an imperfective morpheme (e.g., –ing). Madden and Zwaan interpreted the finding as evidence that when encountering an event described in the perfective aspect, English-speaking adults constructed a representation of the event as having been completed. By contrast, when encountering an event described in the imperfective aspect, they constructed a representation of the event as having both intermediate phases and endpoint. Other event information encoded in aspectual morphemes like event location and participant roles has also been found to play an important role in sentence comprehension (e.g., Carreiras et al., 1997; Ferretti et al., 2007).

Taken together, previous research has shown that event information associated with verbs and verb morphology plays an important role in sentence comprehension. Adults can use the information immediately and effectively to construct representations of events. Previous research on child sentence processing found that like adults, children are also able to use the argument structure (i.e., typical event participants) associated with verbs to anticipate upcoming referents (Andreu, Sanz-Torrent, & Trueswell, 2013; Fernald, Zangl, Portillo, & Marchman, 2008; Nation, Marshall, & Altmann, 2003). For example, children also exhibited anticipatory eye movements to the edible objects upon hearing a sentence containing the verb *eat* (e.g., (1)). Similar to adults, this effect occurred before the onset of the object noun, e.g., *cake*. This is evidence that event information associated with verbs can be activated immediately by children in online sentence comprehension.

Using off-line judgement tasks, Wagner and colleagues found that three-year-old English-speaking children already make a distinction between perfective and imperfective aspect (e.g., Wagner, 2001, 2006; Wagner & Carey, 2003). However, as far as we know, no previous studies have looked at children's online use of grammatical aspect, i.e., whether or not the temporal information encoded in aspectual morphemes (e.g., *ongoing* versus *completed*) function to facilitate children's event recognition during online sentence comprehension. The present study

addresses this question by investigating young Mandarin-speaking children's use of grammatical aspect in online sentence comprehension. This is the first study to explore the role of grammatical aspect in children's event recognition during online sentence comprehension. In order to use this abstract aspectual information to facilitate event recognition, children need to establish the mapping between grammatical aspect and the temporal structures of events. For example, children need to understand that the perfective aspect refers to a completed event, whereas the imperfective aspect refers to an ongoing event. In other words, the immediate use of grammatical aspect in online sentence comprehension requires the ability to quickly map the temporal reference encoded in aspectual morphemes onto the events under consideration. The development of this ability involves the development of the concept of time – one of the fundamental domains in human cognition, as well as the knowledge of how linguistic devices are used to encode time (e.g., grammatical morphemes). Thus, by investigating whether or not the temporal reference encoded in aspectual morphemes can be used immediately by young children to facilitate event recognition, the present study will contribute to our understanding of how children develop the mapping between their concept of time and their knowledge of how time is encoded in language. The findings will also contribute to our understanding of the development of the incremental sentence processing mechanism in children. Previous research found that children can use abstract grammatical features of human language, like grammatical gender and case markers, to facilitate sentence comprehension (Choi & Trueswell, 2010; Lew-Williams & Fernald, 2007; Sekerina & Trueswell, 2012; Van Heugten & Shi, 2009). By looking at another abstract grammatical feature of human language – grammatical aspect, the present study will add further evidence for the incremental nature of the human sentence processing mechanism. In addition, most previous studies on the role of grammatical aspect in sentence comprehension have been limited to Indo-European languages (English mainly), and very few studies have looked at the question from a cross-linguistic perspective. By focusing on Mandarin Chinese, the present study is the first to look at the role of grammatical aspect in sentence comprehension in a language that is typologically distinct from English. The findings will thus provide cross-linguistic evidence attesting to the role of grammatical aspect in sentence comprehension.

Before presenting the experimental studies, we briefly discuss grammatical aspect in Mandarin Chinese. Like English, Mandarin Chinese also uses grammatical morphemes to mark grammatical aspect. There are four primary grammatical aspectual morphemes in Mandarin Chinese: the progressive morpheme *zai–*, the durative morpheme *–zhe*, the perfective morpheme *–le*, and the experiential morpheme *–guo* (Chao, 1968; Li & Thompson, 1981; Yang, 1995). In the present study, we focus on the contrast between the perfective morpheme *–le* and the (imperfective) durative morpheme *–zhe*. The perfective morpheme *–le* is often used to indicate that an event has been completed, whereas the durative morpheme *–zhe* indicates that an event is still in progress or continuing. Sentences (4a) and

(4b) are used to illustrate. Throughout the text, PERF is used to indicate a perfective morpheme, and DUR is used to indicate a durative morpheme. In (4a), the durative morpheme *–zhe* is attached to the verb *zhong* 'plant', which indicates that the event of planting a flower is still in progress. But if the durative morpheme is replaced by the perfective morpheme *–le*, as in (4b), then the sentence indicates that the event of planting a flower has been completed.

(4) a. Laonainai zhong-zhe yi-duo xiaohua.
       old lady   plant-DUR one-CL flower
       'The old lady is planting a flower.'

    b. Laonainai zhong-le   yi-duo xiaohua.
       old lady   plant-PERF one-CL flower
       'The old lady has planted a flower.'

The present study takes advantage of the contrast between the two aspectual morphemes to investigate whether the temporal information encoded in the two aspectual morphemes (e.g., *ongoing* versus *completed*) function to facilitate children's event recognition during online sentence comprehension. More specifically, the question we ask is: when children (and adults) hear sentences like (4a) and (4b), will they be able to activate the temporal reference encoded in the two aspectual morphemes immediately to facilitate their event recognition in online sentence comprehension (i.e., the perfective morpheme *–le* refers to a completed event and the durative morpheme *–zhe* refers to an ongoing event). We use the visual world eye-tracking paradigm. On each trial, children will be presented with spoken sentences containing either of the two aspectual morphemes (e.g., (4a) or (4b)) while viewing a visual image containing two pictures, one representing a completed event and one representing an ongoing event (see Fig. 1). Children's eye movements will be recorded. We anticipate that if children are able to activate the temporal reference encoded in the two aspectual morphemes to facilitate their event recognition in online sentence comprehension, then they should look more to the completed event (e.g., the upper panel of Fig. 1) after hearing the perfective morpheme *–le* than after hearing the durative morpheme *–zhe*. By contrast, they would be expected to look more to the ongoing event (e.g., the lower panel of Fig. 1) after hearing the durative morpheme *–zhe* than after hearing the perfective morpheme *–le*. Mandarin Chinese is ideally suited for investigating the role of grammatical aspect in online sentence comprehension, since sentences containing the two aspectual morphemes form minimal pairs (e.g., (4a) and (4b)).

2. The present study

2.1. Participants

Thirty-four Mandarin-speaking adults (mean age 24, range 22–25, 20 women and 14 men) and 99 monolingual Mandarin-speaking children participated in the experiment. The child participants were divided into three age groups: 35 children were between the ages of 3;5 and 3;11 (mean age 3;6, 20 boys and 15 girls), 32 children were between the ages of 4;0 and 4;11 (mean age 4;5, 16 boys and 16 girls) and 32 children were between the ages of

Fig. 1. Example visual image used in the experiment.

5;1 and 5;11 (mean 5;6, 18 boys and 14 girls). The adult participants were students at the Beijing Language and Culture University. They had no self-reported speech or hearing disorders. The child participants were recruited from the kindergarten at the Beijing Language and Culture University. They had no reported history of speech, hearing or language disorders.

2.2. Materials and design

A total of 16 target items were constructed each consisting of a visual image and two spoken sentences, one with the perfective aspectual morpheme –le and one with the durative aspectual morpheme –zhe. Each visual image contained two pictures, one in which the target character has completed an event (hereafter 'completed event'), and the other in which the character is still conducting the event (hereafter 'ongoing event'). In order to control for potential preferences for looking at particular displayed objects, the position of the completed event and the ongoing event was counterbalanced across trials. On half of the trials the completed event was in the upper panel and the ongoing event was in the lower panel, and on the other half the position was reversed. All the spoken sentences had the same structure: subject noun phrase (subject NP) + verb + aspectual morpheme + measure word (i.e., one + classifier) + object noun phrase (object NP). The subject NP was always a three-syllable word in Mandarin Chinese, and was about one of the four possible target characters: the little boy, the little girl, the old man, or the old lady. The verb was always a one-syllable word in Mandarin followed by either the aspectual morpheme –le or –zhe. A two-syllable measure word (i.e., the numeral yi 'one' + a classifier) was added between the aspectual morpheme and the object NP, in order to maximise the chances of observing a facilitatory effect triggered by the aspectual morpheme. The object NP was always a two-syllable word in Mandarin. To ensure that children

were familiar with the nouns and the verbs we used, all the noun phrases and verbs used in the target sentences were assessed by the teachers in the kindergarten where the experiment was conducted. All the words used in the target sentences were judged by the teachers to be familiar to the children in the kindergarten.

To describe one visual image in detail (see Fig. 1): it contained two pictures, the one in the upper panel depicted a completed event in which the old lady has finished planting the flower, and the one in the lower panel described an ongoing event where the old lady is planting the flower. For this image, two spoken sentences were recorded as in (5), one in which the perfective aspectual morpheme –le was attached to the verb (see (5a)) and the other in which the durative aspectual morpheme –zhe was attached to the verb (see (5b)). Except for the aspectual morphemes, the other words in (5a) and (5b) were exactly the same: the subject NP laonainai 'old lady' + the verb zhong 'plant' + the measure word yi-duo 'one-classifier' + the object NP xiaohua 'flower'.

(5) a. Laonainai zhong-le yi-duo xiaohua.
     old lady plant-PERF one-CL flower
     'The old lady has planted a flower.'

   b. Laonainai zhong-zhe yi-duo xiaohua.
     old lady plant-DUR one-CL flower
     'The old lady is planting a flower.'

The 16 target items were divided into two lists with each participant seeing each visual image but hearing only one of the two spoken sentences that could accompany the visual image. Target sentences with the perfective aspectual morpheme –le and those with the durative aspectual morpheme –zhe were counterbalanced across the two lists with 8 sentences containing –le and 8 sentences containing –zhe in each list. Target sentences with –le were compatible with pictures depicting a completed event and target sentences containing –zhe were compatible with pictures depicting an ongoing event.

In addition, 16 filler items were added to each experimental list. Each filler item consisted of a visual image and a spoken sentence. On half of the filler trials the spoken sentence represented the picture in the upper panel of the visual image, and on the other half the spoken sentence was compatible with the picture in the lower panel. An example of the visual images can be found in Appendix A, where the upper panel depicted an event in which the little boy is holding a hat and the lower panel depicted an event in which the little boy is holding a flower. The spoken sentence corresponding to the example filler image is given in (6), which is an obvious representation of the picture in the lower panel.

(6) Xiaonanhai na-zhe yi-duo xiaohua.
   little boy hold-DUR one-CL flower
   'The little boy is holding a flower.'

Note that the durative aspectual morpheme –zhe was used in (6), but the filler item didn't involve the distinction between the perfective aspectual morpheme –le and the durative aspectual morpheme –zhe, since both pictures of

the example image (see Appendix A) described a state event. In all the filler items the two pictures of a visual image described events that occurred in the same temporal periods (i.e., both were completed events or state events). In each experimental list, the 16 target and 16 filler items were arranged in random order. Participants in each age group were randomly assigned to one of the two lists. A full list of the target sentences is included in Appendix B.

2.3. The production of the test stimuli

The test sentences were produced by a female native speaker of Beijing Mandarin. She was asked to produce the test sentences in a child-directed manner. The recording was conducted in a sound-attenuated recording booth at Macquarie University. For each visual image, two target sentences were recorded, one with the perfective aspectual morpheme –le and one with the durative aspectual morpheme –zhe. To see whether the two types of target sentences were approximately of the same length, we did an acoustic analysis of each element in the target sentences. Each sentence contained a subject NP, a verb, an aspectual morpheme, a measure word and an object NP. The duration of each element was measured and paired *t*-tests were conducted to verify whether there were differences in duration between the two types of target sentences (see Table 1).

As indicated in Table 1, no significant differences were found in the duration of the elements between the two types of target sentences. The results of the acoustic analysis confirmed that the target sentences were approximately of the same length. The mean length of the target sentences with –le was 3402 ms, and the mean length of the target sentences containing –zhe was 3447 ms.

2.4. Procedure

Both children and adults were tested using the visual world paradigm (Tanenhaus et al., 1995). This paradigm is based on an early observation by Cooper (1974), who pointed out that when participants are simultaneously presented with spoken language while viewing a visual scene, their eye movements are very closely synchronised to the referential processing of the concurrent linguistic input. This paradigm has been successfully used to test children's linguistic knowledge in online sentence comprehension (e.g., Arnold, Brown-Schmidt, & Trueswell, 2007; Choi & Trueswell, 2010; Höhle, Berger, Müller, Schmitz, & Weissenborn, 2009; Sekerina & Trueswell, 2012; Snedeker & Trueswell, 2004; Snedeker & Yuan, 2008;

Trueswell, Sekerina, Hill, & Logrip, 1999; Zhou, Crain, & Zhan, 2012; Zhou, Su, Crain, Gao, & Zhan, 2012). In this study, participants were presented with a spoken sentence while viewing a visual image containing two pictures. Participants were told that they were going to see some pictures, and the puppet, Kermit the Frog, was going to explain to them what he saw in the pictures. On each trial, the participant's task was to decide which picture the puppet was talking about. Participants' eye movements were recorded using an EyeLink 1000 eye tracker (by SR Research Ltd., Mississauga, Ontario, Canada) interfaced with a PC computer. The EyeLink 1000 allows remote eye tracking, without a head support. The eye tracker provides information about the participant's point of gaze at a sampling rate of 500 Hz, and it has accuracy of 0.5 degrees of visual angle. The picture stimuli were displayed on the monitor. Spoken sentences were presented to the participants through the PC computer connected to two external speakers. Though the eye tracker does not require head stabilisation, the child participants were held still by an adult experimenter, and they leaned slightly back in a chair in front of the monitor. This manoeuvre was taken to reduce back and forth movements by the child participants. The distance between the participants' eyes and the monitor was about 60 cm.

Before the actual experiment, we had an introduction session to familiarise the child participants with the experimental procedure as well as the objects that were presented in the pictures. The introduction session was followed by the experimental session. The experimental session began with four practice trials followed by 32 test trials (16 target and 16 filler trials). The practice trials were similar to the filler trials. Before each trial, a picture of Kermit the Frog was presented at the centre of the monitor, which anchored the beginning of each trial, and served to capture the participants' attention. The picture was also used to make it appear that the puppet was talking. This picture gave way to the trial as soon as the participant focused on the centre of the monitor.

The spoken sentence started 500 ms after the appearance of the visual stimulus. Participants' eye movements were recorded for 4000 ms from the onset of the subject NP. The mean length of the target sentences was 3424 ms.

2.5. Data treatment

There were two sets of data: the offline responses and the eye-movement data. The offline responses consist of participants' responses to each target trials (i.e., the proportion of responses in which participants correctly chose

Table 1
Duration analyses of the stimuli in the experiment (standard deviation in parentheses).

Dependent variable	Mean for sentences with –le	Mean for sentences with –zhe	Analysis
Subject NP	1269 ms (28)	1279 ms (28)	$t(15) = 1.02, p = .32$
Verb	425 ms (11)	438 ms (13)	$t(15) = 1.34, p = .20$
Aspectual morpheme	575 ms (21)	574 ms (19)	$t(15) = .03, p = .98$
Measure word	390 ms (27)	390 ms (24)	$t(15) = 0, p = 1$
Object NP	743 ms (29)	765 ms (30)	$t(15) = 1.64, p = .12$

the picture that matched the spoken sentence). We only included a participant's eye movement data in the analysis if he/she performed above chance on the target trials. Two three-year-olds and one four-year-old were excluded from the analysis because they responded correctly to the target trials below chance level. The other participants all correctly chose the pictures that were compatible with the target sentences above 87.5% of the time (14/16 trials). Based on the offline data, we know that the participants that were included in the final analysis have knowledge of the contrast between the perfective morpheme –*le* and the durative morpheme –*zhe*. Three adults, two five-year-olds and two three-year-olds were excluded because we were unable to calibrate them on the eye tracker. The remaining 31 adults, 30 five-year-olds (range 5,1–5;11), 31 four-year-olds (range 4;0–4;11) and 31 three-year-olds (range 3;5–3;11) were included in the final analysis. Trials were excluded if there was more than 33% track loss from the onset of the aspectual morpheme until the sentence was completed. Two trials were excluded for the three-year-old group and no trials were excluded for the other three age groups.

In analysing the eye-movement data, participants' fixations were coded in two categories: the area containing the completed event (hereafter 'completed event area') and the area containing the ongoing event (hereafter 'ongoing event area'). Use example (5) (repeated here as (7)) and Fig. 2 to illustrate. In this example, the completed event area is the upper panel (i.e., the old lady has planted the flower) and the ongoing event area is the lower panel (i.e., the old lady is planting the flower). The completed event area is compatible with (7a) containing the perfective aspectual morpheme –*le*, and the ongoing event area is compatible with (7b) containing the durative aspectual morpheme –*zhe*. For each trial, the proportion of fixations

Completed Event Area

Ongoing Event Area

Fig. 2. Example of interest areas.

in the two categories was time-locked to the onset of the aspectual morpheme. The average proportion of fixations following the onset of the aspectual morpheme for each category was then computed in a time window of 1800 ms.

(7) a. Laonainai   zhong-le   yi-duo   xiaohua.
       old lady   plant-PERF one-CL   flower
       'The old lady has planted a flower.'
    b. Laonainai   zhong-zhe yi-duo   xiaohua.
       old lady   plant-DUR one-CL   flower
       'The old lady is planting a flower.'

2.6. Predictions

If the temporal information encoded in the two aspectual morphemes can be used immediately by children (and adults) to facilitate event recognition during online sentence comprehension, then they would be expected to look more to the completed event area when hearing the perfective morpheme –*le* than when hearing the durative morpheme –*zhe*. By contrast, they would be expected to fixate more on the ongoing event area when hearing the durative morpheme –*zhe* than when hearing the perfective morpheme –*le*. In other words, if children (and adults) were able to rapidly map the temporal reference encoded in the aspectual morphemes onto the events under consideration, then hearing the perfective morpheme –*le* should trigger more eye movements to the completed event area, whereas hearing the durative morpheme –*zhe* should trigger more eye movements to the ongoing event area. This effect should occur immediately after the onset of the aspectual morpheme.

3. Results

We computed the proportion of fixations in each 200 ms time window over a time period of 1800 ms following the onset of the aspectual morpheme in the two critical categories: the completed event area and the ongoing event area. To provide an overview of the eye movement data, the results are first presented in the form of descriptive graphs followed by more detailed statistical analyses.

Fig. 3 shows the proportion of fixations of adults in the completed event area (upper panel) and in the ongoing event area (lower panel) across the two conditions. Figs. 4–6 summarise the proportion of fixations of the three age groups of children in the two areas across the two conditions. The figures indicate that the adults and the three age groups of children exhibited similar eye gaze patterns in the two critical areas in the two conditions. For all the four groups, a higher proportion of fixations was observed in the completed event area for the perfective morpheme –*le* than for the durative morpheme –*zhe*. The adults started to look more to the completed event area after hearing the perfective morpheme –*le*, and they started to look less to this area after hearing the durative morpheme –*zhe* (in the time span between 200 and 400 ms after the onset of the aspectual morpheme) (see Fig. 3). The five-year-olds (see Fig. 4), the four-year-olds (see Fig. 5) and the three-year-olds (see Fig. 6) all exhibited similar eye movement
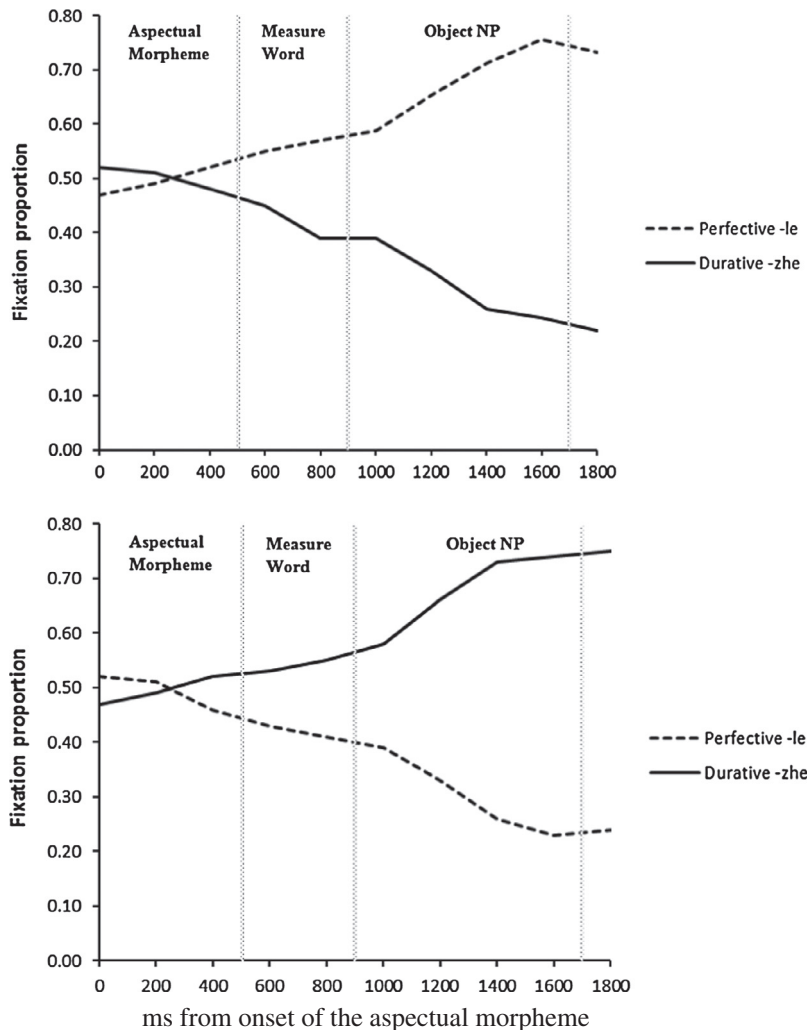
Fig. 3. Average fixation proportions following the onset of the aspectual morpheme in the completed event area (upper panel) and the ongoing event area (lower panel) across the two conditions, adults.

patterns. Like adults, all the three age groups of children showed increased looks to the completed event area when hearing the perfective morpheme –*le*, and they started to launch fewer fixations to this area when hearing the durative morpheme –*zhe* (in the time span between 200 and 400 ms after the onset of the aspectual morpheme). By contrast, an opposite pattern was found in the ongoing event area for all the four groups. There was a higher probability of looks in the ongoing event area for the durative morpheme –*zhe* than for the perfective morpheme –*le*. Again, this effect occurred immediately after the onset of the aspectual morpheme, for both the adults and the three age groups of children.

To assess these fixation patterns statistically, generalised linear mixed models (GLMMs) were applied using the R software package (i.e., lme4), version 3.0.0 (R Development Core Team). We fit the data for the four groups of participants separately, focusing on the looks to the two critical categories (i.e., the completed event area and the ongoing event area) following the onset of the aspectual morpheme (between 0 and 1800 ms). The

models treated aspectual condition (perfective versus durative) and time as fixed effects, with random intercepts and slopes for both participants and items (Baayen, Davidson, & Bates, 2008). Because fixation proportions were used, the data were first transformed using an empirical logit function (Barr, 2008; Jaeger, 2008).[1]

Table 2 summarises the model results for the adult data in the two critical categories. After the onset of the aspectual morpheme, in the completed event area the negative coefficient for the significant main effect of the aspectual condition (='Condition (Durative)') reflects the fact that the adults looked significantly more at this area when hearing the perfective morpheme –*le* than when hearing the durative morpheme –*zhe*. The significant negative

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[1] In the logistic terms, the data expresses the changes in fixation likelihood of looking at versus not looking at an given interest area. According to Jaeger (2008), empirical logit transformation can correct the problem of heterogeneity of variance distribution in using proportional data.
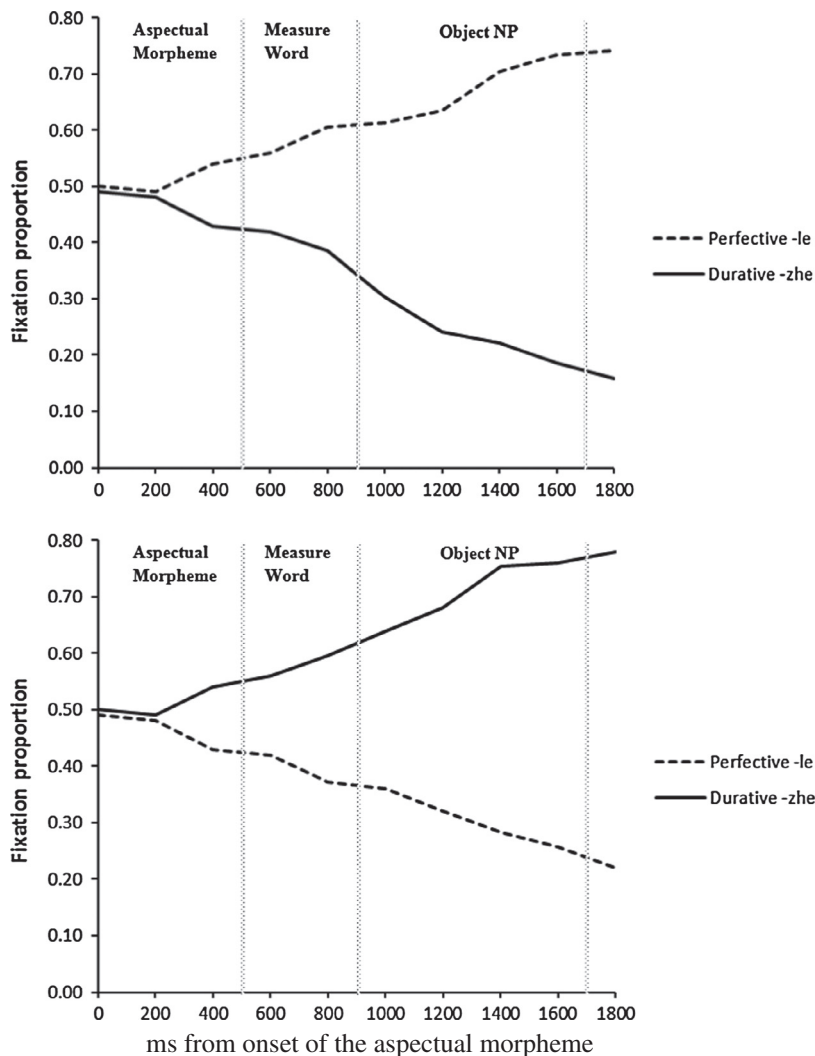
Fig. 4. Average fixation proportions following the onset of the aspectual morpheme in the completed event area (upper panel) and the ongoing event area (lower panel) across the two conditions, 5-year-olds.

coefficient for the interaction between aspectual condition and time (='Condition (Durative) × Time') indicates that the probability of looking at the completed event area decreased over time after hearing the durative morpheme. By contrast, an opposite eye gaze pattern was observed in the ongoing event area. Aspectual condition is a reliable positive predictor in this case, indicating that the adults fixated more on the ongoing event area when hearing the durative morpheme –*zhe* than when hearing the perfective morpheme –*le*. The positive coefficient for the interaction between aspectual condition and time confirms that the probability of fixating on the ongoing event area increased over time after hearing the durative morpheme.

The five-year-olds, the four-year-olds and the three-year-olds all exhibited similar eye gaze patterns. The fixed effects from the models fitted to the data of these three age groups of children appear in Tables 3–5 respectively. After the onset of the aspectual morpheme, in the completed event area all the three age groups of children, like the adults, exhibited a main effect of aspectual condition. The

negative coefficient for this effect indicates that they looked significantly more at the completed event area when hearing the perfective morpheme –*le* than when hearing the durative morpheme –*zhe*. In addition, a significant interaction between aspectual condition and time was also found in the three groups of children. The negative coefficient for the interaction confirms that for all the three groups of children, the probability of looking at the completed event area decreased over time after hearing the durative morpheme. This eye gaze pattern was reversed in the ongoing event area, however. The three groups of children all showed increased looks to the ongoing event area when listening to the durative morpheme –*zhe* than when listening to the perfective morpheme –*le*, as indicated by the positive coefficient for the main effect of aspectual condition. The positive coefficient for the significant interaction between aspectual condition and time confirms that the probability of fixating on the ongoing event area increased over time after listening to the durative morpheme.

The patterns displayed in Figs. 3–6 were supported by the statistical modelling. Both the adults and the three groups of children exhibited similar eye gaze patterns in the two critical categories across the two conditions. A higher proportion of fixations was observed in the completed event area when hearing the perfective morpheme –*le* than when hearing the durative morpheme –*zhe*. By contrast, an opposite eye gaze pattern was observed in the ongoing event area. The difference between the two aspectual conditions occurred immediately after the onset of the aspectual morpheme, both for the adults and the three groups of children.[2] In order to see whether there exist any differences between the adults and the three groups of children in the time course of the eye gaze patterns, new models were developed in which age was included as an experimental factor. More specifically, models were fitted to the entire data set (both the adult and the child data) for the two critical categories, treating aspectual condition, time and age as fixed effects, with random intercepts and slopes for both participants and items. The results are summarised in Table 6. In both the completed event and the ongoing event areas, no significant effects of age (='Five-year-olds (adults)', 'Four-year-olds (adults)', and 'Three-year-olds (adults)') were observed, which confirms that there were no differences between the adults and the children in the time course of the eye gaze patterns.

4. General discussion

In the present study, we sought to investigate whether or not the temporal information encoded in aspectual morphemes can be used immediately by young children to facilitate event recognition during online sentence comprehension. Using the visual world eye-tracking paradigm, we found that both the adults and the three age groups of children exhibited a facilitatory effect trigged by the aspectual morpheme: hearing the perfective morpheme –*le* triggered more eye movements to the completed event area, whereas hearing the durative morpheme –*zhe* triggered more eye movements to the ongoing event area. This effect

occurred immediately after the onset of the aspectual morpheme. This is evidence that young children are able to use the temporal information encoded in aspectual morphemes as rapidly as adults to facilitate event recognition. Children's eye movement patterns reflect a rapid mapping of grammatical aspect onto the temporal structures of events depicted in the visual scene. More specifically, when children (and adults) heard the perfective morpheme –*le*, they immediately constructed a mental representation of a completed event, and then they moved their eyes towards the event in the visual scene that had a temporal structure compatible with this mental representation. Similarly, when children (and adults) heard the durative morpheme –*zhe*, they immediately constructed a mental representation of an ongoing event, and then they moved their eyes towards the event in the visual scene that had a temporal structure consistent with this mental representation. This rapid mapping of grammatical aspect onto the temporal properties of the events depicted in the visual scene was even observed in the three-year-olds, indicating that young children by age three are already able to use the abstract aspectual information encoded in grammatical morphemes as rapidly and effectively as adults to facilitate sentence comprehension.

However, there was a difference in the fixation proportions between the different age groups, namely, the overall proportions of fixations to the target areas increased with age, as indicated in Figs. 4–6. The younger children exhibited fewer looks to the target area compared to the older children. This difference in fixation proportions might reflect an age difference in the cognitive control of visual attention. It has been well documented that children have a shorter visual attention span and pooper inhibitory control than adults (e.g., Bucci, Nassibi, Gerard, Bui-Quoc, & Seassau, 2012; Fadda et al., 2012; Fukushima, Hatta, & Fukushima, 2000; Munoz & Everling, 2004). The age difference in the proportions of looks to the target area reflects the development of the immature visual attention system in children. In addition, we wish to note that the fact that younger children exhibited lower fixation proportions than older children and adults in the target areas has also been reported in previous studies, e.g., Andreu et al. (2013) and Fadda et al. (2012).

Overall, the present study provides the first investigation of young children's use of grammatical aspect in online sentence comprehension. We found that children as young as three were able to use the temporal reference encoded in grammatical aspect to facilitate event recognition during sentence comprehension. This is evidence that event information associated with verb morphology plays an important role in child sentence processing as has been observed in adult sentence processing. As discussed, the use of grammatical aspect to facilitate event recognition requires that children have the concept of time as well as the knowledge of how grammatical aspect in human language is used to encode time. The findings of the present study attest to an emergence of this ability: children by age three already know how time is encoded using grammatical aspect.

The findings also have important implications for our understanding of the development of the sentence

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[2] In order to see whether the difference in fixation proportions between the two aspectual conditions already reached statistical significance at the onset of the measure word, generalised linear mixed models were applied for each age group. We focused on the fixation proportions to the two critical areas (i.e., the completed event area and the ongoing event area) at the onset of the measure word. The models treated aspectual condition (perfective versus durative) as fixed effects, with random intercepts and slopes for both participants and items. Again, because fixation proportions were used, the data were first transformed using an empirical logit function. The models revealed significant main effects of aspectual condition in both the completed event area and the ongoing event area for all the four age groups. At the onset of the measure word, all the four age groups exhibited significantly more fixations to the completed event area after hearing the perfective morpheme –*le* than after hearing the durative morpheme –*zhe* (adults: $\beta = -1.20$, $SE = 0.07$, $t = -2.95$, $p < .01$; five-year-olds: $\beta = -1.24$, $SE = 0.08$, $t = -3.45$, $p < .01$; four-year-olds: $\beta = -0.88$, $SE = 0.09$, $t = -3.01$, $p < .01$; and three-year-olds: $\beta = -0.65$, $SE = 0.07$, $t = -2.76$, $p < .01$). By contrast, all the four age groups exhibited more fixations to the ongoing event area after hearing the durative morpheme –*zhe* than after hearing the perfective morpheme –*le* (adults: $\beta = 1.17$, $SE = 0.07$, $t = 2.96$, $p < .01$; five-year-olds: $\beta = 1.24$, $SE = 0.08$, $t = 3.46$, $p < .01$; four-year-olds: $\beta = 0.84$, $SE = 0.09$, $t = 2.73$, $p < .01$; and three-year-olds: $\beta = 0.67$, $SE = 0.07$, $t = 2.72$, $p < .01$).
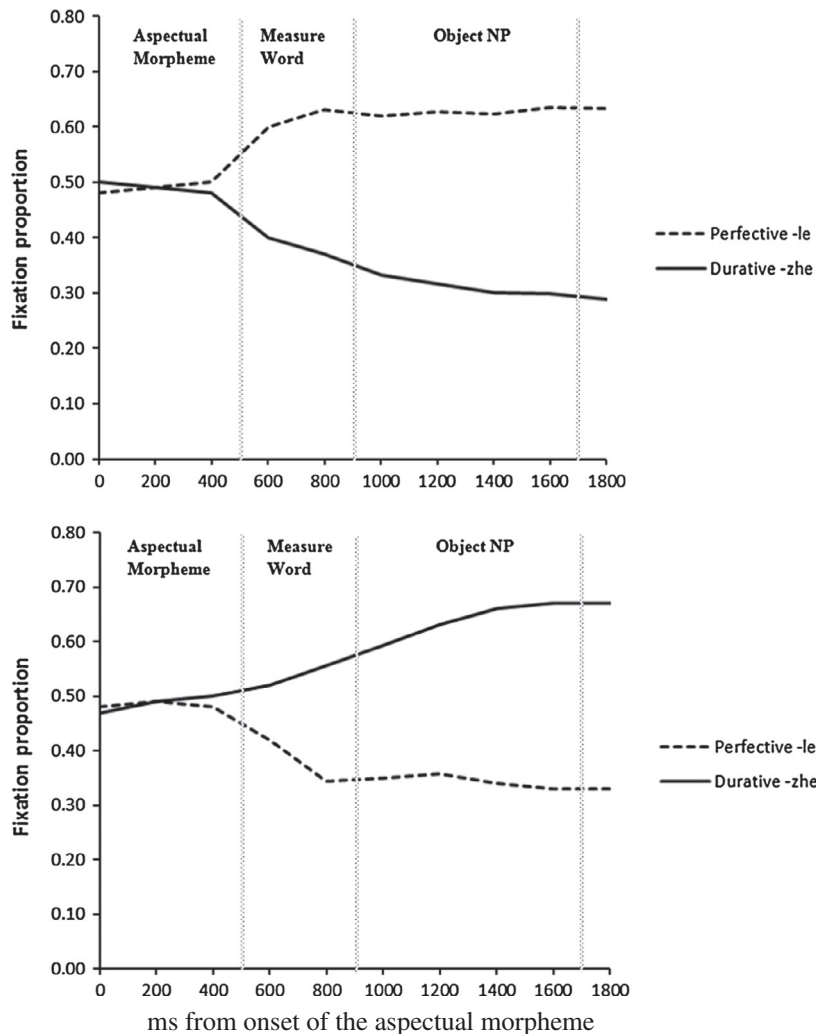
Fig. 5. Average fixation proportions following the onset of the aspectual morpheme in the completed event area (upper panel) and the ongoing event area (lower panel) across the two conditions, 4-year-olds.

processing mechanism in children. Previous research found that children can use abstract grammatical features of human language, like grammatical gender and case markers, to facilitate sentence comprehension (Choi & Trueswell, 2010; Lew-Williams & Fernald, 2007; Sekerina & Trueswell, 2012; Van Heugten & Shi, 2009). The present study extended this facilitatory effect to another abstract grammatical feature of human language – grammatical aspect. Taken together, it seems plausible to conclude that young children can use the abstract information encoded in grammatical morphology to incrementally compute the meanings of sentences. This adds further evidence for the incremental nature of the human sentence processing mechanism. Previous studies also found that when listening to a sentence, children incrementally compute the syntactic representation of the sentence (e.g., Omaki, 2010; Trueswell et al., 1999). The findings of the current study in conjunction with these previous findings indicate that young children incrementally compute the meaning of a spoken sentence using both morphological and syntactic

cues. This is evidence that children start off with an incremental sentence processing mechanism. This incremental property of the parser can help to reduce the burden on short term memory and maximise computational efficiency, since holding unstructured material in memory is costly for the memory system, and therefore the ability to incrementally build a structured representation should help to reduce the memory burden for the parser. More specifically, the incrementally hypothesised representations help to constrain the space of hypothesis about the upcoming input, i.e., what kind of subsequent input is possible. This incremental property of the parser allows the hearer to predict the upcoming information in the sentence and thus efficiently integrate the upcoming information into the previously built representations, and then arrive at an intended interpretation. For this reason, it seems reasonable to see the incremental nature as a design feature for the parser and this feature is especially desirable for children, since many aspects of their working memory capacity are limited compared to that of adults
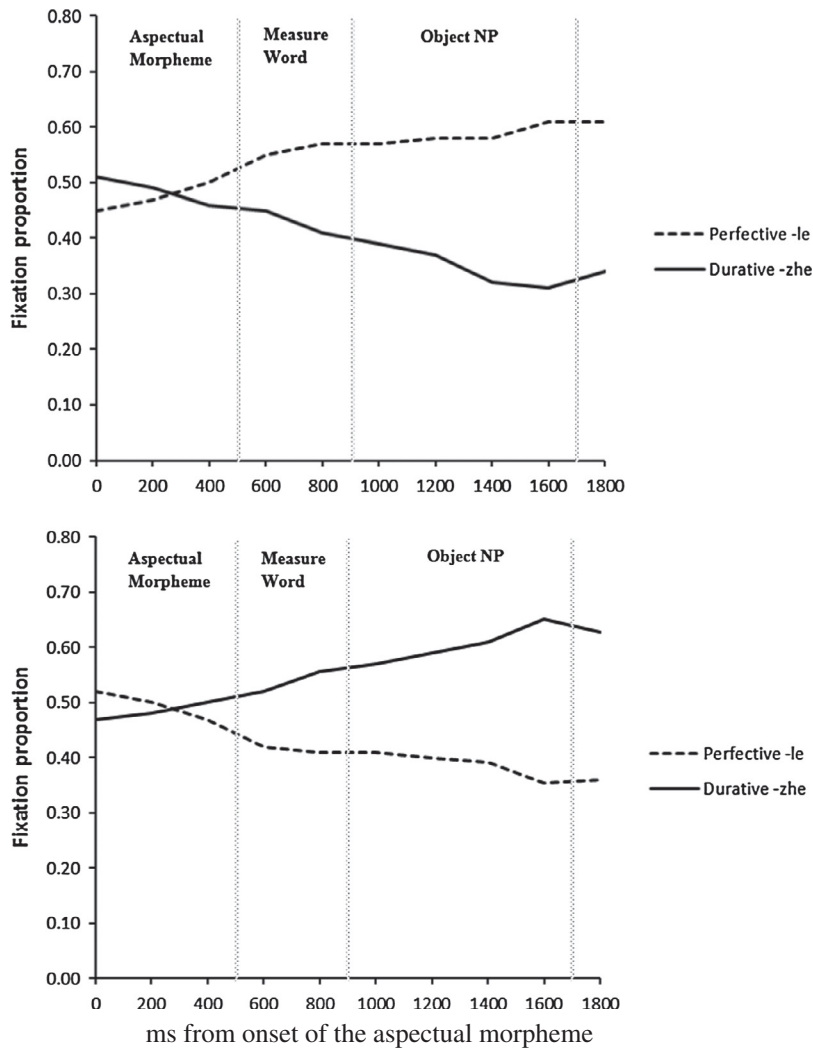
Fig. 6. Average fixation proportions following the onset of the aspectual morpheme in the completed event area (upper panel) and the ongoing event area (lower panel) across the two conditions, 3-year-olds.

Table 2
Fixed effects from the best-fitting model of probability of looks to the completed event area and the ongoing event area following the onset of the aspectual morpheme (empirical logit transformed), adults.

Category	Fixed effects	Estimate	SE	t Value
Completed event area				
	(Intercept)	0.53	0.04	11.38[***]
	Condition (durative)	−1.32	0.06	−14.76[***]
	Time	0.37	0.05	6.93[***]
	Condition (durative) × time	−0.64	0.04	−16.34[***]
Ongoing event area				
	(Intercept)	−0.56	0.04	−14.35[***]
	Condition (durative)	1.12	0.06	14.24[***]
	Time	−0.33	0.05	−7.45[***]
	Condition (durative) × time	0.56	0.04	15.28[***]
Formula in R: fixation ~ condition * time + (1 + condition + time|participant) + (1 + condition + time|item)				

[***] $p < .001$.

(e.g., Diamond, 2006; Gathercole, Pickering, Ambridge, & Wearing, 2004).

In addition, the findings of the present study provide cross-linguistic evidence attesting to the role of grammatical

Table 3
Fixed effects from the best-fitting model of probability of looks to the completed event area and the ongoing event area following the onset of the aspectual morpheme (empirical logit transformed), five-year-olds.

Category	Fixed effects	Estimate	SE	t Value
Completed event area				
	(Intercept)	0.42	0.05	7.65***
	Condition (durative)	−1.29	0.08	−12.12***
	Time	0.24	0.05	4.24***
	Condition (durative) × time	−0.57	0.04	−13.02***
Ongoing event area				
	(Intercept)	−0.51	0.05	−8.77***
	Condition (durative)	1.29	0.08	13.04***
	Time	−0.22	0.05	−4.46***
	Condition (durative) × time	0.46	0.04	11.97***
Formula in R: fixation ~ condition * time + (1 + condition + time|participant) + (1 + condition + time|item)				

*** $p < .001$.

Table 4
Fixed effects from the best-fitting model of probability of looks to the completed event area and the ongoing event area following the onset of the aspectual morpheme (empirical logit transformed), four-year-olds.

Category	Fixed effects	Estimate	SE	t Value
Completed event area				
	(Intercept)	0.36	0.05	5.49***
	Condition (durative)	0.90	0.08	−9.77***
	Time	0.03	0.06	0.43
	Condition (durative) × time	−0.31	0.05	−6.46***
Ongoing event area				
	(Intercept)	−0.40	0.05	−6.94***
	Condition (durative)	0.81	0.08	8.73***
	Time	−0.03	0.06	−0.32
	Condition (durative) × time	0.32	0.05	7.23***
Formula in R: fixation ~ condition * time + (1 + condition + time|participant) + (1 + condition + time|item)				

*** $p < .001$.

Table 5
Fixed effects from the best-fitting model of probability of looks to the completed event area and the ongoing event area following the onset of the aspectual morpheme (empirical logit transformed), three-year-olds.

Category	Fixed effects	Estimate	SE	t Value
Completed event area				
	(Intercept)	0.19	0.06	3.03**
	Condition (durative)	−0.54	0.07	−5.93***
	Time	0.04	0.05	0.82
	Condition (durative) × time	−0.16	0.04	−3.34**
Ongoing event area				
	(Intercept)	−0.28	0.06	−4.41***
	Condition (durative)	0.55	0.09	5.62***
	Time	−0.03	0.05	−0.45
	Condition (durative) × time	0.16	0.04	3.41**
Formula in R: fixation ~ condition * time + (1 + condition + time|participant) + (1 + condition + time|item)				

** $p < .01$.
*** $p < .001$.

aspect in sentence comprehension. By focusing on English, previous studies found that event information associated with grammatical aspect can be used immediately by adults to facilitate event recognition during sentence comprehension. The present study extends this finding to speakers of Mandarin Chinese, a typologically distinctive language. We found that event information encoded in grammatical aspect can be activated rapidly by both Mandarin-speaking children and adults to facilitate event recognition. The findings are evidence that grammatical aspect function similarly in sentence processing across languages.

Table 6
Fixed effects from the best-fitting model of probability of looks to the completed event area and the ongoing event area following the onset of the aspectual morpheme (empirical logit transformed), adult and child data combined.

Category	Fixed effects	Estimate	SE	t Value
Completed event area				
	(Intercept)	0.41	0.03	13.21[***]
	Condition (durative)	−0.78	0.05	−16.27[***]
	Time	0.15	0.03	5.16[***]
	Five-year-olds (adults)	−0.05	0.03	−1.41
	Four-year-olds (adults)	−0.03	0.03	−0.91
	Three-year-olds (adults)	−0.04	0.04	−1.02
	Condition (durative) × time	−0.37	0.02	−16.34[***]
Ongoing event area				
	(Intercept)	−0.47	0.03	−15.63[***]
	Condition (durative)	0.76	0.05	16.05[***]
	Time	−0.15	0.03	−5.01[***]
	Five-year-olds (adults)	0.05	0.03	1.59
	Four-year-olds (adults)	0.04	0.03	1.39
	Three-year-olds (adults)	0.04	0.04	1.04
	Condition (durative) × time	0.36	0.02	16.22[***]

Formula in R: fixation ~ condition * time * age + (1 + condition + time|participant) + (1 + condition + age + time|item)

[***] $p < .001$.

Appendix A

Example filler image used in the experiment.

Appendix B

Target sentences in the experiment (two spoken sentences were recorded for each visual image, one with the perfective aspectual morpheme –*le* and one with the durative aspectual morpheme –*zhe*).

(1)　a.　Xiaonanhai　hua-le　yi-zhi　xiaomao.
　　　　little boy　draw-PERF　one-CL　cat
　　b.　Xiaonanhai　hua-zhe　yi-zhi　xiaomao.
　　　　little boy　draw-DUR　one-CL　cat

(2)　a.　Xiaonühai　da-le　yi-ge　fangzi.
　　　　little girl　build-PERF　one-CL　house
　　b.　Xiaonühai　da-zhe　yi-ge　fangzi.
　　　　little girl　build-DUR　one-CL　house

(3)　a.　Laoyeye　chi-le　yi-ge　pingguo.
　　　　old man　eat-PERF　one-CL　apple
　　b.　Laoyeye　chi-zhe　yi-ge　pingguo.
　　　　old man　eat-DUR　one-CL　apple

(4)　a.　Laonainai　si-le　yi-zhang　baozhi.
　　　　old lady　tear-PERF　one-CL　newspaper
　　b.　Laonainai　si-zhe　yi-zhang　baozhi.
　　　　old lady　tear-DUR　one-CL　newspaper

(5) a. Xiaonanhai   he-le   yi-bei   baishui.
       little boy   drink-   one-   water
                     PERF   CL

   b. Xiaonanhai   he-zhe   yi-bei   baishui.
       little boy   drink-   one-   water
                     DUR   CL

(6) a. Xiaonühai   chui-le   yi-   lazhu.
                                 gen
       little girl   blow-   one-   candle
                     PERF   CL

   b. Xiaonühai   chui-   yi-   lazhu.
                     zhe   gen
       little girl   blow-   one-   candle
                     DUR   CL

(7) a. Laoyeye   xiao-le   yi-   qianbi.
                                 gen
       old man   peel-   one-   pencil
                     PERF   CL

   b. Laoyeye   xiao-   yi-   qianbi.
                     zhe   gen
       old man   peel-   one-   pencil
                     DUR   CL

(8) a. Laonainai   zhong-   yi-   xiaohua.
                     le   duo
       old lady   plant-   one-   flower
                     PERF   CL

   b. Laonainai   zhong-   yi-   xiaohua.
                     zhe   duo
       old lady   plant-   one-   flower
                     DUR   CL

(9) a. Xiaonanhai   chi-le   yi-   xigua.
                                 kuai
       little boy   eat-   one-   watermelon
                     PERF   CL

   b. Xiaonaihai   chi-zhe   yi-   xigua.
                                 kuai
       little boy   eat-   one-   watermelon
                     DUR   CL

(10) a. Xiaonühai   hua-le   yi-ge   pingguo.
        little girl draw-   one-   apple
                     PERF   CL

    b. Xiaonühai   hua-   yi-ge   pingguo.
                     zhe
        little girl draw-   one-   apple
                     DUR   CL

(11) a. Laoyeye   zhong-   yi-ke   xiaoshu.
                     le
        old man   plant-   one-   tree
                     PERF   CL

    b. Laoyeye   zhong-   yi-ke   xiaoshu.
                     zhe
        old man   plant-   one-   tree
                     DUR   CL

(12) a. Laonainai   chui-le   yi-ge   qiqiu.
        old lady   blow-   one-   balloon

                     PERF   CL
    b. Laonainai   chui-   yi-ge   qiqiu.
                     zhe
        old lady   blow-   one-   balloon
                     DUR   CL

(13) a. Xiaonanhai si-le   yi-   zhaopian.
                                 zhang
        little boy   tear-   one-   photo
                     PERF   CL

    b. Xiaonanhai si-zhe   yi-   zhaopian.
                                 zhang
        little boy   tear-   one-   photo
                     DUR   CL

(14) a. Xiaonühai   he-le   yi-bei   chengzhi.
        little girl drink-   one-   juice
                     PERF   CL

    b. Xiaonühai   he-zhe   yi-bei   chengzhi.
        little girl drink-   one-   juice
                     DUR   CL

(15) a. Laoyeye   da-le   yi-ge   feichuan.
        old man   build-   one-   spaceship
                     PERF   CL

    b. Laoyeye   da-zhe   yi-ge   feichuan.
        old man   build-   one-   spaceship
                     DUR   CL

(16) a. Laonainai   xiao-le   yi-ge   yali.
        old lady   peel-   one-   pear
                     PERF   CL

    b. Laonainai   xiao-   yi-ge   yali.
                     zhe
        old lady   peel-   one-   pear
                     DUR   CL

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