Journal of Memory and Language xxx (2013) xxx–xxx

Contents lists available at ScienceDirect

Journal of Memory and Language

journal homepage: www.elsevier.com/locate/jml

Children's assignment of grammatical roles in the online processing of Mandarin passive sentences

Yi Ting Huang[a,*], Zheng Xiaobei[b], Meng Xiangzhi[b], Jesse Snedeker[c]

[a] University of Maryland College Park, United States
[b] Peking University, China
[c] Harvard University, United States

ARTICLE INFO

Article history:
Received 24 May 2012
Received in revised form 7 August 2013
Available online xxxx

Keywords:
Language development
Passives
Mandarin
Eye-tracking
Role assignment

ABSTRACT

Children's difficulty understanding passives in English has been attributed to the syntactic complexity, overall frequency, cue reliability, and/or incremental processing of this construction. To understand the role of these factors, we used the visual-world paradigm to examine comprehension in Mandarin Chinese where passives are infrequent but signaled by a highly valid marker (BEI). Eye-movements during sentences indicated that these markers triggered incremental role assignments in adults and 5-year-olds. Actions after sentences indicated that passives were often misinterpreted as actives when markers appeared *after* the referential noun ("*Seal BEI it eat*" → The seal is eaten by it). However, they were more likely to be interpreted correctly when markers appeared *before* ("*It BEI seal eat*" → It is eaten by the seal). The actions and the eye-movements suggest that for both adults and children, interpretations of passive are easier when they do not require revision of an earlier role assignment.

Introduction

One of the basic problems facing language learners is determining who did what to whom. For example, given an active sentence like (1), a learner of English might decide that first noun phrases (NP1s) are always mapped onto agents (seal = *the eater*) and second noun phrases (NP2s) are always mapped onto themes (fish = *the eaten*). However, this strategy would lead to misinterpretations when the learner encounters a passive construction like (2).

(1) The seal is quickly eating the fish.
(2) The seal is quickly eaten by the shark.

This alternation between actives and passives has long served as an important test case for exploring the development of the syntax-semantics interface. Prior research has found that while young English-speaking children readily produce and comprehend actives, they have profound difficulties with passives (Bever, 1970; Borer & Wexler, 1987; Brooks & Tomasello, 1999; Budwig, 2001; Harris & Flora, 1982; Horgan, 1978). This pattern is also observed in languages like French (Sinclair, Sinclair, & De Marcellus, 1971), German (Mills, 1985), and Hebrew (Berman, 1985). Critically, it persists throughout the school-aged years (Gordon & Chafetz, 1990; Maratsos, Fox, Becker, & Chalkley, 1985; Messenger, Branigan, & McLean, 2012b; Messenger, Branigan, McLean, & Sorace, 2012a; Stromswold, Eisenband, Norland, & Ratzan, 2002; Sudhalter & Braine, 1985), raising questions about the nature of syntactic development and the possible role of processing constraints during language acquisition.

In the present paper, we explore these questions by turning to a useful cross-linguistic test case, passive sentences in Mandarin Chinese. In the remainder of the

* Corresponding author. Address: Department of Hearing and Speech Sciences, University of Maryland College Park, College Park, MD 20742, United States.
E-mail address: ythuang1@umd.edu (Y.T. Huang).

0749-596X/$ - see front matter © 2013 Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.jml.2013.08.002

Introduction, we will briefly review prior developmental research on passives in English, introduce four accounts explaining children's patterns of comprehension, and discuss reasons why data from Mandarin might be informative. Finally, we will lay out an experiment that distinguishes between these accounts by examining interpretations of passives using an eye-tracking and act-out paradigm.

Q3

Children's difficulties with passives and possible explanations

Previous studies have noted several idiosyncrasies in children's performance with passive sentences in English (see Messenger et al., 2012a for a more detailed summary of this literature). For example, relative to their active counterparts, full passives (those that include the *by*-phrase) are rare in children's speech and do not reliably appear in naturalistic samples until age four (Budwig, 2001; Harris & Flora, 1982; Horgan, 1978). This asymmetry also extends to children's comprehension. Three- to 5-year-olds are slower and less accurate at selecting depicted events for passives compared to actives (Stromswold et al., 2002). Furthermore, when asked to act-out passive sentences, children will often perform active versions instead (Baldie, 1977; Bever, 1970; Brooks & Tomasello, 1999; Gordon & Chafetz, 1990; Harris & Flora, 1982; Horgan, 1978; Lempert, 1990; Maratsos et al., 1985; Messenger et al., 2012b; Pinker, Lebeaux, & Frost, 1987; Sudhalter & Braine, 1985; Turner & Rommetveit, 1967).

Several hypotheses have been suggested for why these errors occur. These theories often draw on common mechanisms and are not mutually exclusive. In fact, the each of the last two theories can be seen as building upon the one before. However, in order to make clearer connections between theories and predictions, we will focus on the core properties of four prominent accounts.

Syntactic account

Transformational theories of syntax have argued that passives are derived from initial representations of their active counterparts, followed by a movement operation that raises sentence objects into subject position (Borer & Wexler, 1987, 1992; Chomsky, 1981; Wexler 2005). Borer and Wexler (1987, 1992) have suggested that knowledge of this movement operation is absent in children's early grammar and does not mature until the early school-aged years (*A-Chain Deficit Hypothesis*). This theory provides a straightforward account for why young children fail to produce passives in their spontaneous speech. It also explains why passives are often misconstrued as actives during early comprehension.

Frequency account

Many have argued that early difficulties with passives reflect a lack of experience with the construction (Brooks & Tomasello, 1999; Demuth, 1989; Gordon & Chafetz, 1990; Harris & Flora, 1982). Passives are far less frequent than actives in children's input: In a survey of the CHILDES corpora, Stromswold, Eisenband, Norland, and Ratzan (2002) found that full passives accounted for less than 0.2% of adult utterances to children (see also calculations by Maratsos et al., 1985 and Gordon & Chafetz, 1990). Even within the passive construction, comprehension has been found to be better for more frequent forms. Children are more likely to understand *get*-passives compared to *be*-passives (Harris & Flora, 1982) and are more successful with sentences featuring known verbs compared to novel ones (Brooks & Tomasello, 1999; Tomasello, Brooks, & Stern, 1998). Finally, cross-linguistic evidence has revealed greater proficiency in languages where passives are more frequent, e.g., Inuktitut (Allen & Crago, 1996), K'iche' Mayan (Pye & Poz, 1988), and Sesotho (Demuth, 1989, 1990). For example, Demuth (1989) found that 2- and 3-year-old speakers of Sesotho, a Bantu language with productive passivization, produced three times as many passive sentences as their English-speaking counterparts.

Cue-based account

Cue-based accounts, like the Bates and MacWhinney's Competition Model (1987, 1989) propose that children determine the meaning of sentence by using linguistic and non-linguistic cues whose strength depend upon the degree to which they are associated with a particular interpretation. The relative weight of each cue depends on its reliability (the proportion of times it predicts the relevant role assignment) and its frequency, with the combination of the two determining its validity. In the case of role assignments, NP1s in English are typically agents since active sentences occur far more frequently than passive sentences (Gordon & Chafetz, 1990; Maratsos et al., 1985; Stromswold et al., 2002). In contrast, passives in English are associated with less reliable cues, including verb morphology (*-en* in *eaten*) and the *by*-phrase ("*by the shark*") (Li, Bates, & MacWhinney, 1993; Maratsos & Abramovitch, 1975; Stromswold et al., 2002). The *-ed*/*-en* suffix is typically associated with the past tense ("*The girl kicked the ball*") or adjectival states ("*The girl was tired*"). Similarly, the *by*-phrase is often used to mark locations ("*I passed by the mall*") and maker/author relationships ("*I read a book by Tolstoy*"). Also in passive constructions, it is often dropped altogether. Since the package of morphological cues that mark the English passive are only informative as a set, the acquisition of these distributed cues might be particularly difficult for children (Slobin, 1973).

Consequently, the greater reliability of word order compared to morphological cues may lead English-speaking children to favor the former over the latter during sentence interpretation. This bias would lead to successful comprehension of actives but, it would cause systematic misinterpretations for passives. Prior work has found that children sometimes ignore the verb morphology and *by*-phrase and generate active interpretations for passive sentences (Bever, 1970; Turner & Rommetveit, 1967). Similarly, cross-linguistic research has found that 2-year-olds identified the likely agent based on the cue that was most informative in their language. While learners of English relied on word order (NP1 = agent), learners of Italian relied on animacy cues (animate NP = agent) (Bates et al., 1984). This and other work has highlighted strong effects of cue reliability during

Please cite this article in press as: Huang, Y. T., et al. Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language* (2013), http://dx.doi.org/10.1016/j.jml.2013.08.002

language acquisition (MacWhinney, Bates, & Kliegl, 1984; MacWhinney, Pléh, & Bates, 1985).

Incremental processing hypothesis

Over the past ten years, new accounts of children's language processing have emerged (Trueswell & Gleitman, 2004) inspired largely by theories on incremental language processing in adults (MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell & Tanenhaus, 1994). Like the Competition Model, these theories propose that children use multiple probabilistic constraints to resolve linguistic ambiguity. However, unlike the Competition Model, they also place a strong emphasis on how constraints unfold over time as the utterance is spoken. Cues that are available early in an utterance may lead a child to commit to an interpretation that is inconsistent with other cues that emerge later on.

For example, Trueswell, Sekerina, Hill, and Logrip (1999) found that when presented with a garden-path sentence like "*Put the frog on the napkin in the box*," both adults and 5-year-olds initially misconstrued the first prepositional phrase ("*on the napkin*") as the destination of the verb. However, upon hearing the second prepositional phrase ("*in the box*"), adults correctly revised their interpretation to be a modifier of the noun (*put the frog that's on the napkin*). Children, in contrast, never did so. They continued to analyze the first phrase as a destination and produced actions consistent with this misinterpretation (*putting a frog on a napkin and then putting it in a box*). This tendency to hold onto an initial misanalysis has been replicated under a variety of conditions (Choi & Trueswell, 2010; Hurewitz, Brown-Schmidt, Thorpe, Gleitman, & Trueswell, 2000; Weighall, 2008) and cross-sectional data suggest that it gradually diminishes during middle childhood (Weighall, 2008). This period of development is characterized by substantial improvements in cognitive control, raising the possibility this system serves as the basis for revising default interpretations (Novick, Trueswell, & Thompson-Schill, 2005). Additional support comes from recent studies in adults (January, Trueswell, & Thompson-Schill, 2009; Novick, Hussey, Teubner-Rhodes, Harbison, & Bunting, in press) and Broca's aphasics (Novick, Kan, Trueswell, & Thompson-Schill, 2010), which find parallels in individuals' performance with garden-path sentences and cognitive control tasks (e.g., Stroop, n-back).

Critically, children's failure to revise syntactic interpretations in the early school-aged years provides a potential explanation for why they have difficulties with passive sentences. The greater frequency of actives may lead children to initially misconstrue NP1s in passive sentences as agents (Bever, 1970; Turner & Rommetveit, 1967). Once children have entertained this interpretation, they may be unable to reanalyze these arguments as themes, even after they have heard the relevant linguistic cues (e.g., verb morphology, *by*-phrase). On this account children's difficulties with passives reflect a propensity to incrementally assign grammatical roles to arguments, coupled with a subsequent failure to revise their initial interpretations.

Features of Mandarin passive sentences

Each of these four approaches provides a prima facie adequate explanation for why passives are late to develop in English and other similar languages. In order to tease apart these theoretical possibilities, we will be exploring children's comprehension of passives in Mandarin Chinese. Like English, Mandarin has a default subject-verb-object (SVO) word order (Sun & Givon, 1985). Thus, as in English, the first argument of a Mandarin sentence will typically be an agent (Philipp, Bornkessel, Bisang, & Swchlesewsky, 2008; Yang, Gordon, Hendrick, & Hue, 2003). However, unlike English, Mandarin also allows for noun-noun–verb (NNV) constructions that often co-occur with the morphosyntactic markers BA and BEI.[1] These markers appear between the two noun phrases and disambiguate the roles of the adjacent arguments (Li & Thompson, 1976, 1981). In sentences like (3), the object marker BA indicates that NP1 is an agent (*seal*) and NP2 is a theme (*fish*); this construction is often used to describe transitive, resultive events (Li, 1990; Sun, 1991). In sentences like (4), the passive marker BEI indicates that NP1 is a theme (*seal*) and NP2 is an agent (*shark*); this construction often emphasizes the topicality of the theme (Li, 1990; Sun, 1991).

(3)	Seal	BA	fish	quickly	eat
	海豹	把	小鱼	很快就	吃掉了
	The seal is quickly eating the fish				
(4)	Seal	BEI	shark	quickly	eat
	海豹	被	鲨鱼	很快就	吃掉了
	The seal is quickly eaten by the shark				

Two features of Mandarin passives are worth noting. First, as in English, BEI passive sentences in Mandarin occur less frequently than their BA active counterparts (Li et al., 1993; McEnery & Xiao, 2005). In fact, corpus analyses suggest that the passive construction is even less frequent in Mandarin than in English (McEnery & Xiao, 2005). An analysis of written text from the Lancaster Oslo Bergen Corpus (Johansson, Leech, & Goodluck, 1978) and the Lancaster Corpus of Mandarin Chinese (McEnery, Xiao, & Mo, 2003) revealed that passives occurred an estimated 1026 times per 100,000 words in English but only 110 times per 100,000 in Mandarin. While the statistics for spoken languages are likely to be somewhat different (Gordon & Chafetz, 1990; Maratsos et al., 1985; Stromswold et al., 2002), the striking disparity between these languages suggests that BEI may be quite rare in children's input.

Second, while the linguistic cues for English passives are recruited for multiple purposes, BEI is used exclusively to signal a passive construction in Mandarin. We confirmed

[1] We refer to BA and BEI as morphosyntactic markers to distinguish them from the case markers typically found in Indo-European languages. While the two are functionally equivalent, BA and BEI do not bind to the words they modify like traditional case markers do. Instead they historically derive from verbs or prepositions whose function became grammaticalized over time (Wang, 1970: Li & Thompson, 1981). For this reason, they are sometimes referred to as coverbs or prepositional particles (Philipp et al., 2008; Yang et al., 2003).

Please cite this article in press as: Huang, Y. T., et al. Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language* (2013), http://dx.doi.org/10.1016/j.jml.2013.08.002

Table 1
Frequency of constructions in a search of 20,376 sentences from the Lancaster Corpus of Mandarin Chinese (McEnery, Xiao, & Mo, 2003). *Notes*: AG is the agent, TH is the theme, MK is the marker, BEI is the passive marker, and BA is the object marker.

Total		Constructions					
		All arguments			Dropped argument		
		AG TH Verb	TH AG Verb	SVO	MK TH Verb	TH Mk Verb	Other
% of all BA	2118 (62%)	836 (40%)	0 (0%)	0 (0%)	1147 (54%)	0 (0%)	135 (6%)
% of all BEI	1278 (38%)	0 (0%)	505 (39%)	0 (0%)	0 (0%)	747 (58%)	26 (3%)

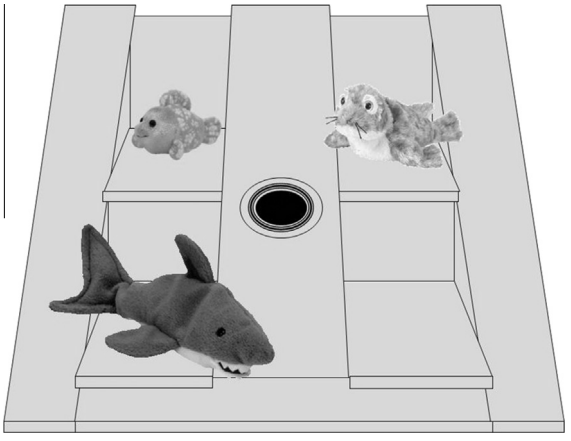

Fig. 1. An example of a visual-world display featuring a likely agent (*shark*), a likely theme (*fish*), and an expressed noun (*seal*).

this pattern by searching 20,376 sentences from the Lancaster Corpus of Mandarin Chinese (McEnery et al., 2003) and analyzing the 3396 sentences featuring either BA or BEI. Table 1 confirmed that BA was more frequent than BEI, accounting for a larger proportion of utterances containing either marker (62% vs. 38%). Critically, the interpretations associated with the two markers were categorically distinct. When both arguments were included in NNV constructions, NP1s were always associated with agents in the presence of BA and themes in the presence of BEI. Neither marker occurred in the canonical SVO construction. Also since Mandarin is a pro-drop language, the argument corresponding to the agent was often omitted (54% of the time for BA, 58% of the time for BEI). Critically, even in these situations, the two markers continued to be linked to distinct constructions. For active sentences, the presence of BA indicated that the argument *following* the marker was a theme (e.g., "BA seal eat" → (it) eats the seal). For passive sentences, the presence of BEI indicated that the argument *preceding* the marker was a theme (e.g., "seal BEI eat" → the seal is eaten (by it)).

Current study

The following experiments examine the interpretation of sentences with BA and BEI in Mandarin-speaking adults and 5-year-olds. This age group is of particular interest since it lies at the intersection of two relevant literatures: Children of this age continue to struggle with passives (Gordon & Chafetz, 1990; Maratsos et al., 1985; Messenger et al., 2012b; Stromswold et al., 2002; Sudhalter & Braine, 1985) and also fail to revise initial misinterpretations (Choi & Trueswell, 2010; Hurewitz et al., 2000; Trueswell et al., 1999; Weighall, 2008). Thus if developmental difficulties with passives are tied to challenges with syntactic revision, then manipulations that affect incremental syntactic parsing should have consequences on passive comprehension in this age group. In the current study, both adults and children were presented with displays like those in Fig. 1, featuring three thematically-related objects, e.g., an expressed item (SEAL), a likely agent (SHARK), a likely theme (FISH).

Participants' eye-movements to these objects were recorded as they heard spoken sentences featuring one of the two morphosyntactic markers, BA or BEI (see Kamide, Altmann, and Haywood (2003) and Kamide, Scheepers, and Altmann (2003) for related work on case marker interpretations in German- and Japanese-speaking adults). In the Expressed NP1 trials, participants heard sentences like (5).

(5) Expressed NP1: Seal BA (BEI) it quickly eat
海豹把(被) 它很快就吃掉了
The seal is quickly eating it (eaten by it)

Following the onset of the pronoun (*it*), looks to the likely agent or likely theme provide an implicit measure of the participants' interpretation of the utterance.[2] When the expressed noun (*seal*) is followed by BA, this initial argument must then be the agent of the sentence, making the pronoun a likely theme. In contrast, when the expressed noun is followed by BEI, this initial argument is revealed to be the theme, making the pronoun a likely agent. In the Pronoun NP1 trials, the positions of the expressed noun and pronoun were switched as in (6).

(6) Pronoun NP1: It BA (BEI) seal quickly eat
它把(被) 海豹很快就吃掉了
It is quickly eating the seal (eaten by the seal)

Here the identity of the pronoun is the opposite of sentence (5). When the expressed noun is preceded by BA, this second argument is now revealed to be the theme of the sentence, making the pronoun a likely agent. Conversely,

[2] Unlike in English, the same pronoun in Mandarin (它) is used to refer to antecedents that are male, female, and inanimate. For simplicity, we translate this pronoun as *it* throughout the paper.

Please cite this article in press as: Huang, Y. T., et al. Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language* (2013), http://dx.doi.org/10.1016/j.jml.2013.08.002

when the expressed noun is preceded by BEI, this second argument is revealed to be the agent, making the pronoun a likely theme.

All four accounts of children's passive comprehension make clear prediction for this study. Both syntactic and frequency theories predict that children's comprehension of passives in Mandarin should largely mirror their performance in English. Since passives in both languages involve a grammatical movement of the object to subject position (Li & Thompson, 1981), a syntactic account predicts that Mandarin-speaking children should also have difficulties with this construction. Similarly, since passives are less frequent than actives in Mandarin, a frequency-based account predicts that children should have more difficulties with the former compared to the latter. Thus according to these theories, children in the current study should consistently succeed with BA but falter with BEI in both the Expressed NP1 and Pronoun NP1 conditions.

In contrast, cue-based accounts like the Bates and MacWhinney's Competition Model (1987, 1989) argue that role assignments occur as a function of the set of cues favoring each role. However, to determine the precise predictions of a theory like this, we would need to consider the effects of all possible cues (e.g., the order of the nouns relative to the verb, animacy, prosody and information structure). In many cases, it is unclear how a given cue should be defined or counted. Is it the relative order of the nouns that matters or their position with respect to the verb? Is it the raw frequency of the morphosyntactic marker that matters or only its frequency is the construction of interest? Thus, there are many alternate possible instantiation of cue validity models which would make different predictions.

One way around such disputes is to test adults on all possible combinations of the relevant cues and then use their interpretive preferences as a way of determine relative cue strength. Research in the Competition Model framework has typically argued that relative cue strength in adults is a good predictor of the order in which cues are acquired by children. Li and colleagues study (1993) provides cue strength estimates for the relevant constructions in Mandarin. They find that given a NNV construction without markers, participants showed a bias to interpret NP2 as "the doer of an action" roughly 60% of the time. Critically, in the presence of BEI, this preference increased to around 80% of the time. The presence of BA also affected interpretation but it appeared to be a weaker cue than either word order or BEI. Li attributes this to the fact that BA has other homophonous meanings and encodes the combination of definiteness and affectedness. Given these data, cue-based accounts should predict that children in the present study will perform either equally well on BA and BEI (because BA is more frequent but less reliable than BEI) or better on sentences with BEI (because adult performance suggests that it is stronger cue). Critically, cue-based accounts make no reference to how these markers unfold over the time-course of a spoken utterance or how they interact with other aspects of linguistic processing (such as reference assignment). Consequently, they predict no differences between the Expressed NP1 and Pronoun NP1 sentences.

Finally, the Incremental Processing Hypothesis proposes that children's comprehension is heavily influenced by both the need to incrementally interpret utterances as they unfold and the difficulty of revising initial interpretive commitments. Mandarin has a default SVO word order, which is both more common and preferred in discourse contexts like those in the present study (Philipp et al., 2008; Sun & Givon, 1985; Yang et al., 2003). Consequently, their ability to use BEI to correctly interpret NP1 as a theme may depend on whether they need to revise this agent-first bias. This would predict differences across the two constructions. In the Expressed NP1 trials, children may be inclined to interpret the first argument (*seal*) as the agent but have difficulty revising this analysis after the onset of BEI. However, in the Pronoun NP1 trials, the first argument (*it*) is a pronoun. Previous research suggests that pronouns can facilitate the interpretation of complex constructions, since their referents are already assumed to exist in the discourse (Chafe, 1987; Gibson, 1998; Gordon, Hendrick, & Johnson, 2001; Warren & Gibson, 2002). In the current study, the pronoun's NP1 position also introduces a referential ambiguity where the identity of the argument cannot initially be assigned to any referent in the display. Critically, this may prevent children from linking the agent role to a particular object, and thus lead them to postpone role assignment until after the onset of BEI and the expressed noun. This delay may allow children to infer that NP1 is a theme without having to revise an agent-first bias and lead to the correct interpretation of BEI in the Pronoun NP1 trials but not in the Expressed NP1 trials.

In Experiment 1, we used this procedure to first examine comprehension in Mandarin-speaking adults. The goals of this experiment were twofold. First, prior work has demonstrated that adults efficiently use the presence of case makers in German and Japanese to generate on-line predictions of up-coming grammatical roles (Kamide, Altmann, et al., 2003; Kamide, Scheepers, et al., 2003). We wanted to extend these patterns to a language like Mandarin. Our study differs from prior adult work in this area (cf. Li et al., 1993) since it adopts a task that requires no meta-linguistic judgment and measures real-time interpretation as it unfolds. Second, we also wanted to link these real-time interpretations to subsequent performance in an off-line act-out task. Since prior research has relied on act-out measures as a window into children's interpretations, it was important to establish a pattern of adult-like performance with the current materials.

Experiment 1

Methods

Participants

Thirty-four undergraduates at Peking University participated in this study for course credit. Seventeen participants were in the Expressed NP1 condition and 17 participants were in the Pronoun NP1 condition. All were native monolingual Mandarin speakers.

Procedure

Participants sat in front of an inclined podium divided into four quadrants, each containing a shelf where an object

Please cite this article in press as: Huang, Y. T., et al. Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language* (2013), http://dx.doi.org/10.1016/j.jml.2013.08.002

could be placed. A camera at the center of the display was focused on participants' face and recorded the direction of their gaze while they were performing the task. A second camera recorded both their actions and the location of the items in the display. At the beginning of the study, the experimenter took out three objects and told participants that they could use these objects to act out the sentences they heard during the study.

Each set of three objects was used for two consecutive trials. This allowed for more sentences to be used during the experiment by reducing the delays associated with introducing and removing objects from the display. The experimenter presented each set by individually labeling the objects as they were placed on the shelf in a pre-specified order. This was followed by the first pre-recorded sentence describing an event. The participants were then encouraged to pick up the objects and use them to act-out what was said. Once the participant did this, the trial ended and the objects were returned to their pre-specified locations on the shelf. This was followed by a second pre-recorded sentence describing another event involving the same objects. Once the participants performed this action, the objects were removed from the display, and the next trial began with a new set of objects.

Materials

The four critical trial types represented the cells of a 2 × 2 design in which the first factor, Morphosyntactic Marker, contrasts the use of the object marker (BA) with the passive marker (BEI). This was varied within subjects. The second factor, NP1 Status, contrasts the use of an expressed noun (e.g., *seal*) with a pronoun (*it*) in the subject position. Pilot testing indicated that children experienced interference when sentences alternated between Expressed NP1 and Pronoun NP1 constructions. To lessen this confusion, we varied this factor between subjects in both children and adults.

Fig. 1 illustrates that the visual displays for critical trials featured 3-object sets pairing the expressed item (e.g., SEAL) with a likely agent (e.g., SHARK) and a likely theme (e.g., FISH). Across trials, each object type appeared randomly in each location 33% of the time to ensure that the role of the object could not be predicted based on the display arrangement. The size of the items was controlled to ensure the plausibility of the relationship: Likely agents were always larger than expressed items, which in turn were larger than likely themes. Two sets of independent norming data were obtained to validate these stimuli. First, to verify that likely agents and likely themes had the predicted relationship to expressed items, 48 adults were presented with one pair from each object set (e.g., *seal/shark* or *seal/fish*) and were asked to rate "how likely will X do something to Y" on a scale of 1 (not at all likely) to 7 (very likely). Across all sets, ratings indicated that expressed items were more likely to act on likely themes ($M = 5.8$, $SD = 1.1$) than likely agents ($M = 3.9$, $SD = 1.6$) ($t1 = 5.55$, $p < .001$; $t2 = 3.21$, $p < .01$). Expressed items were also more likely to be acted upon by likely agents ($M = 5.1$, $SD = 1.1$) than likely themes ($M = 2.8$, $SD = 1.5$) ($t1 = 8.49$, $p < .001$; $t2 = 4.31$, $p < .01$). Second, to ensure that eye-movements and actions involving likely agents and likely themes were not caused by a non-linguistic preference for objects associated with expressed items, 60 adults were presented with each pair of items and were asked to rate "how related are the meanings of X and Y" on a scale of 1 (not at all related) to 7 (very related). Across all sets, ratings indicated that expressed items were equally associated with likely agents ($M = 4.4$, $SD = 1.4$) and likely themes ($M = 4.4$, $SD = 1.8$) (all p's > .90).

For each object set, we constructed a quartet of target sentences like (5) and (6). These sentences always mentioned an expressed noun and a pronoun but the two conditions differed in the order in which these occurred. They also featured a morphosyntactic marker between NP1 and NP2 but differed in whether it was the object or passive marker. An adverb (e.g., *quickly*) was always embedded between NP2 and the verb, creating a period in which the relationship between the subject and object could not be informed by the verb meaning. During recording, a target sentences were spoken by a female actor in slow, clear, and consistent manner. Final sound files were selected to roughly equate the lengths of two regions: (1) from sentence onset to the adverb ("*Seal BA (BEI) it*" vs. "*It BA (BEI) seal*") and (2) from the onset of the adverb to the offset of the verb ("*quickly eat*"). No subsequent adjustments were made to the audio.

Four versions of each base item were used to create four presentation lists, such that each list contained six items in each condition and each base item appeared just once in every list. A complete list of the materials for the 12 critical items is provided in Appendix A. The critical trials were mixed with 36 filler trials. These trials were design to divert attention away from the manipulated variables without systematically biasing participants to treat NP1 as the agent or theme. To do so, we created sentences that recruited symmetric predicates (e.g., *dance*, *fight*), experience and stimulus verbs (e.g., *like*, *scare*), and agent/theme intransitives (e.g., *sing*, *break*). These sentences always referred to either one or two of the objects in the display. Since each object set was used for two consecutive trials (see Procedure), 12 of these sentences involved the same object as those used in the critical sentences, but were presented as the second trial in that set. The remaining 24 trials were paired together and used 12 additional object sets that were designed to be qualitatively equivalent to those in the critical sets.

Coding

Eye movements were coded by trained research assistants using frame-by-frame viewing of the participants' face on a Sony digital VCR. Research assistants were always blind to the location of each object and condition of each trial. Each recorded trial began at the onset of the instruction and ended with the onset of the corresponding action. Each change in gaze direction was coded as a look towards one of the quadrants, at the center, or missing due to looks away from the display or blinking. These missing frames accounted for 3.7% of coded frames. The remaining looks were then recoded based on their relation to the final instruction: (1) Expressed items; (2) Likely agents; (3) Likely themes. Twenty-five percent of the trials were checked by a second coder who confirmed the direction of fixation for 94.5% of

Please cite this article in press as: Huang, Y. T., et al. Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language* (2013), http://dx.doi.org/10.1016/j.jml.2013.08.002

Table 2
Duration of the four time windows in eye-movement analyses. *Notes*: BEI is the passive marker and BA is the object marker.

	Length of regions in the instructions (in ms)			
	NP1 region	NP2 region	Adverb region	Verb region
Expressed NP1	Seal (700) 海 豹	BEI/BA it (667) 把/被 它	Quickly (767) 很 快 就	Eat (833) 吃 掉 了
Pronoun NP1	It BEI/BA (567) 它 把/被	Seal (800) 海 豹	Quickly (767) 很 快 就	Eat (833) 吃 掉 了

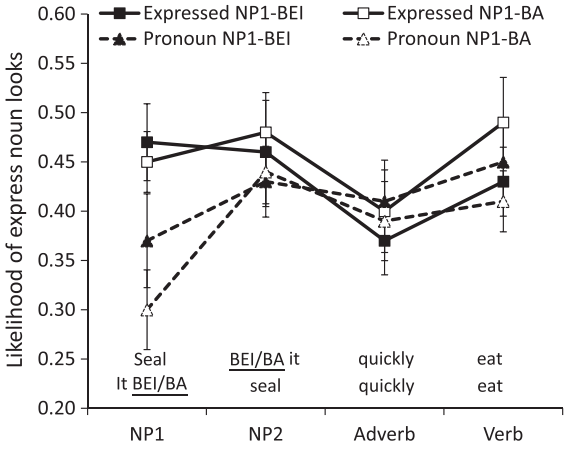

Fig. 2. The time-course of adults' likelihood of looking at the expressed noun in the Expressed NP1 condition and Pronoun NP1 condition. *Notes*: BEI is the passive marker and BA is the object marker. Bars indicate standard error of the mean.

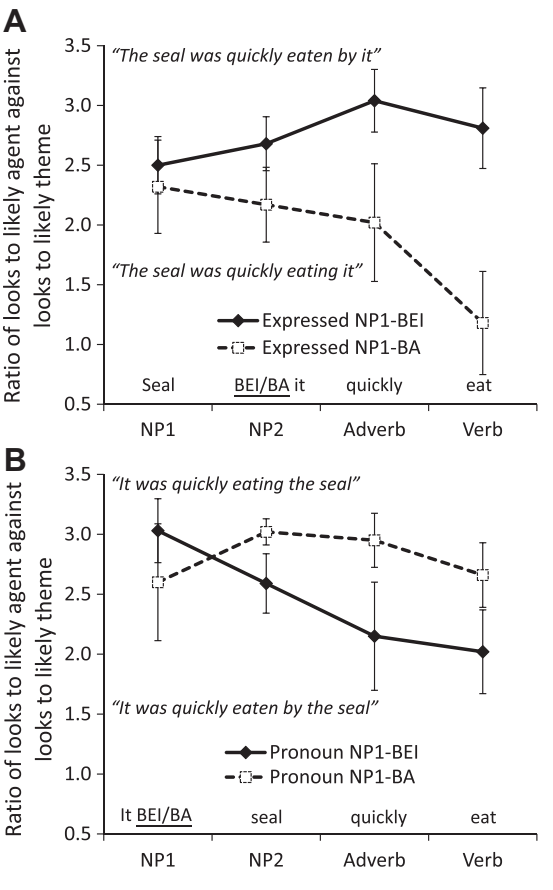

Fig. 3. The time-course of adults' preferences for the likely agent (e.g. SHARK) against the likely theme (e.g. FISH) in the (A) Expressed NP1 condition and (B) Pronoun NP1 condition. *Notes*: BEI is the passive marker and BA is the object marker. Bars indicate standard error of the mean.

coded frames. Any disagreements between the two coders were resolved by a third coder. Research assistants also coded videotapes of the participants' actions and categorized them based upon responses involving: (1) Expressed items and likely agents; (2) Expressed items and likely themes; (3) Expressed items only. Approximately 0.6% of trials were excluded from eye movement and action analyses because of experimenter error.

Results

Eye-movement data

We conducted an analysis of fixations corresponding to regions of the target utterance. Table 2 lists the duration of the four time windows that were analyzed. Given the short length of the pronouns and markers, these words were grouped into a single region to ensure sufficient opprotunity to generate eye-movements in response to the linguistic stimuli. Each period was shifted 200 ms after the relevant input in the speech stream to account for the time it takes to program a saccadic eye-movement (Matin, Shao, & Boff, 1993).

For all analyses, the data were analyzed using the lme4 software package in R (Bates, 2007). Subjects and items were modeled as simultaneous random effects on the intercept only.[3] In each case, the final model was selected by first including all main effects and interactions and then removing predictors until the fit of the smaller model was not significantly worse than the fit of the full model ($p > .05$). First, we examined looks to the expressed item during each time window using a logistic mixed-effects model (see Jaeger, 2008 for similar approaches). Fig. 2 illustrates that looks to the expressed item were greater in the Expressed NP1 condition compared to the Pronoun NP1 condition following the onset of NP1. This led to a significant main effect of NP1 sta-

[3] For all analyses, we also constructed models with random slopes. However in no case did this result in a significant improvement in model fit and were thus excluded from further analyses (see Brown-Schmidt, 2012 for similar approaches).

tus (z = 3.26, p < .01) with no additional effect of Marker or interaction between the two (all p's > .20). This demonstrates that adults were initially more likely to look at the expressed item when it was mentioned in the instructions. Subsequent expressed item looks were no different across conditions in later time windows (all p's > .50).

Second, we examined adults' preference to look at the likely agent over the likely theme during each time window. This was calculated by averaging the ratios within each time window, separately for subjects and items, and then computing the natural log of this term. Thus, unlike proportion, these values were not bounded at 0 and 1 (see Brown-Schmidt, 2012; Ferguson, Scheepers, & Sanford, 2010; Heller, Grodner, & Tanenhaus, 2008 for similar approaches). Critically, positive values indicated a preference for the likely agent while negative values indicated a preference for the likely theme. All eye-movement data were analyzed in a series of linear mixed-effects models. Significance tests for these fixed effects were estimated using a Monte Carlo Markov Chain procedure (MCMC).

Fig. 3 illustrates participant looks to the likely agent (e.g. SHARK), plotted as a ratio with looks to likely theme (e.g. FISH) across regions within the instruction. Following the onset of NP1, preference for the likely agent did not differ across conditions, leading to no reliable effects of Marker, NP1 Status, or interaction between the two (all p's > .20). However, following the onset of NP2, there was evidence of the predicted interaction between Marker and NP1 Status ($t1$ = 1.99, p < .05; $t2$ = 1.61, p < .10) with no additional main effects (all p's > .10). However, planned comparisons within the levels of NP1 Status revealed that likely agent preference in the Expressed NP1 condition did not differ following BA and BEI ($t1$ = 1.31, p > .15; $t2$ = 0.27, p > .70). In contrast, likely agent preference in the Pronoun NP1 condition was greater following BA compared to BEI ($t1$ = 2.06, p < .05; $t2$ = 2.18, p < .05).

Critically during the adverb region, these predicted differences in likely agent preference became robust across conditions. While there were again no effects of Marker or NP1 Status (p's > .70), there was a significant interaction between the two variables ($t1$ = 2.51, p < .05; $t2$ = 2.38, p < .05). Planned comparisons revealed that likely agent preference in the Expressed NP1 condition was now significantly greater following BEI compared to BA ($t1$ = 1.97, p < .05; $t2$ = 1.94, p < .05). In the Pronoun NP1 condition, this pattern appropriately reversed, with likely agent preference again significantly greater following BA compared to BEI ($t1$ = 1.96, p < .05; $t2$ = 1.92, p < .05). This demonstrates that as expected, adults were more likely to interpret NP1 as a theme if they had heard BEI rather than BA. Thus, in the Expressed NP1 condition, they were more likely to assign the agent role to the NP2 pronoun (resulting in more looks to the likely agent). Conversely, in the Pronoun NP1 condition, they were more likely to assign the theme role to the NP1 pronoun (resulting in more looks to the likely theme). The emergence of these differences prior to the onset of the verb suggests that adults efficiently use the presence of morphosyntactic markers to make rapid on-line predictions of grammatical roles.

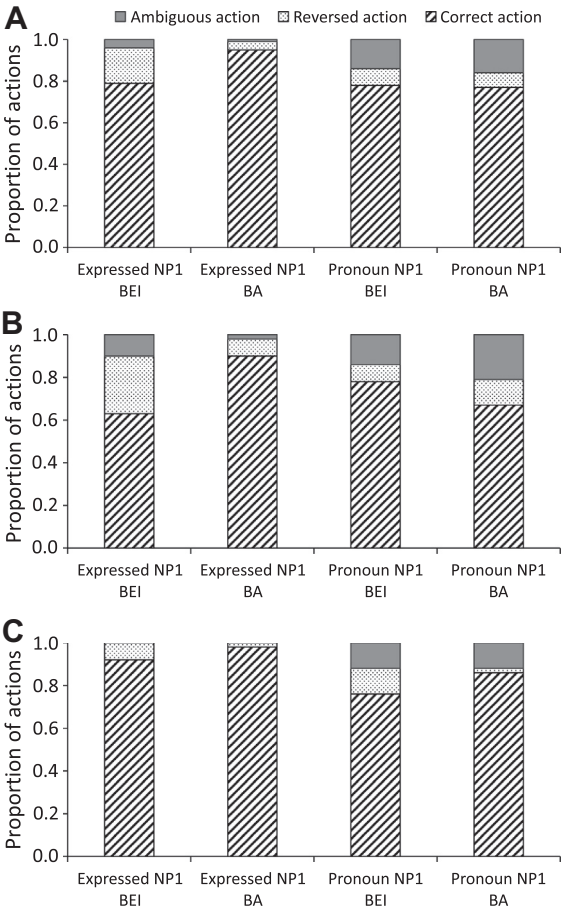

Fig. 4. Adults' actions in (A) total trials, (B) first-half trials, and (C) second-half trials. *Notes*: BEI is the passive marker and BA is the object marker.

The same overall patterns continued into the final verb region. There were again no effects of Marker or NP1 Status (p's > .40), but there was a significant interaction between the two ($t1$ = 3.41, p<.01; $t2$ = 2.99, p < .01). Planned comparisons again revealed that likely agent preference in the Expressed NP1 condition was significantly greater following BEI compared to BA ($t1$ = 3.05, p < .01; $t2$ = 3.67, p < .01). In the Pronoun NP1 condition, this pattern reversed, with likely agent preference greater following BA compared to BEI ($t1$ = 1.95, p < .05; $t2$ = 1.91, p < .05).

Action data

Fig. 4 illustrates that adult actions fell into three categories. "Correct actions" were defined as those which depicted correct thematic role assignments between expressed items and inferred referents. For the Expressed NP1-BEI and Pronoun NP1-BA conditions, this referred to actions involving likely agents doing something to expressed items. For the Expressed NP1-BA and Pronoun NP1-BEI conditions, this referred to actions involving expressed items doing something to likely themes. "Reversed actions" were defined as those which indicated incorrect thematic role assignments. For the Expressed NP1-BEI and pronoun-BA conditions, this referred to actions involving expressed items doing something to likely themes. For the Expressed

Please cite this article in press as: Huang, Y. T., et al. Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language* (2013), http://dx.doi.org/10.1016/j.jml.2013.08.002

NP1-BA and Pronoun NP1-BEI conditions, this referred to actions involving likely agents doing something to expressed items. "Ambiguous actions" were defined as incorrect actions which involved expressed items but no other object. The likelihood of correct actions was compared to chance, which was set conservatively at 50% since adults almost always used two objects in their enactments. This analysis confirmed that adults generated accurate actions across all conditions. Correct performance in the Expressed NP1 condition was above chance following BA ($t1 = 22.15$, $p < .001$; $t2 = 4.55$, $p < .001$) and BEI ($t1 = 5.14$, $p < .001$; $t2 = 5.36$, $p < .001$). Similarly, performance in the Pronoun NP1 condition was above chance following BA ($t1 = 3.27$, $p < .01$; $t2 = 20.21$, $p < .001$) and BEI ($t1 = 3.40$, $p < .01$; $t2 = 3.87$, $p < .01$).

Our primary analysis compared the likelihood of correct actions across conditions. Using a logistic mixed-effects model, subjects and items were modeled simultaneously as random effects variables (intercept only). This analysis revealed a significant main effect of Marker ($z = 2.60$, $p < .01$) and an interaction between marker and NP1 Status ($z = 2.90$, $p < .01$), but no additional main effect of NP1 Status ($z = 0.98$, $p > .30$). Planned comparisons within the levels of NP1 Status confirmed that actions in the Expressed NP1 condition were more accurate with BA compared to BEI ($z = 3.36$, $p < .001$). Critically, in the Pronoun NP1 condition, there were no differences across the two markers ($z = 0.29$, $p > .70$).

Finally, follow-up analyses revealed different patterns of performance across first- and second-half of the trials. In the first-half trials, actions in the Expressed NP1 condition were more accurate with BA compared to BEI ($z = 3.24$, $p < .01$), but this pattern reversed in the Pronoun NP1 condition ($z = 2.02$, $p < .05$). This again led to a significant interaction between NP1 Status and Marker ($z = 2.90$, $p < .01$) but no additional main effects (p's $> .15$). In contrast, in the second-half trials, actions were generally more accurate with BA compared to BEI, but this difference did not vary with NP1 status. This led to a significant main effect of Marker ($z = 2.37$, $p < .05$) but no additional main effect or interaction with NP1 status (p's $> .15$). A closer inspection of these patterns revealed that while performance generally improved from first- to second-half trials, they remained curiously unchanged in the Pronoun NP1-BEI condition (78% vs. 76%). One possibility is that during the first-half trials, the presence of referential ambiguity in the Pronoun NP1 conditions eliminated the agent-first bias, facilitating interpretation of BEI. However, during the second-half trials, adult may have actively sought to resolve the referential ambiguity early in the utterance, leading to the emergence of an agent-first bias. Critically, this bias may have improved performance when NP1 was in fact an agent in the Pronoun NP1-BA condition but hindered performance when NP1 was a theme in the Pronoun NP1-BEI condition.

Discussion

In Experiment 1, Mandarin-speaking adults rapidly used the presence of morphosyntactic markers to assign grammatical roles and generate real-time predictions about the identity of the ambiguous pronoun. These findings extend patterns found in prior research in German and Japanese (Kamide, Altmann, et al., 2003; Kamide, Scheepers, et al., 2003). Curiously, while Mandarin-speaking adults' actions overwhelmingly favor the correct thematic role assignments, they were also affected by the relative difficulty with BA and BEI in precisely the manner predicted by the Incremental Processing Hypothesis. In particular, adults were more likely to interpret BEI incorrectly when they had already committed to the role assignment of the expressed noun.

In Experiment 2, we examined how Mandarin-speaking children would perform in this task. Recall that both the syntactic and the frequency accounts predict that children would experience consistent difficulties with BEI across both Expressed NP1 and Pronoun NP1 conditions. In contrast, a cue-based account predicts that the validity of BA and BEI should lead to correct role assignments across both conditions. Only the Incremental Processing Hypothesis predicts that children's comprehension of BEI should vary as a function of the first argument. When BEI is preceded by an expressed noun, interpretations should falter. However, when it is preceded by a pronoun, they should succeed.

Experiment 2

Methods

Participants

Fifty-seven children (ranging from 5;3 to 5;10, mean age 5;6) participated in this study. Data from five children were not included for further analysis due to a failure to complete the study or experimenter error. Of the remaining 52 participants, 26 were in the Expressed NP1 condition and 26 were in the Pronoun NP1 condition. All were recruited from schools in the greater Beijing metro area and were native monolingual Mandarin speakers.

Procedure and materials

The procedure and materials were identical to Experiment 1.

Coding

The data were coded in the manner described in Experiment 1. Approximately 0.9% of trials were excluded from further analysis due to experimenter error. Missing frames due to blinks or looks away accounted for 6.4% of all coded frames and were also excluded from analysis. First and second coding (conducted on 25% of the trials) had 92.8% intercoder reliability.

Results

Eye-movement data

Children's eye-movements were analyzed using the same dependent measures and analytic strategy that were used in the adult analyses. However, before selecting the time regions for analysis, we examined whether children were as fast to look to referents as adults, by looking at

Please cite this article in press as: Huang, Y. T., et al. Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language* (2013), http://dx.doi.org/10.1016/j.jml.2013.08.002

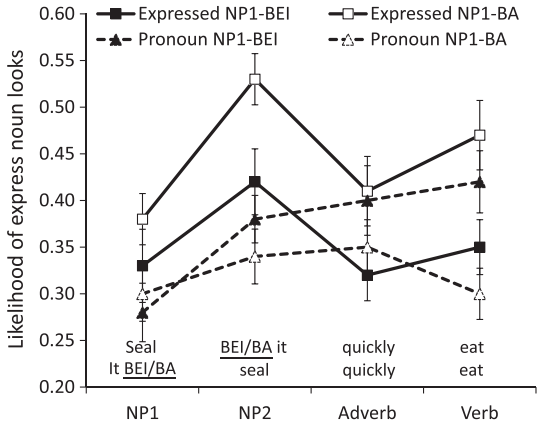

Fig. 5. The time-course of children's likelihood of looking at the expressed noun in the Expressed NP1 condition and Pronoun NP1 condition. *Notes*: BEI is the passive marker and BA is the object marker. Bars indicate standard error of the mean.

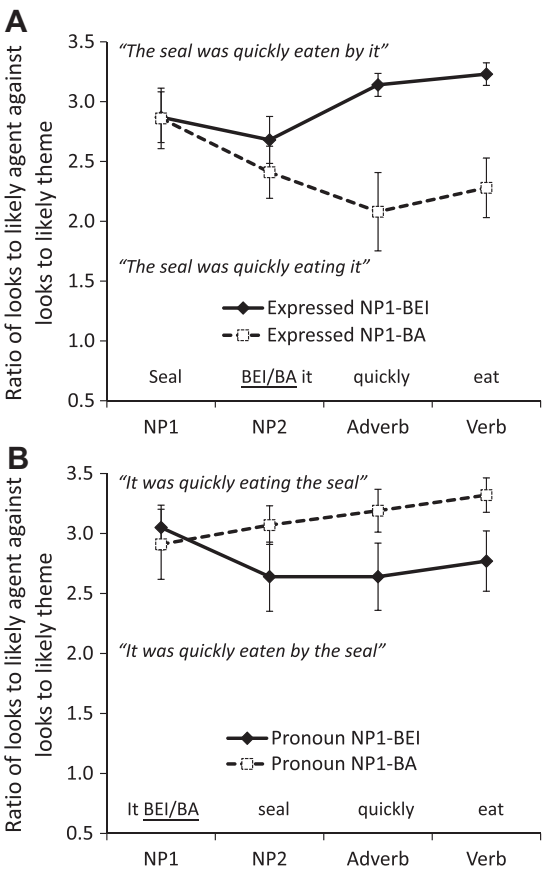

Fig. 6. The time-course of children's preferences for the likely agent (e.g. SHARK) against the likely theme (e.g. FISH) in the (A) Expressed NP1 condition and (B) Pronoun NP1 condition. *Notes*: BEI is the passive marker and BA is the object marker. Bars indicate standard error of the mean.

how quickly the two groups generated eye-movements to the expressed item (e.g., SEAL) followings onset of the expressed noun (e.g., *seal*). We reasoned that any delays in restricting reference for the expressed noun would have cascading effects on their assignments of grammatical roles and postpone children's looks to the likely agent and likely theme. We found that mean latency to shift to the expressed item was 900 ms in adults but 1100 ms in children Thus to account for this difference, each period was shifted an additional 200 ms (400 ms total) after the relevant input in the speech stream. While overall data pattern was the same without this adjustment, the predicted effects were less noisy when this adjustment was made.

We first examined children's looks to the expressed item. Fig. 5 illustrates that expressed item looks did not differ following the onset of NP1 (p's > .20). However following the onset of NP2, these looks were greater in the Expressed NP1 condition compared to the Pronoun NP1 condition. This main effect of NP1 status demonstrates that, like adults, children were initially more likely to look at the expressed item when it was mentioned in the instructions ($z = 4.66$, $p < .001$). However, unlike adults, children also exhibited other differences. Their looks to the expressed item were greater following BA compared to BEI in the Expressed NP1 condition, but this pattern reversed in the Pronoun NP1 condition. This led to interactions between NP1 status and Marker in the NP2 ($z = 8.37$, $p < .001$), adverb ($z = 8.88$, $p < .001$), and verb regions ($z = 16.01$, $p < .001$). These interactions suggest that children's looks may have been influenced by a competition between their preferences for the expressed item versus the inferred object. In conditions where the referent of the pronoun was a likely theme (i.e., an entity that was often smaller, less dangerous, and inanimate), children preferred to look at the expressed item over the inferred object. However, in conditions where the referent of the pronoun was a likely agent (i.e., an entity that was often larger, more dangerous, and animate), children preferred to look at the inferred object over the expressed item instead.

Next we turned to children's preference for the likely agent in their eye-movements. Fig. 6 illustrates looks to the likely agent (e.g. SHARK), plotted as a ratio with looks to likely theme (e.g. FISH) across regions within the instruction. These looks did not differ across conditions during the NP1 and NP2 regions (all p's > .30). However, following the onset of the adverb, the predicted differences emerged. While there were no effects of Marker or NP1 Status (all p's > .20), there was a significant interaction between the two variables ($t1 = 3.51$, $p < .001$; $t2 = 2.13$, $p < .05$). Planned comparisons within the levels of NP1 Status revealed that likely agent preference in the Expressed NP1 condition was significantly greater following BEI compared to BA ($t1 = 3.24$, $p < .01$; $t2 = 2.09$, $p < .05$). In the Pronoun NP1 condition, the means patterned in the opposite direction as expected, but this difference did not reach statistical significance ($t1 = 1.72$, $p < .10$; $t2 = 1.74$, $p < .10$). This pattern persisted after the onset of the verb. While there were again no effects of Marker or NP1 Status (all p's > .20), there was a significant interaction between the two variables ($t1 = 4.17$, $p < .001$; $t2 = 2.58$, $p < .05$). Planned comparisons revealed that the likely agent preference in the Expressed NP1 condition was significantly greater following BEI compared to BA

Please cite this article in press as: Huang, Y. T., et al. Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language* (2013), http://dx.doi.org/10.1016/j.jml.2013.08.002

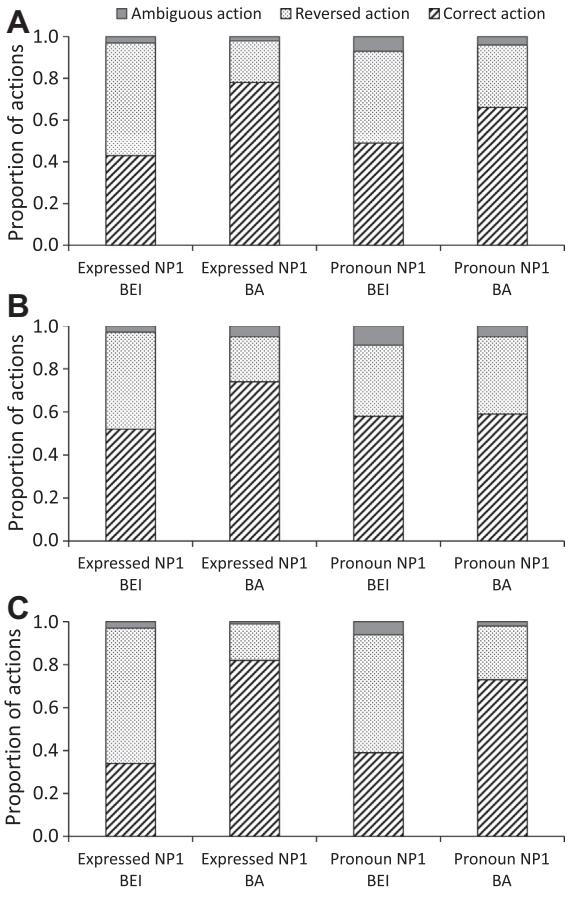

Fig. 7. Children's actions in (A) total trials, (B) first-half trials, and (C) second-half trials. *Notes*: BEI is the passive marker and BA is the object marker.

($t1$ = 4.03, p < .001; $t2$ = 2.40, p < .05). In the Pronoun NP1 condition, this pattern appropriately reversed, with likely agent preference greater following BA compared to BEI ($t1$ = 2.03, p < .05; $t2$ = 1.67, p < .10). Altogether these results indicate that children, like adults, use morphosyntactic markers to make on-line predictions of grammatical role assignments.

Action data

Children's correct actions were examined using the same analyses as those used for adults' (Fig. 7). First, comparisons to chance revealed that like adults, children's performance with BA was significantly above chance in the Expressed NP1 ($t1$ = 6.39, p < .001; $t2$ = 4.90, p < .001) and Pronoun NP1 conditions ($t1$ = 3.79, p < .001; $t2$ = 2.44, p < .05). However, unlike adults, children's performance with BEI was no different from chance in both conditions (p's > .20). Nevertheless, the comparison across the four cells, showed the same pattern of effects that had been present in adults: a main effect of Marker (z = 6.88, p < .001) and an interaction of Marker with NP1 Status (z = 2.50, p < .05), but no additional effect of NP1 Status (z = 1.07, p > .20). As Fig. 7 illustrates, the interaction arose because the relative difficulty of BEI compared to BA was smaller in Pronoun NP1 condition than the Expressed NP condition. Planned comparisons within the levels of NP1 Status revealed that accuracy was greater with BA compared to BEI in the Expressed NP1 (z = 6.46, p < .001) and Pronoun NP1 conditions (z = 3.20, p < .01).

Critically, like adults, follow-up analyses in children revealed different patterns of actions in the first- and second-half trials. First-half trials featured a mix of correct and reversed actions across all conditions. Comparisons across cells confirmed that while children's actions were more accurate with BA compared to BEI in the Expressed NP1 condition (z = 3.13, p < .01), this difference disappeared in the Pronoun NP1 condition (z = 0.15, p > .80). As with adults, this led to a main effect of Marker (z = 2.30, p < .05), an interaction between Marker and NP1 Status (z = 2.08, p < .05), but no additional effect of NP1 Status (z = 0.81, p > .40). In contrast, second-half trials featured a strong preference for correct actions in the BA condition but a preference for reversed actions in the BEI condition (resulting in active interpretations for both types of utterances). Comparisons across conditions confirmed a main effect of Marker (z = 7.25, p < .001), but no additional effect of NP1 status or interaction between the two (p's > .40). Thus for the first half of the trials, the children, like the adults showed the pattern predicted by the incremental processing account: reliably better performance on the BEI trials than the BA trials, but only in the Expressed NP1 condition where the agent role can immediately be assigned to a referent. In contrast, in the second half of the study, the children settled into a pattern of consisting interpreting all of the utterances as if they were active (BA) sentences.

Comparison between adults and children

We directly compared performance across the two age groups through a series of linear (eye-movements) and logistic (actions) mixed-effects models. Within each NP1 Status condition, we listed Morphosyntactic Marker (BA vs. BEI) as a within-subjects variable and Age (adult vs. child) as a between-subjects variable. The analysis of eye-movements again examined likely agent preferences across all trials. However, given the presence of order effects in actions for both age groups, we focused the analysis of correct actions on first-half trials only.

These analyses revealed three patterns of interest. First, children's eye-movements showed an adult-like proficiency in distinguishing between the two constructions. During the adverb region, both groups increased their likely agent preference following BEI compared to BA in the Expressed NP1 condition. The pattern appropriately reversed in the Pronoun NP1 condition. This led to significant main effects of Marker in both the Expressed NP1 ($t1$ = 3.45, p < .001; $t2$ = 2.50, p < .05) and Pronoun NP1 conditions ($t1$ = 2.39, p < .05; $t2$ = 2.48, p < .05), with no additional effects of Age or interactions between Age and Marker (p's > .60). Second, adults' actions were generally more accurate than children's, leading to main effects of Age in both the Expressed NP1 (z = 2.12, p < .05) and Pronoun NP1 conditions (z = 2.08, p < .05). Critically, while both groups were more accurate with BA compared to BEI in the Expressed NP1 condition (z = 4.54, p < .001), this difference disappeared in the Pronoun NP1 condition (z = 0.78, p > .40). The absence of interactions between Age and Marker (p's > .20) suggests that for both adults and children, the passive marker was more difficult

to interpret when it required revision of an agent-first bias but easier when it did not require revision of this role assignment.

General discussion

In two experiments, we explored the nature of developmental difficulties with passive sentences in English by examining on-line and off-line interpretation in Mandarin Chinese. We found that, like adults, children used morphosyntactic markers to make real-time predictions of grammatical roles. Even before encountering the verb, children's eye-movement indicated some sensitivity to the grammatical roles specified by the cues in their language. Critically, children's actions also indicated that interpretations of passives varied with the order of information in the sentence. Children were more successful when the passive marker occurred *before* the first grammatical role could be assigned to a referent, but struggled when the marker occurred *after* an initial role had been assigned to a specific referent. Finally, in the second-half trials, children's tendency to misinterpret the passives as actives across both types of NP1 suggests that their knowledge of BEI may be more fragile and prone to interference than their knowledge of BA.

The performance of the adults showed many of the same features, lending additional support to this account. While adults' actions were above chance in all conditions, they also performed more poorly when the passive marker was preceded by an expressed noun. This demonstrates that passives were demanding even for a population that has had extensive experience with this construction. In contrast, during the first block of trials, both the children and adults in the Pronoun NP1 condition, performed as well or better on BEI than they did on BA, suggesting that they were less likely to prematurely assign the NP1 to the agent role when they could not immediately identify the referent. These results are difficult to explain under a syntactic complexity or frequency-based account, since both theories predict uniform difficulties with passives. Similarly, a cue-based account fails to explain why children continue to struggle when role assignments are predicted by what has been found to be a highly reliable cue (Li et al., 1993; see Mandarin passives and cue-based accounts for more a detailed discussion of this account).

Instead, these findings are most consistent with an Incremental Processing Hypothesis, where children's difficulties with the comprehension of passives stem from a tendency to rapidly assign grammatical roles coupled with a subsequent failure to revise these interpretations. In reaching this conclusion, we are *not* implying that syntactic complexity, frequency, and cue validity do not affect language comprehension and development. The evidence that they do is overwhelming (Bates et al., 1984; Gibson, 1998; Gordon et al., 2001;MacWhinney et al., 1984, 1985; Warren & Gibson, 2002). In fact, models of incremental processing typically incorporate notions such as cue reliability and frequency (MacDonald et al., 1994; Trueswell & Gleitman, 2004; Trueswell & Tanenhaus, 1994). Our data simply demonstrate that language comprehension, in both adult and children, is also influenced by the degree to which these cues are available in real time to make referential commitments.

In the remainder of this discussion, we will focus on three additional issues related to these findings. First, we consider whether children's patterns of interpretation reflected features of our task that may have been pragmatically infelicitous. Second, we will address a possible tension between what was revealed through children's eye-movements versus their actions. Third, we will turn our attention specifically to cue-based accounts and discuss how the current results compare with prior work in this tradition.

Can discourse infelicity explain children's actions?

We have argued that comprehension of passive sentences is difficult when it requires listeners to revise an initial role assignment. However, it is possible that the patterns we observed were instead driven by features of our task that were pragmatically infelicitous. Here we consider two versions of this hypothesis.

One possibility is that sentences in the Expressed NP1 condition violated the communicative tendency to place older, more given information earlier in a sentence and newer information later (Chafe, 1976; Gundel, 1974; Reinhart, 1982; van Kuppevelt, 1996). These trials instead featured an expressed noun (a new entity) occurring before the pronoun (a reduced form referring to a prior antecedent). It may be that adults were able to overcome this pragmatic infelicity, but children – who are less experienced with language use – were not. On this account, children performed better in the Pronoun NP1 condition because these sentences obeyed the tendency for given information to appear first.

We see two reasons to reject this account of our data. First, there was no evidence in our study to suggest that participants experienced more difficulty with Expressed NP1 sentences. In both adults and children, overall accuracy of the actions in the Pronoun NP1 and Expressed NP1 conditions were comparable (there were no main effects of NP1 status). Second, an account appealing to variations in the information structure fails to explain the interaction between NP1 status and morphosyntactic marker. It offers no explanation for why children's (and adult's) difficulties in the Expressed NP1 condition were isolated to the BEI utterances. In contrast, an account appealing to incremental role assignments correctly predicts that performance was best in the Expressed NP1-BA condition (where early commitment facilitates interpretation), worse in the Expressed NP1-BEI condition (where early commitment hinders interpretation) and intermediate in both cells of the Pronoun NP1 condition (where early commitment is blocked by referential uncertainty).

A second possibility is that children's ability to interpret passives depends on the salience of the pronoun in the sentence. Since passives are typically used to highlight the theme relative to the agent (Creider, 1979; Johnson-Laird, 1968; Williams, 1977), it is possible that placing the pronoun in topic (NP1) position facilitated inferences about its identity. In contrast, children may have had difficulties inferring the referent when the pronoun occurs in non-topic

Please cite this article in press as: Huang, Y. T., et al. Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language* (2013), http://dx.doi.org/10.1016/j.jml.2013.08.002

(NP2) position. This explains why children were successful with BEI in the Pronoun NP1 condition but not in the Expressed NP1 condition.

Yet other features of children's performance are unaddressed by this account. First, if children were having difficulty assigning a referent to the pronoun in the Expressed NP1-BEI condition, then we might expect them to make more errors in which they dropped this argument altogether and acted solely on the expressed noun. But these errors were actually more common in the Pronoun NP1-BEI condition. Second, difficulty resolving the pronoun fails to account for the specificity of children's errors in the Expressed NP1-BEI condition. Of all the things they could have done, their mistakes almost always involved the expressed item (e.g., SEAL) as an agent, acting upon a likely theme (e.g., FISH).

The relationship between children's online processing and offline actions

At first glance, the results of children's eye-movement and action analyses may seem to tell different stories. Recall that in the Expressed NP1 condition, children's actions revealed correct interpretations when the expressed noun was followed by BA but incorrect interpretations when it was followed by BEI. These results suggest that they had misanalyzed the expressed noun as an agent rather than a theme. Nevertheless, children's eye-movements had indicated that they correctly distinguished BA and BEI following the onset of the adverb. They generated appropriate looks to the likely theme following BA and sustained their looks to the likely agent following BEI. This raises the question: Why would children initially predict the correct referent of the pronoun, but subsequently misinterpret the role assignment of passive sentences?

One possibility is that children's eye-movements and actions are reflecting different underlying processes. Children may be sensitive to correct role assignments in their on-line processing but are unable to recruit this information to plan their actions. Asymmetries of this kind are well-documented in developmental research. For example, studies of object perception have found that 3-month-olds look longer to a display where a rolling ball appears to pass through a solid wall (Baillargeon, 1993; Spelke, Breinlinger, Macomber, & Jacobson, 1992). This suggests an early sensitivity to violations of physical laws. However, other studies have found less robust knowledge in measures of children's actions. When presented with a rolling ball that is stopped by a wall, 3-year-olds have difficulty selecting the final position of the ball (Berthier, DeBlois, Poirier, Novak, & Clifton, 2000; Butler, Bertheir, & Clifton, 2002). Rather than using the location of the wall as a cue, they guess at random. This suggests that there may be a period when children's implicit knowledge of physics does not inform their subsequent actions. Similar patterns have also been found in other domains such as the development of theory of mind (Onishi & Baillargeon, 2005; Wimmer & Perner, 1983). This leaves open the possibility that there is a similar trajectory in children's interpretation of the passive construction.

Alternatively, it is possible that children's eye-movements and actions are reflecting the same underlying processes. In the Expressed NP1 condition, children may initially interpret NP1 as the agent and commit to an analysis in which the pronoun is a theme in both the BA and BEI trials. However, during the adverb and verb time windows, children may use their knowledge of BEI to partially revise this commitment, resulting in more likely agent looks in the BEI trials compared to BA trials. In fact, the children's actions, particularly in the first half of the study, indicate that they are using their knowledge of the passive marker to override this commitment and successfully interpret the BEI sentences some of the time. After all, if absolutely no revision had occurred, children should have produced the same kinds of actions on the BEI trials as they did on the BA trials, making NP1 the agent 3.5 times as often as NP2. Instead they showed a slightly preference for actions in which NP2 served as the agent.

However, one possible objection to this account is that it fails to explain why we did not find a smaller eye-movement difference between the BA and BEI trials in the Expressed NP1 condition (where revision is necessary but incomplete) than we did in the Pronoun NP1 condition (where revision is unnecessary), see Fig. 6. Recall, however, that our analyses of children's eye-movements focused on *looks to the likely agent*. Since this measure has no logical or normative baseline, any differences across conditions could reflect knowledge of either both markers or one but not the other. In contrast, the analyses of children's actions focused on *correct interpretations*. This measure is normative and identifies errors relative to an expected pattern. Thus it provides additional information about children's performance across conditions. In particular, it suggests that patterns in the Expressed NP1 condition reflect an ability to correctly interpret BA but an inability to consistently interpret BEI. In contrast, in the Pronoun NP1 condition, children show systematic interpretation of both markers.

Critically, children's actions can also be recoded as a preference for the likely agent. This would correspond to the proportion of all transitive actions that involved the likely agent and expressed item (as opposed to those that involved the likely theme and the expressed item). In the Expressed NP1 condition, the difference in likely agent preference across markers is calculated as correct actions following BEI (43%/43% + 54% = 44%) minus reverse actions following BA (20%/78% + 20% = 20%), resulting in a difference of 24%. In the Pronoun NP1 condition, this difference is calculated as correct actions following BA (66%/66% + 30% = 68%) minus reverse actions following BEI (44%/49% + 44% = 47%), resulting in a difference of 21%. Thus, when actions and eye-movements are coded in the same way, comparisons across markers reveal that *in both cases*, differences in likely agent preference are no greater in the Pronoun NP1 condition than they are in the Expressed NP1 condition.

Mandarin passives and cue-based accounts

Our results introduce a tension with prior work on the interpretation of morphosyntactic markers in Mandarin.

Please cite this article in press as: Huang, Y. T., et al. Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language* (2013), http://dx.doi.org/10.1016/j.jml.2013.08.002

Recall that Li, Bates, and MacWhinney (1993) asked adults to select "the doer of the action" and found greater accuracy in the use BEI to inform role assignments (construing NP2 as the agent 80% of the time) compared to BA (construing NP2 as the theme 70% of the time). Li, Bates, and MacWhinney (1993) attribute the more limited effects of BA to the existence of phonologically-similar markers (to indicate questions or hesitation) and to the interaction of BA with word order constraints. Critically, this contrasts with our finding that adults were sometimes as likely to produce correct actions with BEI and BA (in the Pronoun NP1 condition) and were sometimes less likely to produce correct actions with BEI compared to BA (in the Expressed NP1 condition).

Comparisons of the two studies highlight two important methodological differences. First, the current study adopted a task where participants' role assignments were measured implicitly by their resolution of a referential ambiguity (who is "it" in the sentence?). In contrast, Li, Bates, and MacWhinney (1993) adopted a task which relied on participants' explicit metalinguistic judgments (who is the agent in the sentence?). Critically, performance in this judgment task may have been affected by the instructions: Since participants were asked to find the *agent*, they may have found the task easier in sentences where the onset of the cue (BEI) signaled that the agent was about to appear. In contrast, if the task had been to find the *theme*, participants might have been more accurate for BA instead. A second methodological difference is that Li et al. (1993) used a speeded task and a blocked design. During pilot testing, they found that adults had difficulty shifting between BEI and BA trials and the randomized presentation of the two caused confusion. This raises the possibility that participants in their study tended to adopt judgment strategies like the one described above, which might promote rapid responding in a blocked design but would result in more errors when trials are intermixed.

These considerations suggest that Li et al. (1993) may have overestimated the cue strength of BEI and underestimated the cue strength of BA. If so, this eliminates the obvious difference between our findings and the predictions of a cue-based account and raises the question of whether such an account could, in principle, explain the current results. To do so, the cue-based account would have to have two features. First, it would have to predict that the cue strength of BEI would be less than the cue strength of BA. As discussed, on cue-based accounts the accuracy of thematic role assignment depends on cue validity which is a function of both cue reliability and cue frequency. Our own corpus analysis (see Introduction) found that while both BA and BEI were highly reliable cues to role assignment, BA was more frequent. Thus it is conceivable that as cue-based account could capture the main effect of marker. Second, a successful cue-based account would have to capture the effects of pronominalization on thematic role assignment. One possible hypothesis is that prominalization might be a cue to agentivity. Pronouns are typically given information, given information is more likely to occur in subject position and, since active constructions are more common in Mandarin than passive constructions, subjects are more likely to be agents than themes (see Can discourse infelicity explain children's actions? for a discussion on the discourse function of pronouns). However, this hypothesis is inconsistent with the observed data pattern. If pronominalization was a cue to agentivity, then we would expect the performance difference between BA and BEI to be most pronounced Pronoun NP1 conditions (where both prominalization and the agent-first strategy would favor BA) and least pronounced in the Expressed NP1 condition (where prominalization should work against the agent-first strategy). Instead the opposite pattern was found. While this pattern could be consistent with a cue-based account which treats pronominalization as a valid cue to themehood, there is limited empirical evidence to support this analysis (Li & Thompson, 1981; Yang et al., 2003).

Conclusion

This study examined the causes of children's difficulties with passives by examining this construction in Mandarin Chinese. We considered four possible accounts for why children initially make errors with passives. The syntactic account argues that early on, children do not have the relevant grammar to interpret passives (Borer & Wexler, 1987, 1992). The frequency account argues that in a language like English, children lack the relevant experience with this construction (Brooks & Tomasello, 1999; Demuth, 1989). A cue-based account suggests that in a language like English, children are not given strong and unambiguous cues to the passive construction (Bates & MacWhinney, 1987, 1989). Finally, the Incremental Processing Hypothesis proposes that the interpretation of passives is difficult when it requires children to revise an earlier commitment to a role assignment (Trueswell & Gleitman, 2004). We conclude that our data support the Incremental Processing Hypothesis. In this way, these results highlight ways in which the moment-to-moment changes that occur during language processing can provide a window onto the year-to-year changes that occur during language acquisition.

Uncited reference

Tanenhaus, Spivey-Knowlton, Eberhard, and Sedivy (1995).

Acknowledgments

We are grateful to Chen Jie, Amanda Worek, and Carlyn Friedberg for their assistance in data collection and coding. We also thank Judy Huang, Jane Pollock, and Claire Huang for their help in assembling the materials for the study and Hugh Rabagliati for comments on an earlier draft. Por-

A. Appendix

List of objects and sentences for the critical trials.

1. Cat (expressed noun), dog (likely agent), mouse (likely theme)					
Expressed NP1:	Cat	BA/BEI	it	quickly	scare
	小貓	把 (被)	它	很 快地	嚇住了
	The cat is quickly scaring it (scared by it)				
Pronoun NP1:	It	BA/BEI	cat	quickly	scare
	它	把 (被)	小貓	很 快地	嚇住了
	It is quickly scaring the cat (scared by the cat)				
2. Child (expressed noun), Father (likely agent), Toy (likely theme)					
Expressed NP1:	Child	BA/BEI	it	carefully	lift
	孩子	把 (被)	它	小心地	舉起來
	The child is carefully lifting it (lifted by it)				
Pronoun NP1:	It	BA/BEI	child	carefully	lift
	它	把 (被)	孩子	小心地	舉起來
	It is carefully lifting the child (lifted by the child)				
3. Rabbit (expressed noun), Fox (likely agent), Carrot (likely theme)					
Expressed NP1:	Rabbit	BA/BEI	it	slowly	eat
	兔子	把 (被)	它	慢慢地	吃光了
	The rabbit is slowly eating it (eaten by it)				
Pronoun NP1:	It	BA/BEI	rabbit	slowly	eat
	它	把 (被)	兔子	慢慢地	吃光了
	It is slowly eating the rabbit (eaten by the rabbit)				
4. Rock (expressed noun), Hammer (likely agent), Egg (likely theme)					
Expressed NP1:	Rock	BA/BEI	it	loudly	smash
	石頭	把 (被)	它	大聲地	砸碎了
	The rock is loudly smashing it (smashed by it)				
Pronoun NP1:	It	BA/BEI	rock	loudly	smash
	它	把 (被)	石頭	大聲地	砸碎了
	It is loudly smashing the rock (smashed by the rock)				
5. Firefighter (expressed noun), Helicopter (likely agent), Child (likely theme)					
Expressed NP1:	Firefighter	BA/BEI	it	quickly	rescue
	消防員	把 (被)	它	很快地	救出來
	The firefighter is happily rescuing it (rescued by it)				
Pronoun NP1:	It	BA/BEI	firefighter	quickly	rescue
	它	把 (被)	消防員	很快地	救出來
	It is happily rescuing the firefighter (rescued by the firefighter)				
6. Boy (expressed noun), Horse (likely agent), Ball (likely theme)					
Expressed NP1:	Boy	BA/BEI	it	gently	kick
	男孩	把 (被)	它	輕柔地	踢了一腳
	The boy is gently kicking it (kicked by it)				
Pronoun NP1:	It	BA/BEI	boy	gently	kick
	它	把 (被)	男孩	輕柔地	踢了一腳
	It is gently kicking the boy (kicked by the boy)				
7. Dog (expressed noun), Hunter (likely agent), Rabbit (likely theme)					
Expressed NP1:	Dog	BA/BEI	it	slowly	chase
	小狗	把 (被)	它	慢慢地	追趕著
	The dog is slowly chasing it (chased by it)				
Pronoun NP1:	It	BA/BEI	dog	slowly	chase
	它	把 (被)	小狗	慢慢地	追趕著
	It is slowly chasing the dog (chased by the dog)				

(*continued on next page*)

1379 tions of this work have been presented at the 33rd annual meeting of the Boston University Conference on Language 1380

8. Child (expressed noun), Mother (likely agent), Chicken (likely theme)

Expressed NP1:	Child	BA/BEI	it	quickly	feed
	孩子	把 (被)	它	很快地	餵飽了
	The child is happily feeding it (fed by it)				
Pronoun NP1:	It	BA/BEI	child	quickly	feed
	它	把 (被)	孩子	很快地	餵飽了
	It is happily feeding the child (fed by the child)				

9. Girl (expressed noun), Mother (likely agent), Doll (likely theme)

Expressed NP1:	Girl	BA/BEI	it	tightly	hug
	女孩	把 (被)	它	緊緊地	抱在懷裡
	The girl is tightly hugging it (hugged by it)				
Pronoun NP1:	It	BA/BEI	girl	tightly	hug
	它	把 (被)	女孩	緊緊地	抱在懷裡
	It is tightly hugging the girl (hugged by the girl)				

10. Frog (expressed noun), Puppy (likely agent), Fly (likely theme)

Expressed NP1:	Frog	BA/BEI	it	gently	catch
	青蛙	把 (被)	它	輕輕地	抓住了
	The frog is quietly catching it (caught by it)				
Pronoun NP1:	It	BA/BEI	frog	gently	catch
	它	把 (被)	青蛙	輕輕地	抓住了
	It is quietly catching the frog (caught by the frog)				

11. Washing machine (expressed noun), Woman (likely agent), Clothes (likely theme)

Expressed NP1:	Washing machine BA/BEI	it	gently	clean	
	洗衣機	把 (被)	它	溫柔地	洗了
	The washing machine is gently cleaning it (cleaned by it)				
Pronoun NP1:	It	BA/BEI	washing machine gently	clean	
	它	把 (被)	洗衣機	溫柔地	洗了
	It is gently cleaning the washing machine (cleaned by the washing machine)				

12. Seal (expressed noun), shark (likely agent), fish (likely theme)

Expressed NP1:	Seal	BA (BEI)	it	quickly	eat
	海豹	把 (被)	它	很快就	吃掉了
	The seal is quickly eating it (eaten by it)				
Pronoun NP1:	It	BA (BEI)	seal	quickly	eat
	它	把 (被)	海豹	很快就	吃掉了
	It is quickly eating the seal (eaten by the seal)				

Development and the 2010 CUNY Conference on Human Sentence Processing. This work was supported by a National Research Service Award from NICHD to YH (HD061173), a grant from NSF to J.S. (BCS-0623845), and a grant from the National Natural Science Foundation of China (NSFC) to M.X. (31070917).

References

Allen, S., & Crago, M. (1996). Early passive acquisition in Inuktitut. *Journal of Child Language, 23*, 129–155.

Baillargeon, R. (1993). The object concept revisited: New directions in the investigation of infants' physical knowledge. In C. E. Granrud (Ed.), *Visual perception and cognition in infancy* (pp. 265–315). Hillsdale, NJ: Erlbaum.

Baldie, B. (1977). The acquisition of the passive voice. *Journal of Child Language, 3*, 331–348.

Bates, D. (2007). *Linear mixed model implementation in lme4*. Manuscript: University of Wisconsin-Madison (January 2007).

Bates, E., MacWhinney, B., Caselli, C., Devescovi, A., Natale, F., & Venza, V. (1984). A cross-linguistic study of the development of sentence interpretation strategies. *Child Development, 55*, 341–354.

Bates, E., & MacWhinney, B. (1987). Competition, variation, and language learning. In B. MacWhinney (Ed.), *Mechanisms of language acquisition*. Hillsdale, NJ: Erlbaum.

Bates, E., & MacWhinney, B. (1989). Functionalism and the competition model. In B. MacWhinney & E. Bates (Eds.), *The cross-linguistic study of sentence processing*. New York: Cambridge University Press.

Berman, R. (1985). The acquisition of Hebrew. In D. Slobin (Ed.). *The cross-linguistic study of language acquisition* (Vol. 1, pp. 255–371). Hillsdale, NJ: Erlbaum.

Berthier, N. E., DeBlois, S., Poirier, C. R., Novak, J. A., & Clifton, R. K. (2000). Where's the ball? Two- and three-year-olds reason about unseen events. *Developmental Psychology, 36*, 394–401.

Bever, T. G. (1970). The cognitive basis for linguistic structure. In J. R. Hayes (Ed.), *Cognition and the development of language* (pp. 279–362). New York: Wiley.

Borer, H., & Wexler, K. (1987). The maturation of syntax. In T. Roeper & E. Williams (Eds.), *Parameter setting* (pp. 123–172). Dordrecht: D. Reidel Publishing Co.

Borer, H., & Wexler, K. (1992). Bi-unique relations and the maturation of grammatical principles. *Natural Language and Linguistic Theory, 10*, 147–189.

Brooks, P. J., & Tomasello, M. (1999). Young children learn to produce passives with nonce verbs. *Developmental Psychology, 35*, 29–44.

Brown-Schmidt, S. (2012). Beyond common and privileged: Gradient representations of common ground in real-time language use. *Language and Cognitive Processes, 27*, 62–89.

Budwig, N. (2001). An exploration into children's use of passives. In M. Tomasello & E. Bates (Eds.), *Language development: The essential readings* (pp. 227–247). Malden, MA: Blackwell Publishers.

Butler, S. C., Bertheir, N. E., & Clifton, R. K. (2002). Two-year-olds' search strategies and visual tracking in hidden displacement task. *Developmental Psychology, 38*, 581–590.

Chafe, W. L. (1976). Givenness, contrastiveness, definiteness, subjects, topics, and point of view. In C. N. Li (Ed.), *Subject and topic* (pp. 25–56). New York: Academic Press, Inc..

Chafe, W. (1987). Cognitive constraints on information flow. In R. Tomlin (Ed.), *Coherence and grounding in discourse* (pp. 21–51). Philadelphia, PA: John Benjamins.

Choi, Y., & Trueswell, J. (2010). Children's (in)ability to recover from garden paths in a verb-final language: Evidence for developing control in sentence processing. *Journal of Experimental Child Psychology, 106*, 41–61.

Chomsky, N. (1981). *Lectures on government and binding: The Pisa lectures*. New York: Mouton de Gruyter.

Creider, C. (1979). On the explanation of transformations. In T. Givon (Ed.). *Syntax and semantics* (Vol. 12). New York: Academic Press.

Demuth, K. (1990). Subject, topic, and Sesotho passive. *Journal of Child Language, 17*, 67–84.

Demuth, K. (1989). Maturation and the acquisition of the Sesotho passive. *Language, 65*, 56–80.

Ferguson, H. J., Scheepers, C., & Sanford, A. J. (2010). Expectations in counterfactual and theory of mind reasoning. *Language and Cognitive Processes, 25*, 297–346.

Gibson, E. (1998). Linguistic complexity: Locality and syntactic dependencies. *Cognition, 68*, 1–76.

Gordon, P., & Chafetz, J. (1990). Verb-based versus class-based accounts of actionality effects in children's comprehension of passives. *Cognition, 36*, 227–254.

Gordon, P. C., Hendrick, R., & Johnson, M. (2001). Memory interference during language processing. *Journal of Experimental Psychology: Learning, Memory and Cognition, 27*, 1411–1423.

Gundel, J. K. (1974). *The role of topic and comment in linguistic theory*. Doctoral Dissertation. University of Texas at Austin.

Harris, F., & Flora, J. (1982). Children's use of 'get' passives. *Journal of Psycholinguistic Research, 11*, 297–331.

Heller, D., Grodner, D., & Tanenhaus, M. K. (2008). The role of perspective in identifying domains of reference. *Cognition, 108*, 831–836.

Horgan, D. (1978). The development of the full passive. *Journal of Child Language, 5*, 65–80. Q5

Hurewitz, F., Brown-Schmidt, S., Thorpe, K., Gleitman, L., & Trueswell, J. (2000). One frog, two frog, red frog, blue frog: Factors affecting children's syntactic choices in production and comprehension. *Journal of Psycholinguistic Research, 29*, 597–626.

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language, 59*, 434–446.

January, D., Trueswell, J. C., & Thompson-Schill, S. L. (2009). Co-localization of stroop and syntactic ambiguity resolution in Broca's area: Implications for the neural basis of sentence processing. *Journal of Cognitive Neuroscience, 21*, 2434–2444.

Johansson, S., Leech, G., & Goodluck, H. (1978). *Manual of information to accompany the Lancaster-Oslo/Bergen corpus of British English, for use with digital computers*. Oslo: University of Oslo.

Johnson-Laird, P. N. (1968). The choice of the passive voice in a communicative task. *British Journal of Psychology, 59*, 7–15.

Kamide, Y., Altmann, G. T. M., & Haywood, S. (2003). Prediction and thematic information in incremental sentence processing: Evidence from anticipatory eye movements. *Journal of Memory and Language, 49*, 133–156.

Kamide, Y., Scheepers, C., & Altmann, G. (2003). Integration of syntactic and semantic information in predictive processing: Cross-linguistic evidence from German and English. *Journal of Psycholinguistic Research, 32*, 37–55.

Lempert, H. (1990). Acquisition of passives: the role of patient animacy, salience, and lexical accessibility. *Journal of Child Language, 17*, 677–696.

Li, P. (1990). *Aspect and aktionsart in child Mandarin*. Ph.D. dissertation, Leiden University, the Netherlands.

Li, C., & Thompson, S. (1976). Subject and topic: A new typology of language. In C. Li (Ed.), *Subject and topic*. New York: Academic Press.

Li, C., & Thompson, S. (1981). *Mandarin Chinese: A functional reference grammar*. Berkeley: University of California Press.

Li, P., Bates, E., & MacWhinney, B. (1993). Processing a language without inflections: A reaction time study of sentence interpretation in Chinese. *Journal of Memory and Language, 32*, 169–192.

MacDonald, M., Pearlmutter, N., & Seidenberg, M. (1994). The lexical nature of syntactic ambiguity resolution. *Psychological Review, 101*, 676–703.

MacWhinney, B., Bates, E., & Kliegl, R. (1984). Cue validity and sentence interpretation in English, German, and Italian. *Journal of Verbal Learning and Verbal Behavior, 23*, 127–150.

MacWhinney, B., Pléh, C., & Bates, E. (1985). The development of sentence interpretation in Hungarian. *Cognitive Psychology, 17*, 178–209.

Maratsos, M. P., & Abramovitch, R. (1975). How children understand full, truncated and anomalous passives. *Journal of Verbal Learning and Verbal Behavior, 14*, 145–157.

Maratsos, M. P., Fox, D. E. C., Becker, J. A., & Chalkley, M. A. (1985). Semantic restrictions on children's passives. *Cognition, 19*, 167–192.

Matin, E., Shao, K., & Boff, K. (1993). Saccadic overhead: Information processing time with and without saccades. *Perception & Psychophysics, 53*, 372–380.

McEnery, A., Xiao, Z., & Mo, L. (2003). Aspect marking in English and Chinese: Using the Lancaster Corpus of Mandarin Chinese for contrastive language study. *Literary and Linguistic Computing, 18*, 361–378.

McEnery, A., & Xiao, Z. (2005). Passive constructions in English and Chinese: A corpus-based contrastive study. In *Proceedings of corpus linguistics 2005*. Birmingham University.

Messenger, K., Branigan, H. P., McLean, J. F., & Sorace, A. (2012a). Is young children's passive syntax semantically constrained? Evidence from syntactic priming. *Journal of Memory and Language, 66*, 568–587.

Messenger, K., Branigan, H. P., & McLean, J. F. (2012b). Is children's acquisition of the passive a staged process? Evidence from six- and nine-year-olds' production. *Journal of Child Language, 39*, 991–1016.

Mills, A. (1985). The acquisition of German. In D. Slobin (Ed.). *The cross-linguistic study of language acquisition* (Vol. 1, pp. 141–254). Hillsdale, NJ: Erlbaum.

Novick, J. M., Trueswell, J. C., & Thompson-Schill, S. L. (2005). Cognitive control and parsing: Re-examining the role of Broca's area in sentence comprehension. *Journal of Cognitive, Affective, and Behavioral Neuroscience, 5*, 263–281.

Novick, J. M., Kan, I. P., Trueswell, J. C., & Thompson-Schill, S. (2010). A case for conflict across multiple domains: Memory and language impairments following damage to ventrolateral prefrontal cortex. *Cognitive Neuropsychology, 26*, 527–567.

Novick, J. M., Hussey, E., Teubner-Rhodes, S., Harbison, J. I., & Bunting, M.F. (2013). Clearing the garden-path: Improving sentence processing through cognitive control training. *Language and Cognitive Processes* (in press).

Onishi, K. H., & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science, 308*, 255–258.

Philipp, M., Bornkessel, I., Bisang, W., & Swchlesewsky, M. (2008). The role of animacy in the real time comprehension of Mandarin Chinese: Evidence from auditory event-related potential. *Brain and Language, 105*, 112–133.

Pinker, S., Lebeaux, D. S., & Frost, L. A. (1987). Productivity and constraints in the acquisition of the passive. *Cognition, 26*, 195–267.

Pye, C., & Poz, P. Q. (1988). Precocious passives and anti-passives in Quiche Mayan. *Papers and Reports on Child Language Development, 27*, 71–80.

Reinhart, T. (1982). *Pragmatics and linguistics: An analysis of sentence topics*. Ms, distributed by the Indiana University Linguistics Club.

Sinclair, A., Sinclair, H., & De Marcellus, O. (1971). Young children's comprehension and production of passive sentences. *Archives de Psychologie, 61*, 1–20.

Slobin, D. I. (1973). Cognitive prerequisites for the development of grammar. *Studies of Child Language Development, 1*, 75–208.

Spelke, E. S., Breinlinger, K., Macomber, J., & Jacobson, K. (1992). Origins of knowledge. *Psycholoigcal Review, 99*, 605–632.

Stromswold, K., Eisenband, J., Norland, E., & Ratzan, J. (2002). Tracking the acquisition and processing of English passives: Using acoustic cues to disambiguate actives and passives. In *Paper presented at the CUNY conference on sentence processing*, New York, New York.

Sudhalter, V., & Braine, M. D. S. (1985). How does comprehension of passives develop? A comparison of actional and experiential verbs. *Journal of Child Language, 12*, 455–470.

Please cite this article in press as: Huang, Y. T., et al. Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language* (2013), http://dx.doi.org/10.1016/j.jml.2013.08.002

Sun, C. F. (1991). Transitivity and the BA construction. In *Paper presented at the 3rd North American conference on Chinese linguistics*. Ithaca: Cornell University.

Sun, C. F., & Givon, T. (1985). On the so-called SOV word order in Mandarin Chinese: A quantified text study and its implications. *Language, 61*, 329–351.

Tanenhaus, M. K., Spivey-Knowlton, M., Eberhard, K., & Sedivy, J. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science, 268*, 1632.

Trueswell, J., & Tanenhaus, M. (1994). Toward a lexicalist framework of constraint-based syntactic ambiguity resolution. In C. Clifton & L. Frazier (Eds.), *Perspectives on sentence processing*. Hillsdale, NJ: Lawrence Erlbaum.

Trueswell, J., Sekerina, I., Hill, N., & Logrip, M. (1999). The kindergarten-path effect: Studying on-line sentence processing in young children. *Cognition, 73*, 89–134.

Trueswell, J., & Gleitman, L. (2004). Children's eye movements during listening: Evidence for a constraint based theory of parsing and word learning. In J. Henderson & F. Ferreira (Eds.), *Interface of language, vision, and action: Eye movements and the visual world*. New York: Psychology Press.

Turner, E. A., & Rommetveit, R. (1967). The acquisition of sentence voice and reversibility. *Child Development, 38*, 649–660.

van Kuppevelt, J. (1996). Directionality in discourse: Prominence differences in subordination relations. *Journal of Semantics, 13*, 363–395.

Wang, P. C. T. (1970). *A transformational approach to Chinese BA and BEI*. Doctoral dissertation, University of Texas, Austin.

Warren, T., & Gibson, E. (2002). The influence of referential processing on sentence complexity. *Cognition, 85*, 79–112.

Weighall, A. (2008). The kindergarten path effect revisited: Children's use of context in processing structural ambiguities. *Journal of Experimental Child Psychology, 99*, 75–95.

Wexler, K. (2005). Theory of phrasal development. In *Plato's problem: Problems in language acquisition* (Vol. 48). Cambridge, MA: MIT Working Papers in Linguistics.

Williams, E. S. (1977). Discourse and logical form. *Linguistic Inquiry, 8*, 101–139.

Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition, 13*, 103–128.

Yang, C. L., Gordon, P. C., Hendrick, R., & Hue, C. W. (2003). Constraining the comprehension of pronominal expressions in Chinese. *Cognition, 86*, 283–315.

Please cite this article in press as: Huang, Y. T., et al. Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language* (2013), http://dx.doi.org/10.1016/j.jml.2013.08.002