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The role of working memory and contextual constraints in children's processing of relative clauses.

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Abstract

An auditory sentence comprehension task investigated the extent to which the integration of contextual and structural cues was mediated by verbal memory span with 32 English-speaking 6- to 8-year old children. Spoken relative clause sentences were accompanied by visual context pictures which fully (depicting the actions described within the relative clause) or partially (depicting several referents) met the pragmatic assumptions of relativisation. Comprehension of the main and relative clauses of centre-embedded and right-branching structures was compared for each context. Pragmatically-appropriate contexts exerted a positive effect on relative clause comprehension, but children with higher memory spans demonstrated a further benefit for main clauses. Comprehension for centre-embedded main clauses was found to be very poor, independently of either context or memory span. The results suggest that children have access to adult-like linguistic processing mechanisms, and that sensitivity to extra-linguistic cues is evident in young children and develops as cognitive capacity increases.

Introduction

Theories of parsing make assumptions about how sentence processing ability develops, yet until recently there was very little direct testing of how the findings in the adult literature extend to children (but see Felser, Marinis & Clahsen, 2003; Kidd & Bavin, 2007; Kidd, Brandt, Lieven & Tomasello, 2007;Snedeker & Yuan, 2008; Traxler, 2002; Trueswell, Sekerina, Hill and Logrip, 1999). Controversially, studies with spoken language have shown that whilst contextual cues (e.g., the number of available discourse referents) are important in disambiguating syntactically ambiguous sentences for adults (Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995; Trueswell et al., 1999) children instead rely upon statistically more reliable lexical cues. For example children seem to be particularly sensitive to the frequency with which verbs occur in certain syntactic structures (verb biases) (Trueswell et al., 1999; Snedeker & Trueswell, 2004; Weighall, 2008).

Processing differences between adults and children are predicted by theories of development which assume syntactic knowledge takes priority over pragmatic and discourse based information in the early stages of computing a syntactic representation of a sentence (parsing). It has been suggested that the latter does not influence immediate and online sentence processing until children are well into primary school (Goodluck, 1990); and the ability to integrate non-linguistic information develops slowly as processing capacity increases (Felser et al., 2003; Fragman, Goodluck & Heggie, 2007). In contrast, studies investigating children's sensitivity to contextual information with unambiguous relative clause sentences have claimed that children are able to make use of contextual cues from as early as the age of three- or four- years old (Correa, 1995; Hamburger & Crain, 1982; Kidd & Bavin, 2002). Theories suggesting that children may adopt non-adult processing strategies when attempting to resolve relative clauses (e.g., Tavakolian, 1981; Sheldon, 1974) have been superseded by more recent work which suggests that children process relative clauses in an adult-like way, and that any observed differences can be attributed to general cognitive capacity limitations rather than linguistic differences (Correa, 1995; Kidd & Bavin, 2002; Kidd et al., 2007). In support of this, Felser et al. (2003) report a differential effect of memory span on the attachment

preferences adopted by children for syntactically ambiguous relative clause sentences, and similar effects have been observed with adults (e.g., Swets, Desmut, Hambrick & Ferreira, 2007; Traxler, Williams, Blozis & Morris, 2005). However, memory span has not previously been investigated in relation to contextual integration. We used an offline comprehension task to investigate the influence of contextual information on comprehension for unambiguous relative sentences that vary in complexity, and the extent to which memory span interacts with sentence comprehension.

The syntactic properties of relative clause sentences

Extensive research with children has varied the complexity of relative clause sentences presented to children in order to investigate the extent to which the structural factors of focus and embedding affect children's comprehension. Examples can be seen in table 1 below.

<insert table 1 about here>

Focus refers to the role that the head noun plays in the relative clause (as indicated by the underscore gaps). For example, in (1) the head noun (horse) is the subject of the relative clause, and the same is true of (2). In contrast, the head noun is the object of the relative clause in sentences (3) and (4). There is broad agreement that object-focused relatives are more difficult to process than their subject focused counterparts for both adults (e.g., Gordon, Hendrick & Levine, 2002; Gordon, Hendrick & Johnson, 2001; Mak, Vonk, & Schriefers, 2002; Traxler, Morris & Seely, 2002) and children (Kidd & Bavin, 2002; but see Kidd et al., 2007). Relative clause sentences also vary according to the embedding of the relative clause (where the relative clause occurs in the sentence). There is a further, dissociable, processing cost for adults associated with centre-embedded sentences (e.g., sentences 2 and 4), compared with their right-branching counterparts (e.g., sentences 1 and 3; Bates, Devescovi & d'Amico,1999). Slobin (1973) claimed that centre embedded structures are difficult to process because of the interruption of one clause by another. This pattern has also been found with young children (Kidd & Bavin, 2002; Correa, 1995).

The role of context in children's relative clause comprehension

Many investigations into children's processing of relative clause sentences have made use of the act-out task which requires children to manipulate an array of toys to demonstrate their interpretation of spoken sentences (see Kidd, 2003, for a review). Hamburger and Crain (1982) argued that much early research using this task violated the pragmatic assumptions associated with the use of relative clause structures, and as result had underestimated children's competence. The use of a relative clause (underlined in 5) implies that there should be a referent set to be restricted in the referential context.

(5) The pig bumps into the horse that jumps over the giraffe

For example, sentence (5) presupposes there should be several horses in the discourse context, and 'that jumps over the giraffe' indicates which horse is the intended referent. Many studies with children violate this presupposition by providing only one to-be-restricted referent in the visual scene e.g., only one toy horse (Sheldon, 1974; Goodluck & Tavakolian, 1982). Hamburger and Crain (1982) provided three tokens of the to-be restricted referent in their version of the act out task, also using toys. For a sentence like (5), one pig, one giraffe, but three horses were present in the array. Under these circumstances 3- to 5-year-olds performed significantly better and 5-year-olds achieved 92% correct, compared with a best case of 60% for equivalent sentence types in previous research (e.g., Goodluck & Tavakolian, 1982). Hamburger & Crain (1982) argued that providing appropriate context is imperative in order to gain a true appreciation of children's syntactic competence. Like adults, even young children have knowledge of the referential principle (Crain & Steedman, 1985) which means that when they are presented with two potential referents they expect the incoming language to differentiate between them. Thus, referential context is seen to act as a salient cue for young children.

In contrast, research with ambiguous sentences has indicated that children may be less sensitive to contextual cues than adults. Using an eye movement study combined with an act-out task, Trueswell et al. (1999) investigated 4- to 5-year-old childrens' comprehension of ambiguous sentences like (6).

(6) Put the frog on the napkin in the box

They found that situational cues (e.g. whether there were one or two frogs present) were not effectively employed to avoid the temporary syntactic ambiguity, meaning that children often erroneously interpreted 'on the napkin' as the destination for the frog, rather than as modifying information specifying which frog was the intended referent. This ambiguity was almost entirely avoided by adults when the visual scene biased toward a modifier interpretation of the sentence (i.e., when two frogs were present).

Trueswell at al. (1999; see also Trueswell & Gleitman, 2004) interpret this finding in terms of constraint-based learning whereby the developing parser has access to the same mechanisms as adults but constraints are integrated differentially through development, reflecting changes in the reliability of cues dependent upon linguistic experience. A contrasting account claims that children's sentence comprehension is sentence-oriented with syntactic cues taking priority over discourse context; the latter is not automatically integrated into syntactic analyses (Fragman et al., 2007). Under this view, limited processing capacity prevents children from fully taking all possible constraints into account. The additional demands of resolving ambiguity may explain the differences in referential sensitivity observed by Trueswell et al. (1999) and Hamburger & Crain (1982).[1] However, Hamburger and Crain (1982) did not directly compare a one-referent condition with their several- referent innovation, drawing their conclusions from comparison of their findings and those of Goodluck and Tavakolian (1982).

Eisenberg (2002) made a direct comparison and found no advantage for a two-referent condition in 3- 4-year olds suggesting that children's sensitivity to pragmatic factors had been over-estimated by Hamburger and Crain (1982; but see Kidd, 2003, for arguments against this conclusion). Furthermore, the right-branching subject-relative structure used by Hamburger and Crain (1982) was compared with its more complex centre-embedded counterpart (e.g., sentence (2) in table 1) but a processing difference was not observed.

Correa (1995) designed an alternative act-out task which allowed children to process restrictive relative clauses as part of pragmatically appropriate discourse. Children heard two background sentences before the test sentence such as (7a):

(7a) A cat bumped a bear. Another cat kissed a sheep.

Background sentences were acted out for the child by the experimenter and the child was asked to act out the test sentences, such as (7b):

(7b) The cat that bumped the bear hugs the cow

Correa found that 3- to 6-year-old Portuguese-speaking children performed better than in standard act out studies. Correa manipulated both the focus and embedding of the sentences used and, as would be predicted based upon adult observations, found the right branching subject-focus structures were easiest to comprehend followed by centre-embedded subject-focus structures. Kidd and Bavin (2002) also demonstrated an adult like pattern (right-branching easier than centre-embedded) in a study using the alternative act out task with 3- to 5- year-old English-speaking children.

Providing appropriate discourse context for children appears to result in more effective construal of relative clause sentences and performance consistent with the processing preferences of adults. However, previous studies have not directly compared different types of context within one study, and only Eisenberg (2002) systematically varied the number of referents; these outstanding issues are addressed in the current study.

The role of cognitive capacity in relative clause comprehension

Several theorists have implicated cognitive capacity in explanations of processing differences between adults and children (e.g., Felser et al., 2003; Fragman at al., 2007), both in terms of parsing preferences and children's relative inability to take context into account. Individual differences in working memory span have also been found to influence attachment preferences in syntactic ambiguity resolution in adults (e.g.,

MacDonald, Just & Carpenter, 1992; Mendelsohn & Pearlmutter, 1999; Swets et al., 2007) and relative clauses in adults (Traxler et al., 2005) and children (Booth, MacWhinney & Harasaki, 2000; Felser et al., 2003). Furthermore, several explanations of sentence complexity effects observed in adults rely at least in part upon some form of memory load account (e.g., Gibson, 1998; Gordon et al., 2001). A suggestion arising from the adult literature is that those with a high memory capacity may be better able to take account of non-linguistic constraints because they have the cognitive resources available to incorporate this information (e.g., Just & Carpenter, 1992; MacDonald et al., 1992; Pearlmutter & MacDonald, 1995).

Experiments that have investigated the relationship between sentence comprehension and memory in adults have typically used versions of the Daneman & Carpenter (1980) sentence span test of verbal working memory (e.g., Just, Carpenter & Keller, 1996; MacDonald, Just & Carpenter, 1992; Pearlmutter & MacDonald, 1995; Swets et al., 2007; Traxler et al, 2005). Span tasks are tests of complex memory, involving both processing and storage elements and have been adapted in various forms for use with children (e.g., Gaulin & Campbell, 1994; Stothard & Hulme, 1992). The verbal listening span task devised by Stothard & Hulme (1992) requires children to assess the validity of a series of short spoken sentences (e.g., butter goes on bread, true; processing) and to memorize the final word in each sentence for immediate serial recall (storage). Performance on this task has been found to accurately discriminate between children with good and poor comprehension abilities (Nation, Adams, Bowyer-Crane & Snowling, 1999); and span differences on a similar task (Gaulin & Campbell, 1994) were found to be related to attachment preferences for ambiguous relative clauses in 6- to 7-year-old children (Felser et al., 2003). In this study we investigated whether verbal memory span in 6- to 8-year-old children also interacted with the ability to integrate the kinds of contextual information described earlier, in the form of visual context.

Representing action: the current study

The current study directly compared different types of context and sentence structure with 6- to 8- year-old children; verbal memory span was measured using a listening span task (Stothard & Hulme, 1992). Comprehension performance for right-

branching subject-relative structures (like those used by Hamburger & Crain, 1982) was compared with performance on embedded structures with the same focus (see examples below figure 1). This study made use of an auditory comprehension task, similar to tasks used by Felser et al. (2003) and Booth et al. (2000) enabling us to examine the representation of each clause, and observe the effect (if any) of contextual information on comprehension. This type of comprehension task has been used previously, in conjunction with measures of online processing (Booth et al., 2000; Felser et al., 2003) but was used as a purely offline measure in the present study. Importantly, this task allows us to ascertain whether context influences comprehension even when this information is not essential in meeting the task demands. Both the standard and alternative act-out task force the child to establish reference as an integral part of the task - requiring selection of a referent (e.g. a cat) in order to act out the sentence. The task presented here did not necessitate this kind of referent selection; our question was whether children would spontaneously integrate visual context with their linguistic representation, even when the task did not demand it. An example of the visual contexts that were used can be seen in figure 1, and the corresponding sentences are given below.

<insert Figure 1 about here>

In previous research, studies using the alternative act out task (Correa, 1995; Kidd & Bavin, 2002) fully met the felicity conditions of the relative clause (that there was more one cat, which had been previously mentioned in the discourse context as having bumped a bear) whereas Hamburger and Crain (1982) partially met them (by providing more than one cat in the visual array). In the current study context was provided by presenting pictures prior to auditory presentation of subject relative sentences. Hamburger & Crain (1982) demonstrated that young children can utilise visual context in their comprehension. Furthermore, extensive evidence suggests that visual context (in the form of pictures, or an array of objects) can serve as referential context in much the same way as previous linguistic material, and that such context can affect ultimate comprehension in adults (e.g., Spivey & Tanenhaus, 2004; Tanenhaus et al, 1995; Trueswell et al., 1999). Action contexts (shown in figure 1A) were created to be similar

in principle to the background sentences used by Correa (1995); for example a picture of a cat bumping a bear and another (visually distinct) cat kissing a sheep. For each sentence a corresponding no-action picture (shown in figure 1B) depicted the same animals (e.g. two cats, a bear and a sheep) but not interacting with each other. The no-action condition was analogous to that used by Hamburger and Crain (1982) in that two tokens of the to-be-restricted referent (e.g. the cat) were presented, this way felicity conditions were partially met.

Following exposure to either the action or the no-action context picture a target picture was displayed while children simultaneously heard either an embedded (CE) or right-branching (RB) sentence followed by a question about either the main (MC) or relative clause (RC). The target picture contained both cats and the animal that was either the subject or object of the main clause (e.g. cow). The bear presented in the context pictures was also shown and a distracter bear was included. An example is given in figure 1C. Children were not required to interact with the stimuli, or to manipulate them in any way, but just to view and listen passively. Similar question-answering tasks have been used with adults (e.g., Bates et al, 1999; Sheldon, 1977) and children (Booth, MacWhinney & Harasaki, 2000; Felser at al., 2003; Townsend, Ottaviano & Bever, 1979) but this is the first study to our knowledge that incorporated visual context with spoken sentence comprehension.

Importantly, the questions asked what sort of animal (e.g., what sort of animal bumped the bear; answer = cat); this allowed the child to answer without reference to the visual stimuli. The questions did not ask which animal (which would require a specific answer, e.g., the striped cat). The child did not have to establish a unique referent, indeed it was possible for the question to be answered without reference to the visual stimuli. The question was whether we would observe a positive effect of context on comprehension performance under these circumstances.

The aims of this study were three-fold. First, to directly compare contexts which partially met the felicity conditions of the restrictive relative clause, with those where the pragmatic requirements were fully met. We predicted that comprehension performance would be superior in the action condition, based upon previous findings with the alternative act out task. Second, we explored whether the effects of context interacted

with sentence complexity. Given that cognitive resources are likely to be more taxed when processing the syntactically more complex embedded structure we predicted that context would exert less of an influence on comprehension of this structure, compared to the simpler right-branching sentences. Third, we investigated whether working memory span influenced children's ability to integrate contextual information with syntactic cues, and comprehension performance more generally. Based upon previous research we predicted that children with higher memory spans would be better able to integrate contextual information than those with reduced memory resources.

Method

Participants

Thirty-two 6- 8-year-old children attending a primary school in North Yorkshire, UK, participated. They were drawn from years 2 and 3 and had a mean age of 7; 3 years with an age range of 6; 2 – 8; 2 years. The children were randomly selected from class lists; all were monolingual English speakers raised in English speaking households and possessed no known language or hearing difficulties. The gender split was 11 boys and 21 girls.

Sentence Comprehension Task

Design

The design was a repeated measures factorial design incorporating a pseudo-latin square. There were three repeated measures factors: Type of context picture (Action/No-action) x Sentence type (right-branching (RB)/centre-embedded (CE)) x Question (Main clause (MC)/Relative clause (RC)) and a between-subjects factor of listening span (high/low). 32 sentence pairs were created for the sentence comprehension task using the same animals and verbs, and a question about both the main clause (*MC*) and relative clause (*RC*) was devised. For each sentence pair, there were three associated visual stimuli: Either an action picture or a no-action picture (only one of which was seen with a given sentence on each trial) and a target picture (which was the same for any given trial across conditions). In order to ask questions about both clauses of each sentence it was

necessary for each participant to experience each target picture twice across the whole experiment. However, these targets did not appear in the same condition for any one participant. The experiment was divided into two experimental sessions, and each target was seen only once within each of these sessions. For example, if one participant heard a RB sentence followed by a main clause question as trial 1 that item would be presented in the second session as CE-no action followed by a relative clause question. Four lists were constructed so that each item was presented in each of the 8 conditions, but so that no individual participant experienced any item more than once in each session (and not more than twice across the whole experiment). Each participant responded to 8 items in each condition, yielding a total of 64 experimental trials per participant.

Stimuli

Examples are given below of one pair of centre-embedded (CE) and right-branching (RB) sentences and their corresponding main clause (MC) and relative clause (RC) questions, answers are indicated in parentheses. A full list of the sentences used can be found in the appendix.

1a: Centre-embedded (CE): The cat that bumped the bear will hug the cow.

Main clause question (MC): What sort of animal will hug the cow? (cat)

Relative clause question (RC): What sort of animal bumped the bear? (cat)

1b: Right-branching (RB): The cow will hug the cat that bumped the bear.

Main clause question (MC): What sort of animal will hug the cat? (cow)

Relative clause question (RC): What sort of animal bumped the bear? (cat)

Each animal appeared in each noun position with equal frequency and was never an agent more often than it was a patient. Animals and verbs were not repeated within a sentence and, importantly, no animal pair (e.g., cat-bear) appeared more than once. This was to prevent effects that may arise as a result of paired association of one animal with another. The tense respected the sequence of events referred to in the sentence. The relative clause was in the past tense as it has already happened, but the main clause was in the

future tense, as it has not yet taken place in the discourse context. Sentences were pre-recorded by a male native English speaker and were played to the subjects via Psyscope (Cohen, MacWhinney, Flatt & Provost, 1993). For each sentence pair, there were three associated visual stimuli: Either an action picture or a no-action picture and a target picture. Examples of these stimuli are shown in Figure 1.

Action pictures depicted the action described in the relative clause of the accompanying sentence (e.g. a cat bumping a bear), and a distractor action involving another token of the to-be restricted referent (i.e. another cat doing something else to a bear). No-action pictures contained the same tokens as their action counterparts, but without depiction of the action event. Target pictures depicted the two to-be-restricted referents (e.g., the cats), the object of the relative clause (e.g., the bear), a distractor (a different bear), and the other animal mentioned in the sentence. The rationale was as follows: both cats were included so that there was a referent set to be restricted, ensuring that the restrictive relative clause was pragmatically relevant; the cow was included as it would be infelicitous to say the cow if there had been no cow in the present or preceding context. The bear was included so that all the animals featured in the sentence were represented, and the distractor bear was intended to prevent strategic question answering which may have arisen if there had been two cats and just one of all the other animals (a criticism of the standard act-out task levied by Eisenberg, 2002). The pictures were hand-sketched line drawings, which were scanned into the computer and coloured, compiled and edited using Graphic Converter with a 240-bit palette.

Twenty-four fillers were generated. The purpose of the fillers was to deter strategic responses. In the experimental stimuli the most common correct response is the first animal mentioned in the sentence. The fillers redressed this balance by asking subjects a question, which required the middle animal as the answer. Ideally, we would have included equal numbers of fillers and experimental items but pre-testing revealed that this made the testing sessions too long for children of this age. The fillers mirrored the experimental items. For each set there was a CE and RB version of the sentence, and an action/no-action picture. 12 fillers were used in each experimental session meaning that each filler target picture was seen twice in total, but under different conditions. An example of a set of filler items is given below.

RB Filler: The snake will bump the cat that pushed the hen

Question: What sort of animal will the snake bump? (cat)

CE Filler: The cat that pushed the hen will bump the snake

Question: What sort of animal did the cat push? (hen)

The filler action context pictures were created using composites of experimental context pictures. The action parts of experimental stimuli that had not been mentioned in the experimental sentences were used. To give an example, with reference to Figure 1, the *cat kissing the sheep* was paired with another cat action to create a new filler picture.

Procedure

Children were tested on an individual basis in a quiet area of their school and the experiment was presented via Psyscope using a 14" screen Apple Macintosh lap top computer at a resolution of 640 x 480 pixels.

The experiment was run in two separate experimental sessions, plus a third session for the memory task. Each experimental session consisted of 44 items (32 Experimental and 12 fillers) and these two sessions were separated by a week. Within each session there were two blocks of 22 items (16 experimental and 6 fillers). The first block comprised all action context pictures, the second block contained no-action pictures. The two different types of pictures were presented in separate blocks to rule out the possibility that the presence of one type influenced performance on the other. Of particular concern was the fact that because the *no-action* pictures do not help establish reference they may lead participants to ignore all context pictures, including the *action* contexts. With this in mind action contexts were always presented before no-action contexts[2]. Participants were told that they would see a picture, and then another and that during this second picture they would hear a sentence and then a question about what they had seen and heard. They were asked to look and listen carefully and to answer the question aloud. The first two trials of each block were practice trials intended to

familiarise the participant with the task and followed the same format as the experimental items. The context picture was presented for 5500ms before being replaced by the target picture, previewed for 1000ms before the onset of the sentence. 1500ms after the offset of the sentence the question was presented (during this time the mouse was inactive to ensure consistent presentation times). The target picture remained on screen until the participants answered the question verbally, in their own time. The experimenter pressed the mouse for the next trial and a smiley face appeared on the screen allowing participants to pause between trials. The experimenter recorded the response given for each trial. The experimental session lasted approximately 30 minutes with a short break half way through. When each experimental session was completed the children were given positive feedback and a small reward.

Verbal listening span task

Children undertook the Listening Span Task (Stothard & Hulme, 1992) as a measure of verbal working memory span in a separate testing session one week after the second experimental session. Participants listened to a series of short sentences, and were required to judge each sentence to be true or false. After hearing each series they were required to list in the correct order the last word of each sentence (e.g., Butter goes on bread (true), giants are small (False) – recall: bread, small). Listening span was tested for two, three and four sentences and two sets of sentences were presented at each span length. If a child made three errors at a particular list length testing was discontinued. Performance was scored by awarding 0.2 points for each set of terminal words recalled in the correct order. Further details about this task can be found in Stothard and Hulme (1992).

Results

Verbal listening span

On the basis of their VLS scores children were divided into two groups using a median split[3], those with a relatively high listening span (≥ 2) and those with a lower listening span (≤ 1.8). Of the 32 children who took part in the experiment a listening span was not obtained for one male child as they were absent on the day of the span test,

of the remaining 31 participants 13 were identified as high span (mean age: 7:2; range: 6:5 – 7;11; mean VLS: 2.5, range: 2 – 5.4) and 18 as low span participants (mean age: 7;3, range: 6;2 – 8;2; mean VLS: 0.93, range: 0 – 1.8). The VLS score differed significantly between the two groups ($t(29) = 9.526$, $p = < .001$). Pearson's R confirmed that listening span was not significantly correlated with age ($r = .144$, $n= 31$, $p = .440$).

Sentence comprehension

Comparision of low- and high- Span children

The percentage of correct answers in each condition was calculated for high- and low-span children and these are given in table 2. Comparison of both span groups revealed that overall high-span children performed better than low-span children on the comprehension task. The pattern of responses is similar for both groups with performance on the CE-relative clause and both the RB questions being roughly equivalent, and poorest performance on the CE main clause.

<insert table 2 about here>

Because the data are proportions all data analyses were conducted on the arcsine transformed data, but analyses of the untransformed data revealed the same patterns of significance. Analyses of variance (ANOVA) were conducted on the both the subject (F_1) and item (F_2) means for comprehension accuracy in each condition, only significant main effects and interactions are reported. A preliminary split plot ANOVA with VLS Span (low-span/high-span) entered as a between subjects factor, and the three within-subjects factors of context (action vs/no-action) sentence (CE/RB) and question (Relative clause/ Main clause) revealed a highly significant main effect of VLS group (F_1 (1,29) = 6.994, p <.001, η_p^2 = .194; F_2 (1,31) = 36.786, p < .001, η_p^2 = .543) high-span children answered more comprehension questions correctly overall. A significant main effect of context was found (F_1 (1,29) = 6.921, p = .013, η_p^2 = .193; F_2 (1,31) = 6.555, p = .016, η_p^2 = .175) with better comprehension performance generally observed for action than no-action contexts. Main effects of sentence (F_1 (1,29) = 21.074, p < .001, η_p^2 = .421; F_2 (1,31) = 53.291, p = < .001, η_p^2 = .632), and question (F_1 (1,29) = 36.867, p < .001, η_p^2 = .560; F_2 (1,31) = 74.218, p < .001, η_p^2 = .705), were also observed and a significant

sentence x question interaction question (F_1 (1,29) = 43.892, p < .001, η_p^2 = .616; F_2 (1,31) = 13.423, p < .001, η_p^2 = .798) suggested that relatively poor comprehension performance for the CE Main Clause compared to the other three sentence/question conditions explained these main effects. The 3-way VLS Group x Context x Question interaction was not significant by subjects but reach significance by items (F_1 (1,29) = 2.039, p = .164, η_p^2 = .066; F_2 (1,31) = 5.505, p = .026, η_p^2 = .098) and the 4-way VLS Group x Context x Sentence x Question interaction was significant by subjects (F_1 (1,29) = 8.835, p = .006, η_p^2 = .234), but not by items, (F_2 (1,31) = 3.111, p = .088, η_p^2 = .091). The main effect of VLS group and the 4-way interaction in the subject analysis suggested that the two span groups performed differently on our experimental task. In order to investigate these differences two separate three way ANOVAs with the variables of Context x Sentence x Question were conducted for each VLS-span group.

High span children

For the high span children ANOVA revealed a significant main effect of context, (F_1(1,12) = 12.037, p = .005, η_p^2 = .501; F_2(1,31) = 6.165, p = .019, η_p^2 = .166) confirming that there were more correct answers in the action than no-action condition. There was also a main effect of sentence (F_1 (1,12) = 5.893, p = .032, η_p^2 = .329; F_2(1,31) = 22.416, p < .001, η_p^2 = .420) with RB engendering more correct answers than CE sentences and a main effect of question (F_1(1,12) = 10.657, p = .007, η_p^2 = .470; F_2(1,31) = 4.559, p < .001, η_p^2 = .532) indicating that more correct answers were given for the relative clause than the main clause overall. There was a highly significant sentence x question interaction (F_1(1,12) = 30.321, p < .001, η_p^2 = .716; F_2(1,31) = 98.407, p < .001, η_p^2 = .760) and this can be explained because there was little difference in performance on the relative clause for CE and RB structures, whereas performance on the main clause is worse for CE than RB. A three way Context x Sentence x Question interaction approached significance by subjects, but not by items (F_1(1,12) = 4.082, p = .066, η_p^2 = .254; F_2 (1,31) = 1.361, p = 0.252, η_p^2 = .042).

Post-hoc comparisons with Bonferroni adjustment (alpha = 0.0125) investigated the sentence x question interaction confirming that this effect was carried by significantly worse performance for CE than RB structures when the question was about the main

clause in both action (F_1 (1,12) = 97.299, p < .001, η_p^2 =.557 .; F_2 (1,31) = 48.758, p < 0.001, η_p^2 =.646) and no-action contexts (F_1 (1,12) = 159.053, p <.001, η_p^2 = .586; F_2 (1,31) = 52.023, p < 0.001, η_p^2 =.661) but a difference in the opposite direction when the question was about the relative clause which was not statistically reliable in the action context (F_1 (1,12) = 4.253, p =.052, η_p^2 = .061 ; F_2 (1,31) = 1.106, p = .301, η_p^2 = .040) but reached significance in the no-action context (F_1 (1,12) = 11.258, p = .006, η_p^2 = .128; F_2 (1,31) = 9.950, p = .004, η_p^2 = .272).

These data indicate that high-span children found CE structures more difficult to comprehend than RB structures, but that this difference was carried by a difficulty with the CE main clause coupled with good comprehension of the relative clause part of the sentence. There was also evidence that high span children were sensitive to the additional contextual information provided by the action pictures and that this information improved their comprehension performance.

Low-Span children

Consistent with the data from high span children ANOVA revealed a main effect of sentence (F_1 (1,17) = 20.712, p < .001, η_p^2 = .549; F_2(1,31) = 57.205, p < .001, η_p^2 = .649) with RB engendering more correct answers than CE sentences, and there was also a main effect of question (F_1(1,17) = 36.273, p < .001, η_p^2 = .681; F_2(1,31) = 39.194, p < .001, η_p^2 = .558) indicating, again, that more correct answers were given for the relative clause than the main clause overall. In contrast to the high span group, ANOVA did not reveal significant main effect of context (F_1(1,17) = 2.370, p = .142, η_p^2 = .122; F_2(1,31) = 2.762, p = .107, η_p^2 = .0.82), instead a Context x Question interaction was observed F_1(1,17) = 5.585, p = .030, η_p^2 = .247; F_2(1,31) = 6.517, p = .016, η_p^2 = .0.174). As for the high span group, there was a highly significant Sentence x Question interaction (F_1(1,17) = 14.917, p < .001, η_p^2 = .467; F_2(1,31) = 45.756, p < .001, η_p^2 = .596) confirming there was little difference in performance on the relative clause for CE and RB sentences, whereas performance on the main clause was worse for CE than RB. A three way Context x Sentence x Question interaction was significant by subjects, but not by items (F_1(1,17) = 5.248, p = .035, η_p^2 = .236; F_2 (1,31) = 1.528, p = 0.226, η_p^2 = .047).

Post-hoc comparisons (Bonferroni adjusted alpha = 0.006) to investigate the sentence x question interaction confirmed that this effect was carried by significantly worse performance for CE than RB structures when the question was about the main clause for both action (F_1 (1,17) = 99.760, $p < .001$, $\eta_p^2 = .528$; F_2 (1,31) = 121.637, $p < 0.001$, $\eta_p^2 = .661$) and no-action contexts (F_1 (1,17) = 52.921, $p < .001$, $\eta_p^2 = .373$; F_2 (1,31) = 91.433, $p < 0.001$, $\eta_p^2 = .595$) but no difference when the question was about the relative clause in either action (F_1 (1,17) = 1.313, $p = .268$, $\eta_p^2 = .014$; $F_2 < 1$) or no-action contexts ($F_1 < 1.$; F_2 (1,31) = 1.459, $p = .236$, $\eta_p^2 = .190$.) Like high-span children, low span children found CE structures more difficult to comprehend than RB structures, and this difference was explained by a difficulty with the CE main clause coupled with good comprehension of the relative clause part of the sentence.

Further post-hoc comparisons indicated that the question x context interaction arose because, for this group, context only had a positive effect on the relative clause questions for each sentence type. Mean performance was worse in the action condition than the no action condition for CE main clause questions, but this difference was not statistically significant (F_1 (1,17) = 2.886, $p = .108$, $\eta_p^2 = .078$; F_2 (1,31) = 2.154, $p = 0.152$, $\eta_p^2 = .025$). No significant difference was observed between performance in the action and no-action context for RB main clauses (F_1 (1,17) = 1.029, $p = .325$, $\eta_p^2 = .029$; $F_2 < 1$). Whilst performance was significantly better in the action condition that the no action condition for the CE Relative clause (F_1 (1,17) = 15.385, $p = .001$, $\eta_p^2 = .313$; F_2 (1,31) = 16.049, $p = 0.001$, $\eta_p^2 = .158$) the observed numeric advantage for RB relative clauses in the action condition was not statistically reliable (F_1 (1,17) = 4.219, $p = .056$, $\eta_p^2 = .111$; F_2 (1,31) = 9.004, $p = .005$, $\eta_p^2 = .095$).

Error responses

It is often informative to analyse the errors children make across conditions on linguistic tasks. However, in this study, 85% of errors involved naming the other animal mentioned in the sentence; this error occurred in all conditions and accounted for 97% of the total errors made on the CE Main clause. Other errors were usually ‘don’t know’ responses or, very rarely, the name of an animal not mentioned in the sentence. Given the small number of error types statistical analyses were not revealing and are not

reported here. The predominance of other animal errors for the interrupted main clause of the CE structure is consistent with the occurrence of comprehension errors resulting from a local attachment strategy (assume the second noun is the subject of the second verb).[4] However, given that this error type appeared across conditions it could equally reflect a guessing strategy – if children cannot answer the question they simply name one of the animals recently mentioned. In the latter case we would expect a 50% correct response rate in the CE main clause condition, which is not observed here (performance is below 50% for both groups), even so, our data do not allow us be certain about what drives children's errors.

In summary, both groups found questions about the CE main clause very difficult to answer, moreover both groups demonstrated good comprehension of the relative clause part of CE sentences, and of both clauses within RB sentences. For high span children context had a small but significant positive effect on overall comprehension performance, however, this advantage was only statistically reliable for questions about the centre-embedded relative clause in low span children.

Discussion

Our study investigated three main research questions. With respect to our first prediction that comprehension performance would benefit from action contexts (which fully met the pragmatic presuppositions of the relative clause) we found that children with both high- and low- verbal memory spans demonstrated some ability to utilize this extra-linguistic information in comprehension. Our second aim was to investigate whether context effects would be observed even for complex embedded constructions. Action contexts facilitated comprehension for each clause of both sentence types in high span children, however, facilitation only occurred for questions about the relative clauses (which were directly represented in the action picture) in children with lower verbal spans. The results suggest that contextual information can support comprehension, even for more complex sentences. Our third question concerned the interaction between memory span and contextual integration and it seems that sensitivity to context can be observed even for children with relatively low memory spans. However, children with higher memory spans demonstrated an additional positive effect of context for

comprehension of the main clause suggesting that as memory span increases so does the ability to integrate context fully.

Independently of our context manipulation, both groups of children demonstrated the predicted processing advantage for the right branching, compared with the embedded structures. Crucially, children demonstrated good comprehension for relative clauses in both types of sentence, and for the uninterrupted main clause of right-branching sentences. Therefore, the processing cost associated with embedded sentences can be attributed to difficulties in resolving the interrupted main clause, rather than to the lack of understanding of the function of the relative clauses proposed in previous research (e.g., Freidman & Novogrodsky, 2004; Sheldon, 1981;Tavakolian, 1981). The results are consistent with those observed in studies using the alternative act out task with younger children (Correa, 1995; Kidd and Bavin, 2002) and with cross-linguistic studies that have suggested centre-embeddings are dis-preferred in languages with strong biases towards canonical word order (Bates & MacWhinney, 1989; Bates, d'Amico and Devescovi, 1999). Explanations of the differential effects of context and the observed patterns of comprehension will each be considered in turn.

Sensitivity to contextual information and the role of cognitive capacity

Fully meeting the pragmatic demands of the relative clause produced small but significant increases in comprehension performance for both high and low span children. The importance of presenting children with a pragmatically complete situation was implied by the improvement in performance observed in the alternative act out task (e.g. Correa, 1995; Kidd & Bavin, 2002) compared with the standard task (Hamburger and Crain, 1982), and the present study corroborates this finding. The data suggest that children can integrate referential information with their emerging representation of the incoming language and that this information can support comprehension. This is broadly consistent with a view of a developing parser that is sensitive to extra-linguistic information, even during the initial stages of syntactic analysis (e.g., Trueswell & Gleitman, 2004). However, given that the task used here measured the end-point of comprehension (i.e., it was offline) further research is necessary to confirm whether this information is integrated during the earliest points of syntactic analysis. Furthermore,

given that the children tested were older than those in earlier research (6- to 8-years compared with children aged 3- to 5 in some studies) we cannot be sure just how early this interactive system develops in acquisition. However, contextual information was found to improve comprehension, under certain circumstances, even for children with a low VLS score. This may indicate that, even when memory span is limited, referential information can still be integrated with the emerging syntactic representation, in contrast to theories suggesting that contextual sensitivity only emerges as cognitive capacity increases.

Children in both groups exhibited a significant effect of context on comprehension of the relative clause for CE sentences. However, children with a higher verbal memory span demonstrated an additional positive effect of context for main clause questions, which was not evident in lower span children. The action pictures were a direct visual representation of the relative clause but did not contain information directly relevant to main clause processing. However, they did meet a pragmatic constraint of relativisation in that there was more than one potential referent, and that the relative clause provided information allowing a unique referent for the main clause to be identified. Children with a high memory span seemed to be able to use this information to support their comprehension of main clauses, particularly when the main clause information was difficult to process because of an interruption. For low span children this additional information seemed to decrease performance when the processor was already heavily taxed by maintaining information across an interruption. It is suggested that children utilise context to support their unfolding linguistic abilities, and that they can do this even with relatively limited cognitive capacity. However, as memory span increases contextual information is integrated in a more sophisticated way. It is also possible that high span children are able to use context more consistently because higher span equates to a better ability to manage a more demanding cognitive load.

A question arises as to whether children needed to encode the visual scenes verbally in order to integrate them later with their interpretation of the test sentence[5]. If this was the case then our results could perhaps be explained in terms of high span children having a greater ability to create such verbal representations, and to maintain them in memory. The current data do not rule out this possibility, which could be

explored in future research by directly comparing visual and verbal conditions. However, the adult literature investigating the mapping between the visual world and language suggests that adults do not necessarily verbally encode visual scenes in order to integrate them with language[6].

A limitation of our study is that we used only the verbal listening span task as a measure of working memory. This specific measure was chosen because memory span measured in this way has been shown to affect the processing preferences of children for ambiguous relative clauses (Felser et al., 2003), and to differentiate between children with good and poor comprehension skills (Nation et al., 1999). Furthermore, its reading-based equivalent (Daneman & Carpenter, 1980) has been associated with the extent to which various constraints can influence sentence processing (e.g., Just & Carpenter, 1992; MacDonald et al., 1992; Pearlmutter and Macdonald, 1995). However, we did not measure other aspects of working memory that may be less directly involved in language processing e.g., spatial memory. It has been suggested that verbal span tasks are essentially language processing tasks and may be little more than domain specific measures of language processing abilities (MacDonald & Christiansen, 2002). However, reading span tasks have been shown to correlate with non-linguistic measures (e.g., digit span in children, Booth at al, 2001; and spatial span in adults, Swets et al., 2007) suggesting that such tasks may share a common general component of working memory. In order to gain a full picture of the role of working memory in contextual integration further research is required using more diverse measures of memory with both adults and children.

Sentence complexity effects

As predicted, children comprehended the right branching sentences more accurately than embedded structures. Intriguingly, this effect was entirely carried by poor comprehension performance for the interrupted main clause of this structure, irrespective of verbal memory span. As such this processing cost can be seen as associated with the interruption of one clause by another. It has been suggested that the processing cost associated with this kind of interruption stems from the high demands placed upon short term memory (Miller, 1962; Slobin, 1973) so it is interesting that this

effect does not interact with memory span as measured here. It is possible that resolving the interrupted main clause is so cognitively demanding that it over-taxed even the children in our sample with relatively high memory spans (who still have significantly reduced cognitive capacity compared to adults); or that this effect reflects a processing bias which is unrelated to memory span.

Our results are consistent with other studies which have used similar comprehension tasks with adults (Bates et al., 1999; Sheldon, 1977) and children (MacWhinney & Pleh, 1988; Booth et al., 2000). Booth et al. (2000) included embedded subject-relative (but not right-branching) structures in an offline comprehension task similar to the one used here. Eight- to 11-year-old children were asked to answer a true or false question about each clause. They demonstrated very poor performance on the second verb (comparable to the main clause question in our study) and most errors involved interpretation of the second noun as subject of the second verb (as in the present study). They suggest that children adopt a local attachment strategy such as that proposed by Ford, Bresnan and Caplan (1982) taking the noun that is locally available over the noun that is syntactically correct. Based upon this claim Booth et al. (2000) predicted that children would have little difficulty with right-branching subject-relative structures, a prediction which is clearly borne out in the present study. Moreover, our data do not support the claim that main clause processing necessarily takes precedence over subordinate clauses, which are processed subject to sufficient cognitive resources (Correa, 1995; Townsend and Erb, 1975; Townsend, Ottaviano, & Bever, 1979).

Memory based accounts, originally proposed to account for the subject-object relative processing asymmetry in adults, can be extended to account for the findings observed here. The claim that the length unattached fillers must be carried for predicts cognitive load (Wanner and Maratsos, 1978) can be applied to the observed advantage that children have in processing right-branching structures, compared with embedded structures. Given the examples accompanying Figure 1 the filler phrase the cat must be carried, unattached, for longer than in its right branching counterpart. Furthermore, because both of these entities are semantically similar (both belonging to the same semantic category of animal) participants may experience similarity based interference (Gordon et al., 2001) for the more complex structure. Gordon et al. suggest that syntactic

complexity can be compounded by the confusability of the referents mentioned in each noun phrase. Clearly, the referents used here are highly confusable; 97% of the errors made by children involved naming the wrong animal, suggesting that similarity may play a role in processing difficulty.

However, our results could be interpreted in terms of simple attachment preference, such as the principle of late closure proposed by the garden path model (see Frazier, 1987, for a review). The embedded structure requires high attachment linking the cow as the object of the preceding clause; in comparison the right-branching structure requires low attachment because bear is the object of the most recent clause. If a representation was constructed based upon late closure, then the incorrect animal would be construed as the subject of the main clause, as observed for the embedded structure in our data with children. However, such an account does not predict the observed positive influence of contextual information upon processing.

Further research will be necessary to establish whether simple local attachment or memory-based accounts provide the most parsimonious explanation for the processing cost of centre-embedding in adults and children. If attachment preference alone explains the effect then it should remain even if the semantic content of the interrupting clause is manipulated.

Conclusions

The results presented here suggest that 6- to 8-year-old children are sensitive to the pragmatic constraints associated with the relative clause and that they can integrate extra-linguistic context with the incoming language and utilize this information to support their comprehension. These findings are broadly consistent with accounts that portray language acquisition as developing via some form of constraint based learning (e.g., Bates & MacWhinney, 1989; Seidenberg and MacDonald, 1999; Trueswell & Gleitman, 2004). Consistent with adult findings, embedded structures were found to be more difficult than right-branching sentences. Furthermore, there is clear evidence to suggest that by around the age of 6-years-old children understand relative clauses within both structures, and can consistently answer a comprehension questions about them correctly. The interrupted main clause of the embedded structure caused children's

difficulty with centre-embedded relative structures, rather than any difficulty with understanding the function of relative clause use. The present study provides important evidence for continuity throughout development of the parser demonstrating that even young children with relatively limited memory capacity can make some use of referential context to support their comprehension, but as memory span increases so does a more sophisticated ability to integrate context.

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Notes

[1]It has also been suggested that strong verb biases associated with the verb put may over-ride comparatively weak contextual constraints (see Snedeker & Trueswell, 2004, for further discussion of this issue).

[2]One anonymous reviewer advised that we rule out fatigue effects as an explanation of the relatively poor performance in the no-action conditions, which always occurred second in the experimental sessions. An ANOVA comparing the first half of no-action trials with the second half from both of the two experimental sessions confirmed that there was no main effect of trial position ($F_1(1,29) <1$) nor did it interact with verbal listening span group ($F_1(1,29) <1$).

[3]In doing this we closely followed the approach taken by Felser et al. (2003). However, we accept that splitting continuous data in this way is not uncontroversial. In order to investigate the relationship between memory and performance in an analysis which respects the continuous nature of verbal memory span as a variable, a series of correlational analyses were performed between span score and comprehension performance in each of the eight experimental conditions, as suggested by an anonymous reviewer. A positive significant correlation was found between VLS span and performance on the CE Relative clause in the action condition ($r = .426$, $n= 31$, $p < .05$). Interestingly, this is the condition which demonstrated the greatest improvement in comprehension, compared to its no-action counterpart, in the low VLS group. All other conditions were found to have a weak (but non-significant) positive correlation with span score, with exception of the CE Main clause which had a non-significant negative trend ($r = -.056$, $p > 1$). However, these results must be interpreted cautiously as the range of span scores was quite limited and the number of participants rather small for a correlational design. It should also be noted that an analysis of covariance (ANCOVA) is also consistent with the findings of the main ANOVA reported here.

[4]Booth et al (2000) suggest this explanation for their observation of a predominance of this error type in response to embedded sentences in a similar comprehension task.

[5]We thank an anonymous reviewer for raising this point.

[6]For example, participants have been shown to fixate upon visual competitors (e.g., a piano upon hearing trombone) even when the name of visual competitor does not overlap

phonologically with the spoken input. This suggests that the interaction between the visual world and incoming spoken language is not merely at the level of verbal encoding (Huettig & Altmann, 2005; see also Dahan & Tanenhaus, 2005; Huettig & Altmann, 2007; Huettig & Altmann, 2004).

Table 1: Relative clause types (adapted from Eisenberg, 2002).

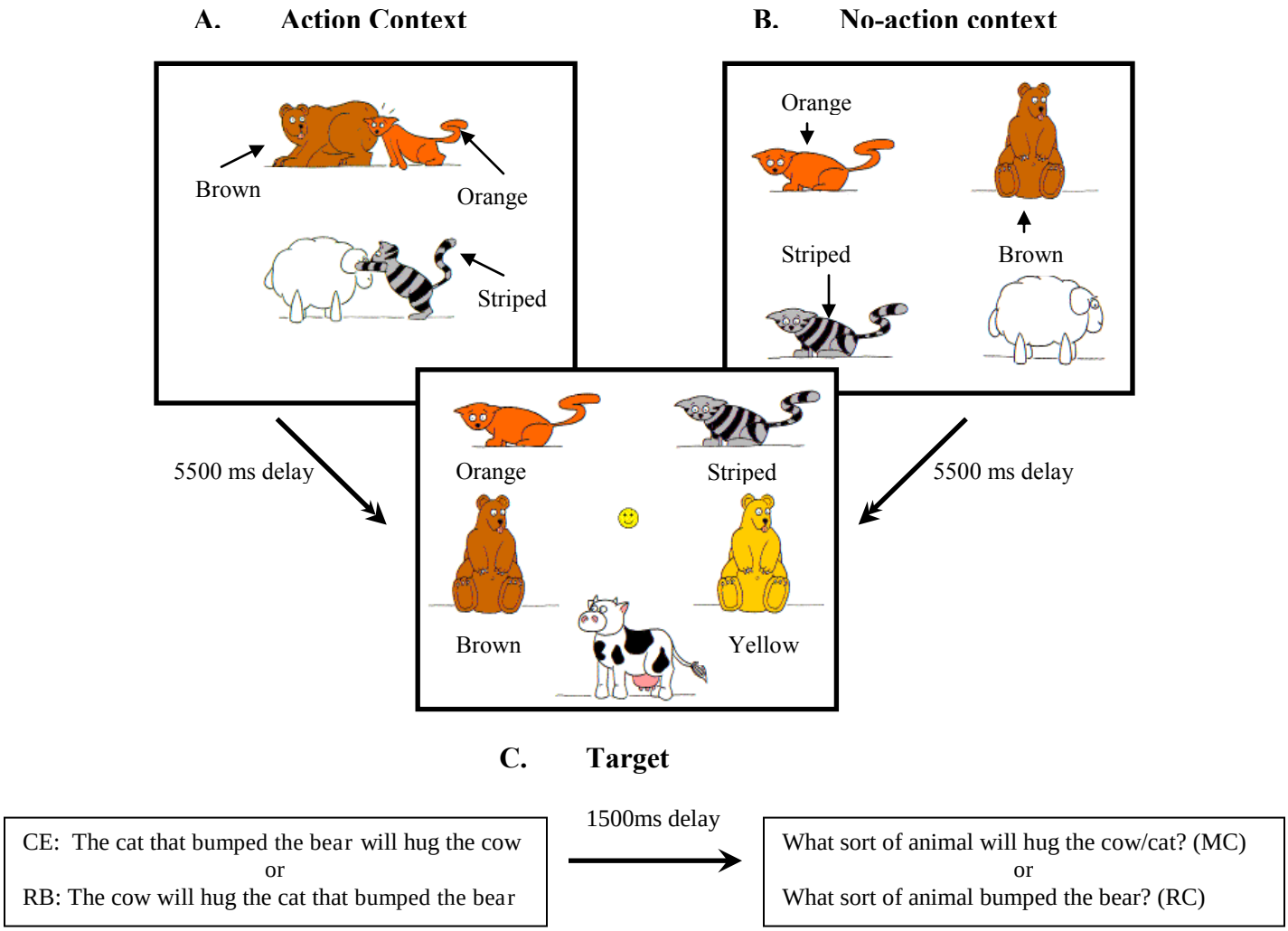
	Focus	
Embeddedness	Subject	Object
Right-branching	1. The pig bumps into the horse [that __ jumps over the giraffe].	3. The dog stands on the horse [that the giraffe jumps over __].
Centre-embedded	2. The dog [that __ jumps over the pig] bumps into the lion	4. The lion [that the horse bumps into __] jumps over the giraffe

Table 2: Percentage of correct answers given by high- and low-span children in each condition.

	High (n = 13)				Low (n = 18)			
Sentence	CE		RB		CE		RB	
Question	MC	RC	MC	RC	MC	RC	MC	RC
No-action	34 (41)	90 (15)	87 (18)	75 (26)	35 (22)	69 (24)	74 (22)	75 (19)
Action	41(39)	95 (8)	90 (9)	88 (18)	27 (29)	87 (16)	78 (27)	81 (24)

Note: Values are percentages. Standard deviations are shown in parentheses.

Fig. 1. Example of stimuli used for each trial Experiments 1 and 2. Participants saw either the action context or the no-action context picture, which was displayed for 5500 ms. They then saw the target picture. After a 1000 ms preview they heard either the accompanying CE or RB sentence. 1500 ms after the offset of the sentence, they heard the appropriate question, which they answered verbally. The target picture remained on screen until after the participants' response. (Original in colour, labels indicate the colours as they appeared on screen).



< figure 1 to be displayed in color on the web>

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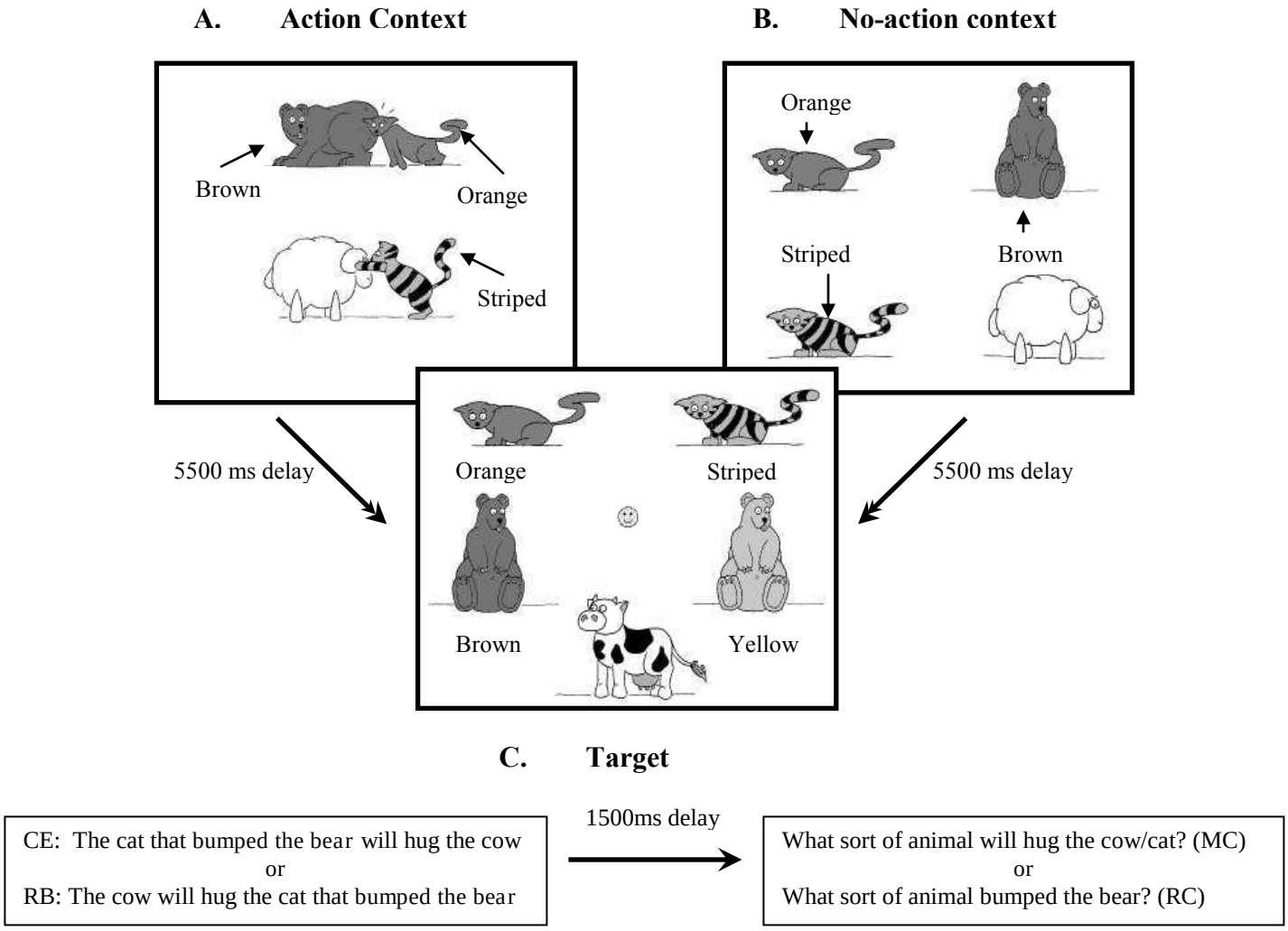

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Acknowledgements

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Appendix

The experimental stimuli are set out below. There were 32 CE/RB sentence pairs and each sentence was accompanied by an action or no-action context picture, followed by a target picture. After hearing each sentence a comprehension question was asked about either the relative or main clause. Questions took the form of '*What sort of animal….'*

Experimental stimuli

1a The cat that bumped the bear will hug the cow
1b The cow will hug the cat that bumped the bear
2a The bird that hugged the squirrel will hit the sheep
2b The sheep will hit the bird that hugged the squirrel
3a The rabbit that pushed the hedgehog will hug the pig
3b The pig will hug the rabbit that pushed the hedgehog
4a The dog that touched the crocodile will kick the hen
4b The hen will kick the dog that touched the crocodile
5a The monkey that kicked the dog will touch the rabbit
5b The rabbit will touch the monkey that kicked the dog
6a The crocodile that kicked the pig will bite the duck
6b The duck will bite the crocodile that kicked the pig
7a The pig that touched the tortoise will follow the cat
7b The cat will follow the pig that touched the tortoise
8a The cow that bit the horse will push the dog
8b The dog will push the cow that bit the horse
9a The elephant that hugged the rabbit will bump the horse
9b The horse will bump the elephant that hugged the rabbit
10a The squirrel that followed the mouse will hit the monkey
10b The monkey will hit the squirrel that followed the mouse
11a The horse that bumped the cat will hug the bird
11b The bird will hug the horse that bumped the cat
12a The mouse that pushed the pig will kick the lion
12b The lion will kick the mouse that pushed the pig
13a The hedgehog that followed the cow will touch the elephant
13b The elephant will touch the hedgehog that followed the cow
14a The kangaroo that bumped the monkey will bite the pig
14b The pig will bite the kangaroo that bumped the monkey
15a The hen that touched the rabbit will follow the snake
15b The snake will follow the hen that touched the rabbit
16a The snake that followed the horse will push the mouse
16b The mouse will push the snake that followed the horse
17a The horse that bit the duck will bump the bear
17b The bear will bump the horse that bit the duck
18a The duck that kicked the cow will hit the tortoise

18b The tortoise will hit the duck that kicked the cow
19a The sheep that hit the hen will hug the hedgehog
19b The hedgehog will hug the sheep that hit the hen
20a The bear that hugged the hen will kick the squirrel
20b The squirrel will kick the bear that hugged the hen
21a The sheep that followed the monkey will touch the crocodile
21b The crocodile will touch the sheep that followed the monkey
22a The hen that kicked the mouse will bite the cow
22b The cow will bite the hen that kicked the mouse
23a The mouse that hugged the duck will follow the sheep
23b The sheep will follow the mouse that hugged the duck
24a The dog that bit the bird will push the mouse
24b The mouse will push the dog that bit the bird
25a The lion that bit the kangaroo will bump the hen
25b The hen will bump the lion that bit the kangaroo
26a The cow that pushed the sheep will hit the rabbit
26b The rabbit will hit the cow that pushed the sheep
27a The rabbit that hit the cat will bump the duck
27b The duck will bump the rabbit that hit the cat
28a The monkey that hit the elephant will kick the cat
28b The cat will kick the monkey that hit the elephant
29a The duck that pushed the lion will touch the dog
29b The dog will touch the duck that pushed the lion
30a The pig that touched the sheep will bite the horse
30b The horse will bite the pig that touched the sheep
31a The tortoise that bumped the snake will follow the monkey
31b The monkey will follow the tortoise that bumped the snake
32a The cat that hit the dog will push the kangaroo
32b The kangaroo will push the cat that hit the dog