Journal of Experimental Child Psychology 112 (2012) 389–402

Contents lists available at SciVerse ScienceDirect

Journal of Experimental Child Psychology

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

Preschoolers' sensitivity to speaker action constraints to infer referential intent

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ARTICLE INFO

Article history:
Received 30 August 2011
Revised 30 March 2012
Available online 29 May 2012

Keywords:
Linguistic reference
Intention
Action
Eye movements

ABSTRACT

We investigated how preschoolers use their understanding of the actions available to a speaker to resolve referential ambiguity. In this study, 58 3- and 4-year-olds were presented with arrays of eight objects in a toy house and were instructed to retrieve various objects from the display. The trials varied in terms of whether the speaker's hands were empty or full when she requested an object as well as whether the request was ambiguous (i.e., more than one potential referent) or unambiguous (i.e., only one potential referent). Results demonstrated that both 3- and 4-year-olds were sensitive to speaker action constraints and used this information to guide on-line processing (as indexed by eye gaze measures) and to make explicit referential decisions.

Introduction

Consider a situation in which a parent walking with a child in a parking lot exclaims "Car!" In this situation, the intended meaning of the utterance is ambiguous because there is insufficient linguistic information to identify which car, of the many cars present in the situation, is the intended referent. If, however, one car is speeding through the parking lot, referential ambiguity is reduced as a result of the child's ability to gauge the parent's situation-specific intention (i.e., to direct attention to the approaching car and ultimately avoid danger). This example highlights the ambiguity inherent in language and the need for listeners to draw on information beyond the specific words in an utterance to clarify a speaker's intentions. In the current study, we investigated preschoolers' sensitivity to information in the communicative context, specifically, the actions currently available to a speaker, to infer a speaker's intent and resolve referential ambiguity.

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http://dx.doi.org/10.1016/j.jecp.2012.03.008

Research suggests that the preschool and kindergarten years are developmentally important in terms of children's ability to both recognize and resolve ambiguous messages. A number of studies have demonstrated that children as old as 6 years can have difficulty in expressing explicit awareness of message ambiguity both when making referential decisions and when evaluating message clarity (e.g., Beal & Flavell, 1982; Bearison & Levey, 1977; Beck, Robinson, & Freeth, 2008). However, studies that have employed highly sensitive measures, such as response latencies and eye gaze measures, have demonstrated that sensitivity to ambiguity emerges earlier during the preschool years (Matthews, Lieven, Theakston, & Tomasello, 2007; Nadig & Sedivy, 2002; Nilsen & Graham, 2009; Nilsen, Graham, Smith, & Chambers, 2008; O'Neill, 1996; Plumert, 1996). For example, 4-year-olds show an implicit appreciation for spatial ambiguity (Plumert, 1996) and can detect ambiguity in contexts where a child is a third party to a communicative exchange (Nilsen & Graham, in press; Nilsen et al., 2008) despite the fact that their explicit responses might not reflect these capabilities.

Although frequent in everyday conversation, ambiguities such as the one described in our opening example rarely surface to conscious awareness. Rather, they are typically resolved through the application of various informational cues. Studies of comprehension with adults and children have demonstrated that these cues are drawn from a variety of linguistic, paralinguistic, and extralinguistic information sources. For example, listeners may draw on linguistic prosody and structural patterns frequently associated with certain lexical items to resolve ambiguities at lexical, syntactic, and referential levels (e.g., Ito & Speer, 2008; Snedeker & Trueswell, 2004; Snedeker & Yuan, 2008; Trueswell, 1996). The role of paralinguistic information is evident in listeners' use of cues provided by speaker identity and the emotional valence conveyed via the speaker's voice (e.g., Berman, Chambers, & Graham, 2010; Creel & Bregman, 2011; Herold, Nygaard, Chicos, & Namy, 2011; Nygaard & Lunders, 2002; van Berkum, van den Brink, Tesink, Kos, & Hagoort, 2008). Relevant extralinguistic cues include information about the speaker's visual perspective (e.g., Nadig & Sedivy, 2002; Nilsen & Graham, 2009) and information from the speaker's eye gaze or gestures (Bangerter, 2004; Hanna & Brennan, 2007). Many of these same cues have been observed to influence the acquisition of new words. For example, in the case of extralinguistic information, studies have demonstrated that children can use eye gaze (e.g., Baldwin, 1993; Moore, Angelopoulos, & Bennett, 1999), a speaker's affective and/or behavioral cues (e.g., Behne, Carpenter, & Tomasello, 2005; Tomasello, Strosberg, & Akhtar, 1996), and the relative novelty of objects or actions in the discourse context (e.g., Akhtar, Carpenter, & Tomasello, 1996) to infer the intended meaning of a novel word.

In this study, we considered children's sensitivity to another type of extralinguistic cue that has received comparatively little empirical attention with children, namely the actions that the environment affords for conversational participants. Studies of real-time comprehension with adults have demonstrated that situation-specific aspects of the physical context are used alongside information from linguistically evoked actions to contour the domain of reference used for referring expressions. The most straightforward examples involve a "first-person" assessment of the communicative environment, where a listener evaluates possible actions from her or his own perspective. For example, on hearing "Put the cube inside the can," listeners rapidly use idiosyncratic information about the size and shape of display objects to limit attention to candidates compatible with a "put inside" action (i.e., containers large enough to accommodate the cube), allowing the referential description to become unambiguous when more than one can is actually present (Chambers, Tanenhaus, Eberhard, Filip, & Carlson, 2002).

A higher order version of this process is illustrated in cases where listeners must evaluate the possible actions available to *another* individual. Hanna and Tanenhaus (2004) investigated whether adults use this information to identify the intended referent of an ambiguous definite noun phrase. Eye movements to real objects in the visual environment were recorded as participants assisted a confederate (the "cook") in following a recipe. The materials for the recipe were located in specific areas on a tabletop workspace such that some were in the participant's area and others were in the cook's area, although some of the materials in the cook's area were also accessible to the participant. Each participant heard a series of instructions, one of which was a critical instruction containing a referentially ambiguous expression (e.g., "Could you put *the cake mix* next to the mixing bowl?" in the presence of two boxes of cake mix). During the critical instruction, one of the potential referents was located in the participant's area and the other in the cook's area. The timing of the critical instruction was such that it occurred either when the cook's hands were empty or when they were holding a tray. The

(in)ability of the cook to reach various objects thereby provided a potential domain restriction for the listener. Specifically, when the cook's hands were empty, participants should infer that the intended referent is the cake mix in their *own* area because that would have been the most plausible referent given the cook's current reaching ability (i.e., the cook could have reached for the cake mix in her own area without the help of the participant). Conversely, when the cook's hands were full, both boxes of cake mix could serve as the potential referent because the cook was no longer capable of reaching either of them. Participants were provided with explicit training prior to performing the task. Specifically, there were two practice trials to demonstrate the experimenter's action constraints, and participants received the specific instruction that throughout the task they "would have to help [the experimenter] out either by moving the objects that [the experimenter] couldn't reach or by moving one of [the experimenter's] own objects if she couldn't do it herself" (p. 109).

Participants' object selections in the Hanna and Tanenhaus (2004) study indicated that they considered the pragmatic constraints imposed by the physical layout to narrow the domain of interpretation in the hands-free condition, allowing the referring expression to become unambiguous. Specifically, participants never selected the object in the cook's area when the cook's hands were empty, but they selected the object in the cook's area 61% of the time when the cook's hands were full. Furthermore, eye-tracking data provided critical evidence that the influence of this constraint was evident during the early moments of referential processing. Thus, in the structured setting of this experiment, adults were efficient at rapidly using the potential actions available to the speaker to infer communicative intent and thereby constrain referential interpretation.

It is unclear whether children, like adults, can rapidly draw on cues such as the potential actions available to a speaker to resolve referential ambiguity. Indeed, studies have demonstrated that children may have difficulty in capitalizing on information in the visual context that is routinely used by adult listeners (Hurewitz, Brown-Schmidt, Thorpe, Gleitman, & Trueswell, 2000; Trueswell, Sekerina, Hill, & Logrip, 1999). For example, Hurewitz and colleagues (2000) showed that a discrepancy exists between children's ability to *notice* relevant aspects of visually presented objects and their ability to *use* the same information to resolve syntactic ambiguity in sentences referring to these objects. In their study, 4- and 5-year-olds readily used modified noun phrases to distinguish between two potential referents. For example, when two frogs were present, children would distinguish between the two referents by saying something such as "The frog *on the book*." However, when hearing an instruction such as "Put the frog on the book into the box," children rarely interpreted *on the book* as a modifier and instead responded by selecting one of the frogs at random, placing it on the book (adopting a "destination" interpretation rather than the intended "modifier" interpretation of *on the book*) and then moving it into the box. Thus, when listening to sentences in a "two-referent" context, children did not appreciate that a rational speaker would provide additional information about which frog was intended (which in turn would clarify the role of the ambiguous phrase) even though children themselves provided this information when describing display objects. Even in simpler cases involving only referential ambiguity and where nonlinguistic cues are directly drawn from the acoustic signal rather than from the external environment (e.g., emotional affect information), children's ability to overtly act on these cues to overcome ambiguity can be somewhat modest, and the relevant sensitivity is detected primarily by using implicit measures of processing (Berman et al., 2010).

These and other results indicate that children's ability to use accompanying cues to guide language interpretation is not uniform in character and is sometimes revealed only by implicit measures. Research that explores this issue, therefore, requires an approach in which the type of informational cue (and the kind of inference involved) is considered on a more case-by-case basis and in which the use of cues is assessed in multiple ways.

Recently, Grosse, Moll, and Tomasello (2010) asked whether 21-month-olds interpret ambiguous messages by drawing on adult-like assumptions that people tend to make requests only for things that they cannot easily obtain themselves. To address this question, an experimenter made a potentially ambiguous request when she asked children to retrieve one of two identical objects. The difference between the objects was their distance from the experimenter; one object was within her reach on a table at which she was seated, and the other was out of her reach on a different table nearly 5 feet away. The experimenter made the request in one of three conditions: hands-free (one of her hands was empty), hands-occupied (she held an object in each hand), and a free-choice baseline condition

(one of her hands was empty, but no request for help was made). Grosse and colleagues concluded that 21-month-olds understand the cooperative logic of requests because children chose the distant object significantly more often in the hands-free condition than they did in the hands-occupied and baseline conditions.

However, several issues with Grosse and colleagues' (2010) study render the findings suggestive, rather than definitive, evidence that toddlers consider speaker action constraints in their referential decisions. First, the behavior identified as successful performance in the hands-free condition in fact involved the at-chance selection of the distant object over the nearby object. Therefore, the success was due only to a relative bias for selecting the nearby object in the other two comparison conditions, where at-chance performance would have been more expected. Second, the origin of this bias is plausible due to the presence of additional cues in the hands-occupied and free-choice conditions. Specifically, the hands-occupied condition included additional commentary on the part of the experimenter ("I will come over to you") at the beginning of each trial in order to give the experimenter a reason to occupy her hands; she picked up some objects as though she intended to bring them to the child. However, informing the child of her intention to move from the table might have suggested that her action constraints were flexible and that if she wanted the distant object she could get up and move toward it. In the hands-free condition, the experimenter gave no indication that she could move from behind the table during the trials.

In the free-choice baseline condition, the notion of choice was created through the use of an indefinite noun phrase ("Take *a* battery") rather than a definite noun phrase ("Take *the* battery"), as used in the hands-free and hands-occupied conditions. Indefinite noun phrases, such as the one used in the free-choice condition, imply that the speaker has no particular referent in mind, whereas definite noun phrases are used to denote a uniquely identifiable referent (Maratsos, 1974). Children begin to use determiners at around 2 years of age and are thought to develop the cognitive abilities necessary to understand determiners even prior to 2 years (Rozendaal & Baker, 2008). Therefore, the absence of free-choice performance must result from an additional factor such as the fact that the distant object required greater effort to retrieve it (i.e., the child would need to retrieve it and then bring it to the experimenter). Furthermore, there is a sense in which the notion of free choice is unexpected within the experimental context because the experimenter had previously demonstrated that only one of the objects was functional (e.g., only one of the batteries would allow the flashlight to function). This may trigger a different set of reasoning processes in this condition. Overall, then, the way in which different types of information varied in importance across conditions makes it difficult to isolate the precise way in which the actions available to the speaker influenced children's reasoning.

The current study builds on the suggestive evidence provided by Grosse and colleagues (2010) by examining preschool-aged children's sensitivity to speaker action constraints in resolving referential ambiguity. Specifically, we examined how 3- and 4-year-olds' sensitivity to cues in the contextual environment (and, more specifically, the actions that this environment affords) would be seen in both explicit *and* implicit measures. That is, we investigated not only whether 3- and 4-year-olds consider the actions available to a speaker when inferring the intended referent for an ambiguous phrase but also *how quickly* and *when* during processing this consideration may take place. To achieve these goals, we compared children's overt awareness of speaker action constraints (object selection) with more sensitive measures (response latencies and eye gaze). In addition, the design of the current study more clearly isolates the influence of speaker action constraints on children's ability to resolve referential ambiguity by avoiding the provision of additional cues about the speaker's action constraints and by using only definite noun phrases.

Preschoolers were asked to help an experimenter pack a backpack with various toys from within a toy house display. Two factors were varied across trials: whether the experimenter's hands were empty or full at the time of the instructions to retrieve objects and whether the instructions were ambiguous (i.e., two potential referents in the array—one located within the reach of both the experimenter and the child and one located within the reach of the child only) or unambiguous (i.e., only one potential referent in the array). The ability or inability of the experimenter to reach the toys in the house offered a potential referential domain restriction during the ambiguous instruction trials. That is, when the experimenter's hands were empty, we expected that the child would restrict the referential domain to the toys within the child's own area, more often selecting the referent that only she

or he could reach. The child's preference for toys in her or his own area should persist even when there is an equally plausible referent in the experimenter's area because the experimenter would retrieve that toy if it were the intended referent. Conversely, when the experimenter's hands were full, we anticipated that the child would expand the referential domain to include the toys in the experimenter's area because the experimenter was no longer capable of reaching those toys herself. If both the experimenter's area and the child's area contained an instance of the mentioned object, therefore, the instruction would be ambiguous.

Method

Participants

Data from 27 3-year-olds (M_{age} = 44.15 months, SD = 3.74) and 31 4-year-olds (M_{age} = 57.08 - months, SD = 2.90) were included in the final sample (overall N = 58, 26 girls and 32 boys, M_{age} = 51.06 months, SD = 7.29). An additional 27 children were tested but excluded from analyses due to the following reasons: did not complete the task (n = 2), experimenter error (n = 5), statistical outliers (i.e., having a z score of ±3.00) on two or more critical variables (n = 5), failure to fixate all objects in the array at least one time on at least three of four ambiguous instruction trials (n = 12), and failure to consider more than one object within one or more of the ambiguous instruction trials (n = 3). The exclusion criteria based on fixation patterns were applied to address the interpretive problem whereby children might appear to use speaker action constraints to isolate a particular referent when in fact they were simply not aware that the display contained an alternative referent for the expression. Controlling for children's awareness of alternative candidates in this way is particularly important given the greater visual complexity of the displays in the current experiment (i.e., a scene containing eight objects) compared with other studies. Participants were from homes in which English was the primary spoken language, were from varied socioeconomic backgrounds, and were primarily Caucasian.

Materials

A large toy house (36 inches wide × 16½ inches high) with three upper compartments (12 inches wide × 8 inches high) and two lower compartments (18 inches wide × 8 inches high) was constructed for this study. Two latched doors on the back of the toy house allowed a second experimenter to place the objects inside of the house for each set of trials. A Sony video camera was placed in the top middle compartment and was hidden from view except for a small opening to allow recording of the children's eye gaze. Another camcorder was placed behind the children to record object selections.

A total of 24 familiar objects were divided into three object sets: one set of eight objects for the training phase and two sets of eight objects for the two testing blocks. The object sets for the testing blocks included two pairs of objects that differed only in color from one another and four unrelated objects. All objects were selected in consultation with the MacArthur–Bates Lexical Developmental Norms, and only those objects whose names were either understood or produced by at least 95% of 2½-year-olds in the normative sample were included.

Procedure

Each child was seated in a chair in front of the toy house. To introduce the task, Experimenter 1 (E1) explained that they would be playing with a toy house and that the second experimenter (E2) would put different toys in the house for the child to look at. E1 told the child that a puppet named "Spot" was going to a friend's house and would like to bring some of the toys to show his friend. E1 then explained that the child would help place toys in the backpack on Spot's request.

Training phase

Following the placement of the eight unrelated training objects in the house, E1 followed a preset script and demonstrated to the child that she could reach only the toys on the left side of the toy house

(E1's area) and could not reach the toys on the right side of the house (child's area). In addition, E1 emphasized that only the child could reach *all* of the toys in the house because the child had the advantage of sitting directly in front of the toy house. Thus, it is important to note that the objects in E1's area and the objects in the child's area were of equal distance from the child, all easily within reach her or his reach. E1 then picked up the backpack with both hands and explained that sometimes her hands would be full and she would not be able to reach *any* of the toys in the house. The child participated in eight training trials, four of which occurred when E1's hands were full and four of which occurred when E1's hands were empty. Furthermore, four of the training trials occurred with the requested object located in E1's area and four occurred with the requested object located in the participant's area. When E1's hands were empty and the object was located in her area, she would say, "My hands are empty. Spot wants the *car*. I'll get it!" and placed it in the backpack herself. When E1's hands were empty but the object was located in the participant's area, she would say, "My hands are empty. Spot wants the *toothbrush*. I can't *reach* it!" and stretch her arm across the house to demonstrate that she was unable to reach the object. When E1's hands were full (holding the backpack), she would say, "I can't get it!" for all trials regardless of where the object was located. After the training phase, E1 pointed out that the child had a very good seat because she or he was able to reach *all* of the toys in the house.

Test phase

Six trials were conducted within each of two testing blocks for a total of 12 trials. Within each block, four trials were critical trials and two trials were reminder trials. The critical trials varied two experimental parameters: the *hand contents* of E1 and the presence of *ambiguity* in the request. See Fig. 1 for an overview of the critical trial and hypotheses. For two of the critical trials within each block, E1's hands were full (holding the backpack), and for the other two critical trials, her hands were empty. The hand contents manipulation was crossed with the ambiguity manipulation. On the *ambiguous instruction* trials, E1's request was referentially indeterminate in that there was more than one potential referent in the house (e.g., "Spot wants the horse" when there were two horses present). On the *unambiguous instruction* trials, there was only one potential referent in the house (e.g., "Spot wants the duck" when there was only one duck in the house). The unambiguous instruction trials were included to prevent children from developing specific expectations regarding which objects E1 would request such as an expectation that the referring expressions would always be ambiguous or that E1's utterance would always refer to a member of a pair. In the two *reminder instruction* trials, E1 verbally and visually reminded the child what she could and could not reach in the house. The six trials within each testing block were presented in a quasi-randomized fashion, and the position of the objects within the toy house was counterbalanced, with the exception that the critical objects were always located in the leftmost and rightmost spaces. This ensured that E1's reaching constraints were salient for the ambiguous instruction trials.

For each testing block, E2 placed the set of test objects in the compartments, beginning with the objects in E1's area. E1 again drew the child's attention to each object by naming the objects, one by one, as they were placed in the house. When the second item of a pair was placed in a compartment, E1 emphasized that the object was part of a pair (e.g., "Oh, and *another* horse!"). The preamble "Oh, and *another* . . ." was used to introduce objects in both E1's area and the child's area, depending on the position of the objects for a particular test phase.

At the beginning of every trial, E1 drew the child's attention to herself and showed the child that her hands were either full or empty. When E1's hands were empty, she held her palms face-up in front of the child and said, "My hands are *empty*!" When E1's hands were full, she held one side of the backpack with each hand, raised it in front of the child, and said, "My hands are *full*!" E1 then directed the child to look back at a smiley face sticker located in the center of the house. When the child's gaze was directed at the smiley face (E1's vantage point allowed her to determine where the child was looking), E1 told the child which object Spot would like (e.g., "Spot wants the *horse*!") and directed the child to put that object in the backpack, which was either in E1's hands (during the hands-full trials) or open on the floor beside the child's chair (during the hands-empty trials). During the trial, E1 directed her eye gaze toward the child to avoid providing any nonverbal cues as to the intended referent. In addition, E1 was careful to produce the instructions with similar prosodic features across conditions.

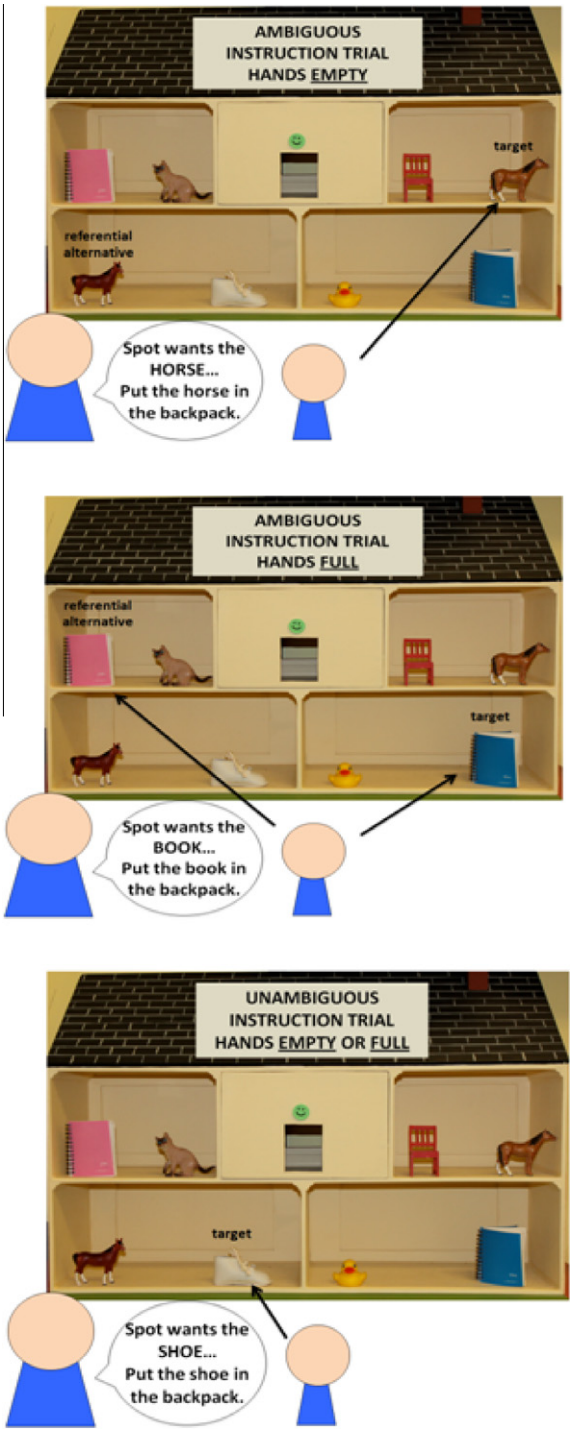

Fig. 1. Example of critical display across conditions and hypothesized object selections.

For the reminder instruction trials, the procedure differed slightly. During the reminder hands-empty trials, E1 requested a referentially unique object that was located in her own area, but rather than ask the child to place the object in the backpack, E1 said, "I'll get it!" and reached for it herself. During the reminder hands-full trials, E1 requested a referentially unique object located within the participant's area, but rather than ask the child to retrieve the object, E1 directed her gaze at the object, with her hands holding the backpack, and said, "I can't get it!" If the child failed to respond to an instruction within approximately 10 s or asked for clarification, E1 repeated the instruction.

Coding

Three key dependent measures were coded. The first measure was the latency for the child to touch an object following the onset of the noun (e.g., the /b/ sound in "book" for the sentence "Spot wants the book"). A research assistant who was unaware of the hypotheses of the study coded this latency using the recording from the scene camera positioned behind the child. A second research assistant coded 10 randomly selected participants (17% of the sample) to provide a measure of interrater reliability. Intraclass correlation coefficients (*ICC*s) were used to establish the pattern and level of agreement of raters (Sattler, 1992). The *ICC* indicated an excellent level of agreement between raters, $ICC(79) = .98$, $p < .001$. The second measure was children's gaze to scene objects as the critical referring expression was heard. This allowed us to test for an implicit awareness of referential ambiguity and sensitivity to speaker action constraints during real-time comprehension. Eye gaze measures place very low task demands on children and provide ecologically valid insights into the moment-to-moment processes underlying the comprehension of language (Fernald, Zangl, Portillo, & Marchman, 2008). In addition, recent research has demonstrated that preschoolers often show evidence of certain referential communication abilities in eye gaze measures prior to demonstrating the abilities in their overt decisions (Berman et al., 2010; Nilsen & Graham, in press; Nilsen et al., 2008).

Children's eye gaze was coded from the onset of the noun until the child touched an object in the house (determined separately using the scene camera recordings). Videos were analyzed on a frame-by-frame basis (33 ms = 1 frame) in FinalCut Pro 5.0.4, with audio and video signals fully synchronized. On the ambiguous instruction trials, the referent in the participant's area was always considered the *target* object, and the other toy from the pair in the experimenter's area was always considered the *referential alternative*. The *ICC*s for total looking time to the target and total looking time to the referential alternative indicated an excellent level of agreement between raters for both variables, $ICC(79) = .99$, $p < .001$.

Finally, object selections were used to measure children's overt ability to attend to the speaker's action constraints and resolve ambiguity during ambiguous instruction trials. For the ambiguous instruction trials, children's object selections were coded as the object that the child touched first—either in the experimenter's area or in the participant's area. As with the eye gaze measures, the referent in the participant's area was always considered the *target* object, and the other toy from the pair in the experimenter's area was always considered the *referential alternative*. Only selections of the target and referential alternative were coded because no children selected a distracter object. Object selections were coded by E2 during the experiment and were then recoded by the primary coder from the videotape record to ensure interrater reliability. There was a 100% level of agreement between raters on this variable, resulting in a Cohen's kappa coefficient of 1.00.

Results

Latency to first touch

Our predictions were as follows. If children recognized the ambiguity (when present), their response latencies would be significantly longer for the ambiguous instruction trials than for the unambiguous instruction trials. Furthermore, if E1's action constraints served as a domain restriction for the ambiguous instruction trials, latency to first touch would be shorter on the ambiguous hands-empty trials compared with the ambiguous hands-full trials.

A 2 (Age Group: 3- vs. 4-year-olds) × 2 (Instruction Type: ambiguous vs. unambiguous) × 2 (Hand Contents: hands-empty vs. hands-full) repeated-measures analysis of variance (ANOVA) yielded a significant main effect only of instruction type, $F(1, 56) = 73.54$, $\eta_p^2 = .57$, $p < .001$. Specifically, children responded faster to the unambiguous instruction trials ($M = 2089$ ms, $SD = 438$) compared with the ambiguous instruction trials ($M = 2951$ ms, $SD = 789$). There were no other significant effects. Thus, 3- and 4-year-olds apparently were sensitive to referential ambiguity when it was present, but information about speaker action constraints was not reflected in the time to touch a selected object even when the action constraint provided a cue to communicative intent (i.e., the ambiguous hands-empty trials).

Eye gaze data

On the ambiguous instruction trials, we expected that children would spend a greater proportion of time looking to the target object (the object in the participant's area) versus the referential alternative (the object in the experimenter's area) when E1's hands were empty but would consider the target and referential alternative equally when E1's hands were full. That is, if preschoolers were sensitive to speaker action constraints in their implicit inferences about communicative intent, they would be more likely to assume that E1 intended to refer to the referent that she could not reach herself (the target) when her hands were empty. Conversely, when E1's hands were full, children should consider both referents to a similar extent. Our analyses focus on the ambiguous instruction trials because it is on these trials that children were required to attend to a speaker's action constraints to resolve ambiguous messages. Children's eye gaze during the unambiguous instruction and reminder instruction trials could not be analyzed because there was only one potential referent for these trials.

Children's looking times to the target and referential alternative were converted to proportion scores by dividing the looking time to the relevant quadrant by the total looking time overall (see Fig. 2). The total looking time was calculated as the interval beginning at the onset of the noun and ending at the time point at which children touched an object in the house. For analysis purposes, we then used a target time advantage score, which reflects the extent to which the target object

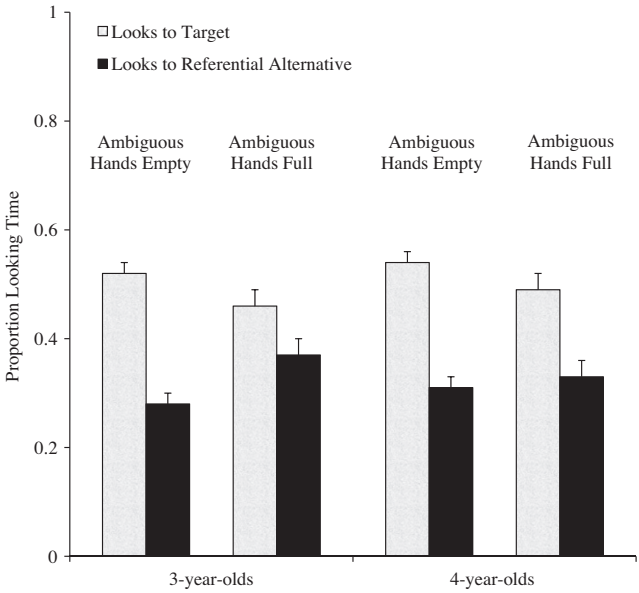

Fig. 2. Proportions of time spent fixating target object and referential alternative during ambiguous instruction trials.

was considered relative to the referential alternative. We calculated this score by subtracting the proportion of time spent fixating the referential alternative from the proportion of time spent fixating the target. If children consider both the target and the referential alternative in response to E1's request, this difference score will be significantly smaller than if children consider the target object to a greater extent than the referential alternative. A 2 (Age Group) × 2 (Hand Contents) repeated-measures ANOVA using the target advantage scores as the dependent measure yielded a main effect only of hand contents. Specifically, there was a significantly greater target time advantage on the ambiguous hands-empty trials ($M = .24$, $SD = .30$) than on the ambiguous hands-full trials ($M = .12$, $SD = .40$), $F(1, 56) = 4.67$, $\eta_p^2 = .08$, $p < .05$. Thus, when the speaker's hands were empty, both 3- and 4-year-olds used this information to infer that the speaker intended to refer to the object that was out of her reach. When the speaker's hands were full, however, children gave more equal consideration to the two potential referents.

The eye gaze data also allowed the assessment of whether children used information about the speaker's action constraints early in processing the instruction, as has been found with adults (Hanna & Tanenhaus, 2004). Children's first looks after the onset of the noun were analyzed for the ambiguous instruction trials to evaluate whether children were more likely to look to the quadrant where the target was located (i.e., on the child's side out of E1's reach) immediately after onset of the noun when E1's hands were empty versus when her hands were full. A 2 (Age Group) × 2 (Hand Contents) ANOVA yielded no significant effects. Both 3- and 4-year-olds were as likely to make their first look to the participant's area for ambiguous hands-empty trials ($M = 56\%$, $SD = 38$) as they were for the ambiguous hands-full trials ($M = 54\%$, $SD = 40$), $F(1, 56) = 0.62$, $p = .81$. Thus, although preschoolers' overall eye gaze patterns indicated that children used speaker action constraints as a cue to communicative intent, this effect was not evident during the earliest moments of processing.

Object selections

On the unambiguous instruction and reminder instruction trials, all children selected the target referent 100% of the time (i.e., there was zero variance in these cells); thus, these data were not included in the analyses. For object selections on the ambiguous instruction trials, we predicted that children would choose the target object more often for the ambiguous hands-empty instruction trials but that

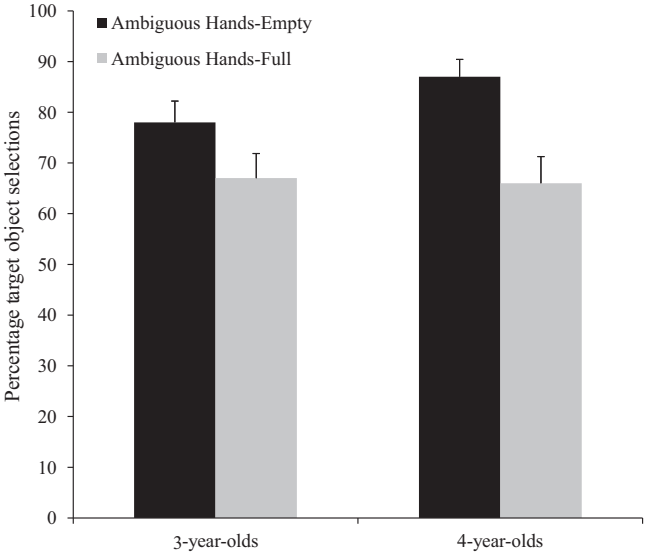

Fig. 3. Percentage target object selections during ambiguous instruction trials.

they would select the target object at chance for the ambiguous hands-full instruction trials. See Fig. 3 for percentage target object selections during ambiguous instruction trials. A 2 (Age Group) × 2 (Hand Contents) ANOVA indicated a significant main effect only of hand contents, $F(1, 56) = 7.88$, $\eta_p^2 = .123$, $p < .01$. Preschoolers selected the target object significantly more often in the ambiguous hands-empty trials ($M = 83\%$, $SD = 29$) than in the ambiguous hands-full trials ($M = 66\%$, $SD = 38$). One-sample t tests revealed that the percentage of target object selections was significantly greater than chance (50%) for both the ambiguous hands-empty trials, $t(57) = 8.62$, $p < .01$, and the ambiguous hands-full trials, $t(57) = 3.30$, $p < .01$. The results indicate that although children demonstrated a general preference for the object that E1 could not reach (i.e., the target), 3- and 4-year-olds used the speaker's action constraints to infer her communicative intent and make a referential decision.

Discussion

The purpose of this study was to evaluate preschoolers' ability to extract information from the broader communicative context and use that information to deduce a speaker's intention. Our results provide several insights into this ability. First, both 3- and 4-year-olds showed implicit evidence of using speaker action constraints when interpreting referential ambiguity. Specifically, children's looking patterns revealed that when the instruction was ambiguous and E1's hands were empty, children looked significantly longer at the target object than at the referential alternative. Thus, children in both age groups recognized that the speaker's empty hands could be used as a cue to her communicative intention in that the speaker would not intend to refer to an object that she could obviously retrieve herself. When the instruction was ambiguous and the speaker's hands were full, however, both 3- and 4-year-olds spent roughly equal proportions of time looking to the target and referential alternative because the speaker's additional action constraint (full hands) meant that both referents were equally plausible.

A second insight provided by the eye gaze measure is that the domain restriction effect was not immediate for children, in contrast to what has been shown with adults in a similar pragmatic situation (Hanna & Tanenhaus, 2004). That is, children's first eye movements on hearing the linguistically ambiguous description were just as likely to be toward the participant's side of the house (i.e., where the target object was located) when the experimenter's hands were full as they were when the experimenter's hands were empty. This suggests that inferencing on the basis of the actions available to the speaker is a process that is comparatively demanding even though the "correct" solution can be attained by young children.

A third critical finding from this study is that children translated their implicit knowledge to infer the speaker's communicative intention and make the appropriate referential decision. When the speaker made an ambiguous request (i.e., asked for an object in the presence of two equally plausible referents) and her hands were empty, children selected the target object (the object out of the speaker's reach) significantly more often than they did when the speaker's hands were full. Thus, when the speaker's hands were empty, the physical scenario invited the inference that the speaker must be referring to an object that is out of her reach, thereby allowing ambiguous instructions to be disambiguated. When the speaker's hands were full, however, the limited actions available to her did not allow this inference to be drawn. This result is noteworthy because past studies have sometimes shown that children do not extend implicit sensitivities to contextual information into their overt referential decisions (Berman et al., 2010; Nilsen et al., 2008). Furthermore, the 3- and 4-year-olds' use of speaker action constraints revealed a much stronger pattern of target object selections for the ambiguous hands-empty trials relative to what was found in Grosse and colleagues' (2010) study. Recall that the children in that study selected the distant object (the object that would be considered the target in the current study) at chance level even when the experimenter's hands were empty. This difference in findings may be due to differences in the experimental procedures (as discussed in the Introduction) and the ages of the children tested.

Despite the significantly greater number of target selections for the ambiguous hands-empty versus ambiguous hands-full trials, it is noteworthy that children still demonstrated a general preference for the target object relative to the referential alternative across conditions. One possible explanation

for this pattern of findings is that knowledge of the speaker's action constraints was relevant only some of the time because the unambiguous instruction trials did not require extralinguistic information for a successful interpretation. Thus, on realizing that the speaker's action constraints were irrelevant on some trials, children may have selected the item that the speaker could *never* reach; this would explain the preference for the right side of the house (i.e., the target). Another possible explanation for children's bias to the target is due to the nature of the game scenario in which children were asked to engage. Specifically, the game was such that the experimenter's action goals were always mediated by language (i.e., the intention to retrieve an object was announced even when the experimenter got the object herself). This is somewhat unlike real-world interactions where people are more likely to simply retrieve an object without any accompanying commentary if indeed they are capable of doing so without help. Thus, children might have had a default expectation that in any situation where the experimenter "announced" an instruction, the object in question was probably not one that was accessible to the speaker. Critically, however, even if such expectations were present, children's tendency to select the target was clearly moderated by whether the speaker's hands were empty or full.

Preschoolers' sensitivity to speaker action constraints to resolve referential ambiguity is impressive when one considers that identifying the target referent involved a comparatively complex range of abilities. First, children needed to survey the overall scene, process, and then remember which areas of the toy house only *they* could reach and which areas of the toy house the experimenter *also* could reach. Second, children needed to process the information that was presented to them by the speaker at the beginning of each trial regarding her ability to use her hands (e.g., "[Child's name], look at me! My hands are empty!"). Children then needed to hold this information in mind while the experimenter provided the actual instruction (e.g., "Spot wants the book. Put the book in the backpack"). Furthermore, when the object that was requested belonged to a pair, children were required to recognize the ambiguity in the utterance and identify the need to use information beyond the actual instruction to infer a rational speaker's referential intent. Finally, children needed to determine whether the information about the speaker's action constraints, presented at the beginning of the trial, could be used for the purpose of identifying her referential intent (i.e., which of two plausible referents she meant to request). In fact, information about the speaker's action constraints was helpful only some of the time because the unambiguous instruction trials did not require any extralinguistic information in order to make a successful interpretation. Underscoring the chain of reasoning described above is, of course, the fundamental assumption that the experimenter was a rational/cooperative speaker. That is, children needed to assume that the speaker would not say "the X" to refer to the member of the pair that she could pick up.

Of course, an alternative explanation is that, rather than making inferences about a speaker's communicative intentions, children simply learned an association between the speaker's hand status and the direction to reach as a result of the initial training phase. This explanation is unlikely for a number of reasons. First, recall that during the training phase, children were presented with unambiguous instructions (i.e., there was only one candidate referent in the display); thus, the training emphasized the experimenter's reaching constraints rather than a particular response strategy that could be applied when a request was ambiguous. Second, the unambiguous instruction trials served to prevent children from forming expectations such as the following: "When the speaker's hands are empty, reach to my right; when the speaker's hands are full, reach to my left." Specifically, on the unambiguous instruction trials, children may have been required to select an object from their own area when E1's hands were full or to select an object from E1's area when her hands were empty, and either of these situations would prevent the development of expectations about object selection. Given that children's eye gaze patterns and object selections were influenced by the experimenter's hand status only on the ambiguous trials, children were evidently integrating information about the nature of the request and the experimenter's reaching constraints.

Despite the uptake of speaker action constraints to infer communicative intention in experimental settings, it remains to be determined the extent to which children and adults draw on these cues in an incidental manner in natural communicative contexts. Ordinary conversational interactions are obviously much different from those created for experimental purposes in that listeners are exposed to more than one cue to the speaker's communicative intention and do not receive explicit preparation.

Recall that our procedure included a training phase in which E1 demonstrated that (a) when her hands were empty she could reach only objects in the experimenter's area, (b) when her hands were full she could reach none of the objects, and (c) the participant could reach *all* of the objects. Recall also that the adults in the study by Hanna and Tanenhaus (2004) were provided with explicit training prior to performing the task. An interesting avenue for future research will be to examine the utility of speaker action constraints for children and adults in more naturalistic interactions with others.

In conclusion, the current study demonstrates that speaker action constraints are part of the repertoire of cues that preschoolers use to infer communicative intentions. It is in some ways surprising that children can draw on these constraints given evidence that they sometimes have difficulty in using information from the visual environment to guide aspects of language interpretation, even with explicit highlighting (e.g., Hurewitz et al., 2000). One possibility is that the expression of intentional action in situations such as that presented in this experiment provides particularly salient cues for subdividing the visual scene into likely candidates for reference (cues that are largely absent in studies demonstrating the limited use of contextual information during real-time interpretation). After all, the seeds of the intention recognition process are already in place by infancy for determining the basis behind overt actions (e.g., Woodward, 1998). It is likely that children can directly build on this foundation to identify the more sophisticated and indirect forms of intentionality that accompany language and shape its interpretation.

Acknowledgments

This research was supported by an operating grant from the Social Sciences and Humanities Research Council (SSHRC) of Canada awarded to S.A.G. and C.G.C. as well as funds from the Canada Foundation for Innovation and the Canada Research Chairs program awarded to S.A.G. S.J.C. was supported by graduate funding from SSHRC and Alberta Innovates–Health Solutions. We are grateful for the participation of all the children and parents. We also thank Vanessa Schell, Kim Tan-McNeil, Monica Hernandez, and Katerina Mrkva for their assistance with this research. Some of these data were presented to the University of Calgary in partial fulfillment of the MSc degree for S.J.C.

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