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Logically Speaking: Evidence for Item-Based Acquisition of the Connectives AND & OR

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Why is it that young children use connectives correctly in conversation, yet frequently err when asked to use the same connectives in formal reasoning? One possibility is that connective acquisition is item-based in which usage rules are induced from natural language input. This possibility was evaluated by examining the correspondence between the structure of children's natural language environment and their own productions. AND and OR use was coded within 100,626 turns between parents and children between 2.0 and 5.0 for (a) frequency, (b) meanings, (c) syntactic frames, and (d) formal or informal use. The results are consistent with item-based learning in that children's initial productions were very similar to those of adults on each dimension investigated. AND was produced significantly more frequently than OR, meaning and syntactic frame use were highly consistent across ages and producers, and use was nearly always informal.

Why is it that young children use connectives correctly in conversation, yet frequently err when asked to use the same connectives in formal reasoning? This observation highlights a crucial question in the study of logical reasoning: What is the relation between its linguistic (e.g., acquiring and using connectives) and cognitive (e.g., processing the necessary implications of truth-values) components? Although there have been many studies that examine when children can reason with logical connectives such as AND and OR (e.g., Paris, 1973), there are few studies that examine the opportunities young children have to hear and process logical connectives in natural language. There are two goals of the present investigation: (1) to investigate the conditions under which children acquire the connectives AND and OR (i.e., structure of the natural language environment), and (2) to

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investigate young children's experience with logical uses of these connectives. Both issues are crucial because the representations of connectives influence how children construe (or misconstrue) connectives that influence their reasoning responses (Johnson-Laird, 1983, 1999; Scholnick & Wing, 1991, 1992).

I propose that the course of logical development is such, in part, because connectives are item-based acquisitions. Item-based theories posit that language is meaning-based (i.e., symbolic), and children acquire word uses closely related to those used in natural language input, only later using a word to convey a broader range of meanings (Akhtar, 1999; Lieven, Pine, & Baldwin, 1997; MacWhinney, 1982; Nelson, 1985, 1986; Tomasello, 2003). Given item-based acquisition, the initial meaning of a connective should be limited to a single, essential meaning—hereafter called a confirmed core meaning (MacWhinney, 2002). In item-based usage, children are not presumed to be endowed with error-free grammatical rules (cf. Chomsky, 1991; Pinker, 1994); instead, children form usage rules induced directly from instances they have heard.

Input is broadly conceived as the functional context in which a person communicates his intentions to others (Tomasello, 2003, 2006). Children use their knowledge of situations, events, and scripts to determine the relation between verbal productions and intentions (Levy & Nelson, 1994; Nelson, 1985, 1986; Tomasello, 2003, 2006). Levy & Nelson (1994) found that children's initial productions of *because* were nearly identical in function to those of their parents (i.e., psychological justification), and only later did these uses expand to include additional functions (e.g., temporal specification). The use of *because* was closely tied to the event in which this term occurred; for example, using *because* consistently during an explanation of why a child is being put to bed ("because it is night").

Through increased attention to the productions of others and more heterogeneous functional contexts, children acquire additional meanings (i.e., logical uses) and rules for appropriate use (i.e., pragmatics), and generalize items to more abstract grammatical structures (Gentner, 2005; Gentner & Namy, 1999, 2006; Levy & Nelson, 1994; Nelson, 1985; Tomasello, 2003). Bloom, Lahey, Hood, Lifter, and Fiess (1980) demonstrated that children initially used AND only to describe conjunction but later used AND to express a variety of meanings (e.g., temporal sequence). Inferential meanings (e.g., necessary AND) might not be present initially, and thus may limit a child's ability to reason with connectives. Acquiring meanings is necessary though not sufficient for logical use because children must also determine the appropriate linguistic contexts in which to use a meaning (i.e., pragmatics). Thus, detecting the relation between specific meanings (e.g., temporal AND) and the conditions for their use underlie the acquisition of pragmatics. For example, Braine (1998) notes that children tend to use connectives conversationally (i.e., non-inferentially) even when inferences are warranted. Finally, children need to create an abstract representation of a connective to extend use to a variety of contexts. One likely mechanism for abstraction is analogical reasoning in

which children detect similarities in function across contexts (Gentner & Namy, 2006). Fisher (1996) found that young children learned verbs by linking causal events and specific syntactic forms (i.e., transitive constructions such as "A moves B"). Such alignments require sufficient input for children to detect the word, function, and similarity across contexts (Gentner & Namy, 2006).

Logical uses of connectives are likely to be represented at such an abstract level. It is likely that connectives begin with a confirmed core that does not include functions of formal logic. It is likely that some inferential uses (e.g., explicit truth values) are later acquisitions added to core meanings. Because children have only a limited understanding of a word, they may err when presented with an unfamiliar use (e.g., assigning truth or falsity; French & Nelson, 1985; Levy & Nelson, 1994).

One source of data to investigate item-based acquisition is provided in input, i.e., natural language exchanges between parents and children. Input provides information about the structure of natural language, specifically the relative frequencies of connectives, types of meanings communicated, types of syntactic frames in which connectives occur, and formal (i.e., logical) or informal use through structural or contextual demands. The structure of the input predicts the nature of initial acquisitions because it provides information about likely meanings and processing operations with which they are associated (Smith, 2000). Examining input allows a description of the set of examples available for guiding use as well as analogical mapping.

STRUCTURE OF INPUT

There has been an increasing body of evidence demonstrating that young children are quite adept at detecting statistical regularities in speech input at the phonemic (Saffran, Aslin, & Newport, 1996), morphosyntactic (Samuelson, 2002), and syntactic (Gomez & Gerken, 1999, 2000) levels. One consistent finding is that the detection of underlying structure is aided by more structured input (i.e., learnability of any input increases as a function of its predictability; Saffran, 2003). Thus, in understanding how natural language opportunity might influence connective use, it is crucial to determine the structure of the language environment.

Frequency refers to both (1) the number of instances with which children have experience, and (2) the relative frequencies (i.e., the probability of a word in normal discourse relative to other words). Words that are produced more frequently by parents are often understood earlier in development and are produced more frequently by children, as demonstrated with nouns (Gentner, 1982; Huttenlocher, Haight, Bryk, Seltzer, and Lyons, 1991; Smiley & Huttenlocher, 1995) and verbs (Huttenlocher et al., 1991; Tomasello & Kruger, 1992). Because children produce AND well before OR (Fenson, Dale, Reznick, Bates, Thal, & Pethick, 1994), it seems likely that AND use may be significantly more frequent than OR use.

The connectives AND & OR can be used to convey more than one meaning. While each connective has a meaning common to all uses, various meanings make use of additional knowledge to convey slight differences in connotation. Various researchers (e.g., MacWhinney, 1989, 2002; Nelson, 1985) have suggested that word acquisition begins with a confirmed core. This confirmed core should (a) have a prototypical meaning, (b) have the least interference with other meanings, and (c) require the least amount of additional cognitive resources (MacWhinney, 1989). A prototypical meaning likely covers the core function ascribed to a word. The likely prototypical meaning for AND is *conjunction* (denoting the inclusion of two or more objects or phrases in a set) while *choice* is a likely candidate for OR. These functions may help form the basis of word meanings and aid in their acquisition (French & Nelson, 1985; Levy & Nelson, 1994; Nelson, 1986).

Interference with other possible meanings could increase the difficulty of acquiring the term; thus initial meanings should occupy a unique area in conceptual space. Levy and Nelson (1994) suggested that a functional understanding of relational terms includes cues of distinctiveness, that is, words convey unique functions related to unique events. For example, while inclusive OR (A, B, A & B) overlaps with AND (A & B) in that the presence of both options is allowable, exclusive OR (A, B, not both) has no overlap with AND, and thus should create less interference during acquisition (in review, see Morris & Jorgensen, in review). The *choice* event representation suggested above provides a distinctive functional representation in that it would not interfere with the representation of *the conjunction of items* expressed by AND (Nelson, 1986).

Confirmed core meanings should require few additional linguistic or cognitive resources to establish their meanings. For example, temporal AND (e.g., *"Grab my keys and start my car"*) conveys conjunction as well as information that the order in which the words appear maps onto the temporal sequence of an event. Such meanings are unlikely to be used initially because children do not typically verbalize descriptions of temporal information until 3–4 years (Levy & Nelson, 1994; Peterson, 1990). Bloom et al. (1980) found that children progress from confirmed core to additional meanings in that AND use initially designated conjunction at 2.0, but later incorporated temporal sequences (26 months) and casual relations (32 months; see Levy & Nelson, 1994, for similar results with *because*). French and Nelson (1985) provided evidence for an exclusive core for OR in that 3–5 year-olds produced OR exclusively; however, these productions were made during descriptions of various scripts and may not be indicative of spontaneous use. Thus, if acquisition is item-based, confirmed core meanings should account for a majority of initial uses, and there should be a close association between parent and child use. Finally, as children acquire additional (i.e., non-core) meanings and differentiate more nuanced conceptual distinctions in their environment (e.g., temporal sequence), there should be age-related increases in the number of different meanings children produce.

The syntactic frame in which a connective is presented might provide another source of information for use. The correspondence between meaning and its presentation in a reliable syntactic frame helps children learn the meaning of a word more rapidly (Naigles & Hoff-Ginsberg, 1995; Tomasello, 2006). For example, an exclusive OR presented in a question frame provides a cue that the speaker requests additional information about a set of options, and such a cue might be related to event representations (e.g., choice). Evidence from previous research (e.g., Akthar, 1999; Akthar & Tomasello, 1997) demonstrated that the relational frames children produce are initially restricted to those used by parents (i.e., functional rather than verbatim imitation). If the same principle holds for connective use, then we should expect to see a close correspondence between the types of frames produced by parents and children in natural language. This "starting point" might help children learn meanings and provide a set of language data from which higher-order meanings can be abstracted (for a discussion, see Tomasello, 2003; Gentner, 2005).

Connectives also may be used for formal or informal functions. Connective use can be described as either informal (descriptive function) or formal (processing first- or second-order relations). Descriptive processing refers to matching states of the world to linguistic utterances (i.e., specifying relations between objects). First-order processing involves assigning explicit truth-values to statements. Although a descriptive process carries with it an assumption about the truth of the statement being made by the speaker (e.g., Grice's (1989) principle of quality), explicitly evaluating the truth or falsity of a statement requires an additional processing step beyond an implicit evaluation (Halford, 1993; Somerville, Hadkinson, & Greenberg, 1979). Second-order processing involves judgments about possibility or necessity (i.e., modal judgments) and requires evaluation of *classes* of statements (e.g., class of statements for which evidence will *not* make a difference—contradictions) rather than evaluating *individual* statements (Moshman, 2004). Children correctly process descriptive statements earlier than first-order evaluations (Johansson & Sjolin, 1975; Somerville et al., 1978), and both are solved earlier than second-order inferences (Morris & Sloutsky, 2002). Thus analysis of the depth of processing allows an examination of the frequency of use for such meanings but also the conditions under which these uses occur. The cues for use provide a set of data from which pragmatic rules may be induced.

Only two studies have directly investigated the relation between children's language experience and logical reasoning (Scholnick & Wing, 1991, 1992). Scholnick and Wing (1991) examined the relation between the frequency, frame, meaning, and inferential use of the connective *If* in exchanges between parents and their children. The results provided strong evidence for item-based acquisition of *If* because (a) children's initial constructions were closely related to adult productions and (b) there was evidence of age-related change to more flexible use. The results demonstrated that there was a confirmed core meaning of *If* used in conversation (i.e., speaker uncertainty), and a consistent presentation

frame (adverbial clause) that provided a prompt for an inference from the listener. Adult production of *If* provided implicit semantic and syntactic cues for use and explicit cues for inferences within a "supportive linguistic context for inference" (Scholnick & Wing, 1991, p. 257). This study provided the first link between language use and logical reasoning in the strong positive correlation between the frequency with which parents use conditionals and the conditional reasoning performance of their children (see also Falmagne, 1990). It is possible, however, that conditionals are different from AND and OR in that the former require suppositions whereas the latter might not (or at least not commonly). If so, then there may differences in processing opportunities based, in part, on the function of the connective itself.

PRESENT INVESTIGATION

The literature reviewed above demonstrates that very little is known about connective use in natural language (for exceptions, see Scholnick & Wing, 1991, 1992). Thus, understanding connective use in natural language may be critical for understanding the acquisition of logical connectives and, perhaps, inferential abilities. The relative frequencies of connectives, their meanings, as well as the syntactic frames in which children produce them might influence children's connective productions. Processing opportunities (e.g., requests for explicit truth-falsity evaluation) may provide children with contexts for exploring various meanings as well as information about conditions for use.

To evaluate this possibility, connective use between parents and their children (ages 2.0–5.0) was analyzed. The purpose is to examine the structure of natural language input and to see to what extent this structure is related to children's productions. To do this, it was necessary to analyze the frequencies, meanings, frames, and formal or informal connective use. There are four research questions: (1) Because in the course of development, AND is produced earlier than OR, is AND produced more frequently by adults than OR? (2) Is there an initial confirmed core meaning for AND and OR? Is there an age-related increase in the number of different meanings used? (3) Does the syntactic frame in which the connective occurs provide a reliable cue to use? (4) What proportion of connective use is formal or informal? For all questions, are there differences in production by connective, age, or producer?

Method

Participants

The data were 240 transcriptions of audiotaped exchanges obtained via the CHILDES database (MacWhinney, 2000). The exchanges consisted of unstruc-

tured situations (e.g., free play) between adults (most often one parent) and one child between the ages of 2.0 and 5.0 years. Each transcript consisting of one child and 1–2 parents was then placed into one of six 6-month age ranges (2.0–2.5, 2.5–3.0, 3.0–3.5, 3.5–4.0, 4.0–4.5, 4.5–5.0; hereafter, single-observation sample). The transcripts were selected from the database to insure that each 6-month age range contained 40 transcripts in which one child and his or her parent(s) were engaged in nonstructured conversation; thus 40 children and their parents are represented in each age range, and each child appeared only once in this dataset (Bates, Bretherton, & Snyder, 1988; Berstein-Ratner, 1984, 1985; Bloom, 1970; Bohannon & Marquis, 1977; Clark, 1978; Demetras, 1989a, 1989b; Fletcher & Garman, 1988; Gathercole, 1980; Gleason, 1980; Gleason & Greif, 1983; Higginson, 1985; Kuczaj, 1976; Sachs, 1983; Snow, 1989; Van Houten, 1986; Warren-Leubecker, 1982; Warren-Leubecker, & Bohannon, 1984). In addition to the data for the 40 children in each age range, data were analyzed from nine children for whom there were observations across three consecutive age ranges (Child A, B, C, 2.0–3.0; Child D, E, F, 3.0–4.0; Child G, H, I, 4.0–5.0; multiple-observation sample). These data were included as a comparison group for the single-observation sample to compare changes between age groups (Bloom, 1970; Clark, 1978; Kuczaj, 1976; Sachs, 1983, Snow, 1989; Warren-Leubecker, 1982; Warren-Leubecker, & Bohannon, 1984).

Corpus

The 240 single-observation transcripts contained 100,626 conversational turns, whereas the 27 multiple-observation transcripts contained 7,040 conversational turns. The CLAN program (MacWhinney, 2000) was used to determine the number of utterances and the number of connectives, and to identify the immediate context of the connective (i.e., four utterances before and after the connective).

Coding

All false starts and uncodable utterances were eliminated. The total percentage of eliminated utterances was as follows: AND (Adult: 8%, Child: 9%), OR (Adult: 18%, Child: 19%). Once these connectives were eliminated, each connective was coded on five dimensions: (1) producer, (2) frequency, (3) meaning, (4) frame, and (5) formal or informal use. A producer code simply indicated whether the child, parent, or other produced the connective.

Meaning

Each connective can be used to convey a range of possible meanings (see Table 1). This paper will examine a small set of possible meanings and should not be seen as providing an exhaustive set of possible meanings. AND has at least four possible meanings: conjunction, explanatory, temporal, extension. A conjunction states a

TABLE 1
Meaning Codes, Explanations, and Examples

	Coding Guidelines	*Example*
AND	**Conjunction**-Combines two items into one set	"That's a mommy **and** two dogs"
	Explanatory-Designates a link between two parts with the intention of explaining or commenting on the first part of the statement; not sequence dependent	"You hit Kim **and** that is not OK"
	Temporal-Used to designate the time sequence of events, usually suggesting that the first part proceeded the second in time.	"He broke the window **and** then stole the television"
	Extension-Functional more than meaningful, this use extends a statement, direct attention, or is simply used as a lead-in.	"**And** who should this be?"
	Null-Does not fit other classifications	
OR	**Exclusive**-One or the other, NOT both	"You can go the table **or** to the free play area"
	Inclusive-One or the other, or both. (Enumerating several acceptable options is a clear indicator)	"You can have apples **or** bananas" "Can I have both" "Yes."
	Conditional-Pair in which meeting the conditions results in the specified action (IF substitute)	"Stop hitting him **or** you will have to have a time out" (includes deontic functions)
	Null-Does not fit other classifications	

co-occurrence between two items. An explanatory use is one in which the second phrase comments upon the first phrase but does not designate time sequence. Temporal use describes a relation between two items or events in which the first precedes the second in time. An extension is a communicative device that functions to link a statement to a previous thought or to continue a line of discussion.

There are at least three possible meanings for OR. An exclusive use presents a situation in which two items or clauses are presented and which is true if one of the two (not both) is present or chosen. An inclusive use (IOR) presents a situation in which two items or clauses are presented and which is true if one of the two or if both are present or chosen. Coding OR meaning was conservative in that IOR was the default code in the absence of explicit linguistic cues (e.g., "not both") or conditions that disambiguated the code (e.g., inability to choose both options). A conditional use is functionally similar to an *If* statement (or an if and only if statement, which has only two possibilities) in that the first item or clause presents conditions

that denote actions in the second item or clause. It is important to note that conditional OR includes all deontic meanings (e.g., obligation; Grice, 1989). A list of possible meanings for each connective was assembled before data collection, and a series of examples was created to illustrate their contextual function. Two raters were then trained on a set of 30 transcripts on which inter-observer agreement was 85% (Cohen's Kappa .75). To check reliability while coding the full corpus, 30% of utterances were double-coded. Inter-rater reliability was 91.4% before discussion (Cohen's Kappa .78).

Frame Frame refers to the syntactic structure of the statement in which the connective is used. A *statement* presents no explicit demand for a response and has three possible subcodes: head, independent, and dependent. Head indicates that the connective begins a new statement (e.g., "And I left the party"). Independent indicates that the connective joins two independent clauses. Dependent indicates that the connective joins an independent and a dependent clause. A *question* provides an explicit demand for a response. Questions will be coded as either closed or open. Closed questions present the listener with a specified set of response options (e.g., Would you like a doughnut or a danish?). Open questions do not specify options (e.g., Or what?). Inter-rater reliability was 96% before discussion (Cohen's Kappa .80).

Formal or Informal Use Statements were coded as being used informally (i.e., at the descriptive level) or formally (i.e., beyond the descriptive level). There are two formal codes: first-order, explicitly processing truth values, and second-order, making judgments about possibility/necessity (see Table 2). Formal use can occur via the structure of the statement itself or through the social context. Structural depth was coded if the form of the statement containing a connective required additional processing (e.g., a contradiction or a tautology). Social context may provide children with opportunities to process truth-values or possible/necessary states associated with utterances based on questions or statements posed by those in the conversation. In order to code for depth of processing, each connective was examined within the context of the four utterances preceding and following the connective. The context was coded for two elements: (1) a request for an explicit truth-value assignment (e.g., "Is that true?") and (2) a request for processing additional possibilities/necessary conclusions. An example of the latter is as follows: A parent asks a child if the remote control is on the sofa or on the table. The child responds, "It's not on the table," and the parent responds, "If it's not on the table, then where does it have to be?" Included in the coding of structural depth was the presence of logical predicates ALL, SOME, NONE used in utterances with AND or OR. The presence of these predicates might signal the need for a logical inference (e.g., Are all of the shapes blue or are there more squares than blue shapes?). Inter-rater reliability for depth codes was 96% before discussion (Co-

TABLE 2
Formal or Informal Use Codes, Explanations, and Examples

	Coding	*Contextual Examples*	*Structural Examples*
D0-Describes State of the World (Simple utterance)	Implicit truth-value; no mention of alternative possibilities	"I'd like peanut butter and jelly."	
D1-Processing Explicit Truth-value (Sentence verification)	Explicit truth-value; no mention of alternative possibilities	"Does the dog have a tennis ball and a hockey puck?" "No."	"You said I could have ice cream or cake and I didn't get any dessert."
D2-Processing Possibility/Necessity (Describes other possibilities)	Explicit truth-value; mention of alternative possibilities or necessary logical truth	C: "I think the picture fell over and broke" P: "How else might this have happened?"	"The boy has a basketball or he does not have a basketball."

hen's Kappa .80). Once each connective was given each of four different codes, the connective was given a final code for formal use if (a) the meaning was a core function and (b) if use was beyond the descriptive level. All other results were coded as informal.

Results

The results are presented in five sections: (1) aggregated connective frequencies, (2) meaning, (3) frame, (4) comparing single- and multiple-observation data, and (5) formal or informal use.

Aggregated connective frequencies and meanings

The first series of analyses examined differences in the frequencies of connectives by age and producer. There were a total of 6,459 usable connective uses: AND was produced 5,994 times whereas OR was produced 465 times. Subsequent analyses are based on these data. Data for frequency and meaning will first be described, and then will be analyzed together. Hereafter, data are reported as the proportion of connective use per 100 turns to control for individual differences in the number of productions (Scholnick & Wing, 1991, 1992). Results demonstrate that AND was produced approximately 12.8 times more frequently than OR (see Figure 1; Parent means: AND 3.13 (SD = .70), OR .35 (SD = .11); Child means: AND 2.63 (SD = .82), OR .13 (SD = .04).

A loglinear analysis was used to compare connective frequencies across producer, meaning, and ages. This type of analysis was used because it is functionally

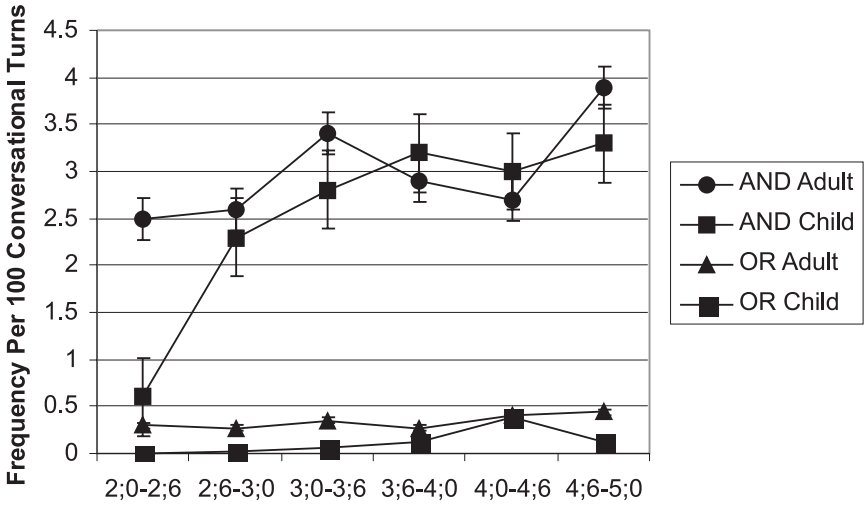

FIGURE 1 Aggregated connective frequencies per 100 turns by age and producer. *Note*. Error bars represent standard errors of the means.

similar to an ANOVA in that it allows comparisons of categorical data across multiple dimensions (Marascuilo & Busk, 1987). A hierarchical loglinear model was used to examine the best fit between the data (observed values) and the expected values of nested combinations of variables as well as the overall matrix (Tabachnick & Fidell, 2001). The goal of the analysis is to find a model that best fits the complete model. This begins with a complete model (i.e., a fully saturated model), and subtracts variable effects using backward elimination until the overall model is no longer improved by additions. The saturated model that best fits the data included significant effects of type of connective, producer, and age (likelihood ratio: $G^2 = 36.11$, df = 20, $p < .53$). The results of two-way associations demonstrate that adults produced significantly more uses of AND than OR, and there was a three-way association between age, connective, and producer, indicating that children and adults at 2.0 produced significantly fewer connectives than at other ages ($p < .01$; see Table 3).

For children and adults there was dominant meaning for each connective: AND as a conjunction and OR as an exclusive. Standardized Parameter Estimates (SPE) were used to examine the differences between cells (following Dickson, Walker, & Fogel, 1997). Standardized Parameter Estimates function like *z*-scores and allow the identification of cells in the matrix that differ significantly from expected values, much like a chi-square test. Thus, an SPE of +1.96 would indicate a cell that would differ from expected values at the .05 level while an SPE of +2.58 would indicate a cell that would differ from expected values at the .01 level. The level of

TABLE 3
Meaning Analysis by Age Range, Producer, and Connective.

	Age Range					
	2.0–2.5	*2.5–3.0*	*3.0–3.5*	*3.5–4.0*	*4.0–4.5*	*4.5–5.0*
Adult AND	**2.5**	**2.6**	**3.4**	**2.9**	**2.7**	**3.9**
Conjunction	0.76	0.75	0.68	0.63	0.69	0.73
Temporal	0.08	0.1	0.22	0.29	0.18	0.2
Explanation	0.03	0.11	0.1	0.05	0.08	0.04
Extension	0.13	0.04	0.02	0.03	0.05	0.03
Child AND	**.60***	**2.3**	**3.1**	**3.2**	**3.0**	**3.5**
Conjunction	0.81	0.74	0.76	0.69	0.67	0.75
Temporal	0.04	0.1	0.19	0.15	0.17	0.16
Explanation	0	0.1	0.02	0.11	0.14	0.05
Extension	0.15	0.06	0.03	0.05	0.02	0.04
Adult OR	**.30**	**.27**	**.35**	**.27**	**.40**	**.44**
Exclusive	0.75	0.76	0.77	0.81	0.73	0.77
Inclusive	0.17	0.12	0.1	0.08	0.1	0
Conditional	0.08	0.12	0.13	0.11	0.17	0.23
Child OR	**0****	**.03***	**.06***	**.13**	**.39**	**.12**
Exclusive	0	0.94	0.89	0.92	0.85	0.75
Inclusive	0	0.06	0.11	0.03	0.05	0.1
Conditional	0	0	0	0.05	0.1	0.15

Note: Numbers in bold denote the mean frequency of use per 100 turns. Other numbers refer to the proportion of generative uses of each function. * Indicates significance at the .05 level. ** Indicates significance at the .01 level.

child AND production at age 2.0 was significantly lower than levels at other ages (SPE = -2.11, $p < .05$). This is likely due to limits in the length of utterances of very young children. The use of a connective necessitates a construction of at least 3 words (5–6 for grammatically correct utterances), yet the average mean length of utterance (MLU) for a child at this age is approximately 1.5–2.5 words (Brown, 1973). The level of child production of OR at 2.0, 2.5, and 3.0 was significantly different than at other ages (SPE = -2.9, -2.85, -2.6, respectively, all *ps* < .01). For adult and child productions, AND was used as a conjunction significantly more frequently than all other coded meanings (all *ps* < .01). For adult and child productions, OR was used as an exclusive significantly more frequently than all other coded meanings (all *ps* < .01). There was also an increase in adult and child use of temporal AND from 2.5–3.0 to 3.0–3.5 (*ps* < .05). These results provide evidence for the first prediction: that initial use is restricted to a simple core function and that child productions are highly similar to adult productions.

A second prediction of item-based acquisition is that, with development, children should acquire additional meanings for words (e.g., temporal AND), expanding connective use beyond the core meaning. Thus, the data should indicate that older children tend to express a greater number of meanings with a single connec-

tive than younger children. To investigate this, the average number of different meanings per connective was compared across age groups (see Figure 2), and an ANOVA indicated significant, age-related increases in the mean number of different uses for AND (F (3, 39) = 28, $p < .01$) and OR (F (2, 39) = 22.2, $p < .05$), providing evidence for item-based acquisition.

The next analysis examined the extent to which parental production levels predicted child production levels. To do this, a series of linear regressions was conducted to determine the extent to which parental use predicted child use. A stepwise method of entry was used to determine the proportions of explained variance.

The results indicate that adult use of AND-conjunction accounted for approximately 21% of the variance in child AND-conjunction use ($r^2 = .21$, $p < .01$), adult use of AND-temporal accounted for approximately 16% ($r^2 = .16$, $p < .01$) of the variance in child AND-temporal use, and adult AND-explanation accounted for approximately 18% ($r^2 = .18$, $p < .01$) of the variance in child AND-explanation. No other variables explained additional variance. For OR, adult production levels did not account for significant amounts of variance for any function (all $ps > .10$). These data suggest that, at least initially, core meanings are not self-generated but are instead functional imitations of adult use (for a discussion, see Tomasello, 2003).

Frame

One frame was used most frequently at each age: statement frame for AND and question frame for OR (see Table 4). The results of a loglinear analysis produced a saturated model that included significant effects for type of frame within a connective and age (for OR) but not significant differences for producer or age for AND

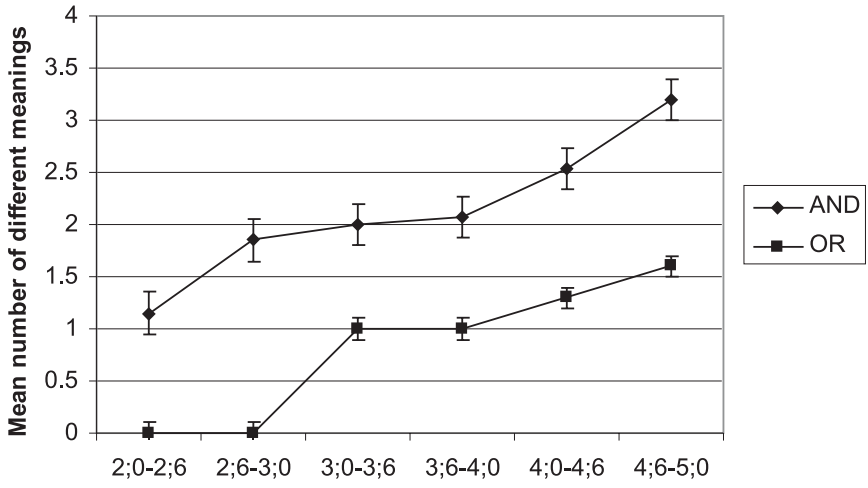

FIGURE 2 Mean connective uses per 100 turns by age. *Note*: Error bars represent standard errors of the means.

(likelihood ratio: $G^2 = 42$, $df = 20$, $p < .88$). One frame for each connective was used most frequently at each age: statement, independent for AND, and closed question for OR. For AND, the majority of uses were in a statement with two independent clauses for both parent and child productions, whereas for OR, the majority of productions were presented in a closed question frame. While the type of frame used differed between connectives, there were no significant differences in the proportions

TABLE 4
Proportion of Frame Use by Connective and Age

	Age Range					
	2.0–2.5	*2.5–3.0*	*3.0–3.5*	*3.5–4.0*	*4.0–4.5*	*4.5–5.0*
Adult AND						
Statement	.97	.96	.97	.95	.95	.95
Head	.12	.15	.07	.02	.03	.03
Independent	.77	.73	.69	.65	.64	.74
Dependent	.11	.12	.24	.33	.33	.23
Question	.03	.04	.03	.05	.05	.05
Open	1.00	1.00	1.00	1.00	1.00	1.00
Closed	0	0	0	0	0	0
Child AND						
Statement	.96	.98	.97	.96	.95	.91
Head	.14	.11	.04	.02	.10	.03
Independent	.82	.77	.75	.76	.48	.44
Dependent	.04	.12	.21	.22	.42	.53
Question	.04	.02	.03	.04	.05	.09
Open	1.00	1.00	1.00	1.00	1.00	1.00
Closed	0	0	0	0	0	0
Adult OR						
Statement	.8	.12	.14	.12	.18	.22
Head	.20	.30	.25	.31	.23	.19
Independent	.0	.4	.4	.3	.5	.3
Dependent	.80	.66	.71	.66	.72	.78
Question	.92	.88	.86	.88	.82	.78
Open	.14	.22	.18	.22	.40	.34
Closed	.86	.78	.82	.78	.60	.66
Child OR						
Statement	0	0	0	.5	.10	.15
Head	0	0	0	.78	.44	.20
Independent	0	0	0	0	.12	.20
Dependent	0	0	0	.22	.44	.60
Question	0	0	1.00	.95	.90	.85
Open	0	0	0	.23	.44	.40
Closed	0	0	1.00	.77	.56	.60

Note: The numbers in bold display the proportion of statement or question uses by connective and age. The numbers in italics display the proportion of use within each category. For example, 97% of the AND statements at age 3 were statements while 3% were questions. Of the total number of statements, 7% were Head, 65% were independent, and 33% were dependent.

of frame use within connectives by different producers and between ages (for AND). There was a significant, age-related decrease in the use of OR as a question and a corresponding increase in statement presentation (all SPE > 1.96).

A second analysis demonstrates a close relation between the types of frames produced by parents and those produced by children. A linear regression indicated that parental productions accounted for a significant amount of explained variance in child production of frames. Adult production of statement frame for AND accounted for 47% ($p < .01$) of the variance in child statement frame production, whereas adult production of the question frame for OR accounted for 33% ($p < .01$) of the variance in child question frame production. The results indicate that frames may help to provide functional information to children about connective use; children initially imitate the function of the relational frames and only later begin to use connectives more flexibly. The data from the meaning and frame analyses suggest that children are presented a stable set of overlapping cues for connective meaning.

Formal or Informal Use

The resulting analysis of inferential function demonstrated that over 99% of uses by parents were at the informal level and the small proportion that required inferential processing were requests by parents for explicit truth evaluations (e.g., Is that true?"). There were very few uses of logical predicates (e.g., SOME, ALL) within the four sentences before and after connectives (less than 1%), and there were no cases of parents providing opportunities to explore second-order functions (e.g., necessity) through either structural or pragmatic cues. Less than 1% of adult connective uses were coded as "formal." These data also demonstrate that children experience few cues for determining conditions for formal or informal use. Thus, children have little data from which to induce pragmatic rules (for a discussion, see Braine & O'Brien, 1998). While this analysis is only descriptive and cannot examine the extent to which children may have engaged in cognitive processes, it does provide information about the frequency of such processing opportunities.

Comparing Single- and Multiple-Observation Samples

Combining single data points from multiple children might not be indicative of individual trends in language development. Therefore, in this analysis single-observation data were compared to multiple-observation data. The means from single-observation datasets were compared to the means from three children at each age grouping on connective frequency, meanings, and frames. A Welch's *t*-test was used because the samples had different degrees of freedom (calculated using the formula $n1 + n2 - 2$; Wonnacott & Wonnacott, 1977). Because this might lead to high levels of Type I errors, the results were compared to a more conservative method of calculating degrees of freedom (i.e., n1 - 1 or n2 - 1, whichever is smaller; Wonnacott & Wonnacott, 1977). There was only one significant differ-

ence between these samples; multiple-observation child AND production at age 4.5 was significantly lower than in the aggregated sample ($t(41) = 1.8$, $p < .05$, one-tailed). The frequency of connective use by children and adults across all other age ranges did not differ significantly from the aggregated means (all $p > .20$). The frequency of meaning and frame use by children and adults did not differ significantly from the aggregated means at any age range (all $p > .30$). These data suggest that in the current dataset the method of aggregating transcripts provided a reasonable approximation of individual language use.

GENERAL DISCUSSION

These data support the suggestion that connectives are item-based acquisitions. Children first form a representation for use based on input from their natural language environments, which may best be described as a conceptual prototype associated with a usage script (Levy & Nelson, 1994; Tomasello, 2003). Relational terms such as connectives are acquired by linking words to communicative functions (e.g., OR denotes a choice event). This process initially leads to conservative use in which productions are restricted to imitating function. Through experience, children acquire additional non-core uses (e.g., assigning explicit truth-values) the conditions under which uses are appropriate (i.e., pragmatics), and form a more abstract connective representation (Gentner & Namy, 2006).

The first purpose of this research was to examine the structure of young children's language environments and determine the relation between parent and child connective uses. The results demonstrate that connectives occur within highly structured language environments. Children hear and use AND much more frequently than OR, hear and use both connectives to convey core meanings within consistent frames, and nearly always hear and use connectives informally (i.e., non-inferentially). The restricted initial uses by children were highly related to parent use, are related to information about function, and together may provide sufficient structure for children to acquire relational terms (for extensive discussions, see Gentner & Namy, 2006; Levy & Nelson, 1994). These data suggest that initial uses were not self-generated, but were functional imitations of adult use. These results are consistent with connectionist models that demonstrate how the statistical structure of the language environment (i.e., implicit positive evidence) may set probabilities for initial use and possible developmental trajectories given these initial settings (Elman, 1993; Rohde & Plaut, 1999).

High levels of consistency between parent and child productions are consistent with the results of Scholnick and Wing's (1991, 1992) research on *If* use. One key difference is that the results of the present study did not indicate a relation between parent use and inferential abilities in children. It is possible that this difference is due to the nature of the communicative functions underlying

use. The connective *If* is inherently suppositional or hypothetical; that is, the function of a conditional is to require an evaluation of the conditions under which possible or necessary conclusions are entailed (Evans & Over, 2004). The connectives AND and OR do not necessarily carry such suppositions (as demonstrated in the data); in fact, only necessary AND requires an inference, and thus may not provide support for reasoning beyond the conversational level. What cannot be concluded from these data is children's competence with inferential functions (as there were very few opportunities) nor under which conditions can children draw correct inferences.

The second purpose of this research was to examine to what extent these connectives were used within logical arguments. Productions were coded for various types of formal uses including assigning truth-values, evaluating necessity and possibility, and use with logical predicates (e.g., SOME, ALL). Nearly all uses were informal, with little evidence of opportunities for children to explore deeper processing with connectives and little information about pragmatic use. While the data from the present experiment demonstrate few opportunities for inferences, the reasons for this are unclear. It is possible that the structure of natural language environments helps guide children's initial understanding of relational events as descriptive (conjunction and choice); yet this same experience, specifically the lack of reasoning opportunities with connectives, may limit opportunities for exploring processing operations used in formal logical reasoning (e.g., judgments of necessity). It is also possible that different uses are needed to trigger inferences. For example, the use of connectives within syllogisms might provide such experiences. While the absence of such cues in the current data is suggestive, additional research is necessary to provide evidence. The results clearly demonstrate that very young children have little experience with non-core functions.

The data demonstrate that initial language use of a connective is not identical to the logical use. This is not surprising given the different functions of each use type. The change from language use to logical use requires possessing the logical meaning (i.e., the non-core meaning), understanding when to use a meaning appropriately (pragmatics), and abstracting meanings for more flexible use. AND and OR are polysemous in that both express a variety of meanings, most that would not be considered "logical." Because the data demonstrate that children's initial uses are restricted to nonlogical functions, logical functions must be acquired. There is broad agreement that there is a general distinction between logical and nonlogical uses for connectives, but there is disagreement whether these meanings are part of a syntax of thought (i.e., given in the cognitive architecture; Braine, 1998) or whether they must be learned. If connectives are a part of a syntax of thought, then what must be learned are conditions for use (i.e., pragmatics; Braine & O'Brien, 1998); however, the results indicate that inferential (i.e., logical) uses were extremely rare. This rarity necessarily limits cues for learning conditions under which inferential functions are used.

If, however, logical functions are learned, then learning likely occurs in reasoning situations in which the goal of connective use matches a logical use. Contexts such as math or science classes in which formal inferences may be required or during parental discussions in which children are asked to explore possible or necessary conclusions (e.g., "David is in the kitchen or in the living room. He is not in the kitchen, so where is he?") may be examples of such instances. Importantly, there were nearly no examples of these contexts in the present data. With experiences that require an exploration of other uses (e.g., a contradiction), a child may begin to learn inferential meanings of connectives and to abstract inferential rules (e.g., any AND statement requires both elements to be true for the entire statement to be true). This might be especially important when children are presented with statements that require logical interpretation of negation as in contradictions and tautologies. Such knowledge seems trivial to adults, but is not initially present (for a discussion, see Morris & Sloutsky, 2002). Children must also learn pragmatics (e.g., when to select appropriately among candidate meanings) by linking specific functions to specific contextual cues.

Abstracting the connective may also be necessary for acquiring logical function. It appears that children's initial uses not only are limited to core functions but also are highly context-dependent (Mareschal, Johnson, Sirois, Spratling, Thomas, & Westermann, 2007). Use across contexts is necessary for logical function as inferences have identical functions regardless of context. Different types of social interactions (e.g., guided participation in reasoning; for a discussion, see Gauvain, 2001) may provide multiple cues; for example, children may receive explicit processing cues (e.g., reasoning problems) from parents and teachers that require non-core functions as well as strategies for solutions and feedback on their efforts. Even after one instance of an inferential problem has been solved (e.g., a contradiction), it may take several instances for a child to recognize isomorphic statement types to which a solution can be extended from a previous problem (e.g., any statement of the form A & ~A). In this way, two seemingly disparate observations about children's use of connectives can be rectified: Children correctly use connectives in conversation, yet are unable to process formal statements making use of these same connectives.

Future research should examine the nature of contemporary parent–child conversations from a more diverse set of parents (as many were professional parents) in a more diverse sample of situations with a greater density of observations over the time specified (for a discussion, see Tomasello & Stahl, 2004). Additionally, comparing these results to adult-to-adult use would be useful in determining frequencies outside of child-directed speech. Finally, it seems critical to examine situations in which the language and inferential functions of connective use are functionally aligned. One such example may be contexts in which adults use connectives to define words or categories (e.g., Is that a car or a van; for an example of such a research design, see Halberda, 2006).

CONCLUSION

The evidence presented here suggests that logical connectives are item-based acquisitions. Children's connective use is initially restricted to simple, noninferential uses similar to those children hear in natural language input. Parent and child use was highly similar in that AND was significantly more frequent than OR, frequently used to convey core concepts (conjunction, choice), used in reliable syntactic frames, and nearly always used informally. The results suggest that the acquisition of a connective indicates a partial representation of function rather than the presence of specific, logical processing operations.

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