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Opposites attract: the role of predicate dimensionality in preschool children's processing of negations*

BRADLEY J. MORRIS
Grand Valley State University

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ABSTRACT

Three experiments investigated the role of oppositional predicate dimensionality in four- and five-year-old children's processing of negation. In Experiment 1 children (37 four-year-olds, mean age 4;8, and 20 five-year-olds, mean age 5;9) were asked to produce opposites for common terms (e.g. 'big'). In Experiment 2 children (27 four-year-olds, mean age 4;8; 23 five-year-olds, mean age 5;9) were asked to make pictures corresponding to statements phrased as negations (e.g. *The arrow is NOT pointing up*). In Experiment 3, children were asked to evaluate a series of pictures made by 'another child' using materials and procedures similar to those used in Experiment 2. Preschool children made use of predicate dimensionality when producing negations but could accurately evaluate truth-values regardless of content. Children often recalled negated items as affirmations (usually corresponding to antipodal opposites), which suggests that children's use of predicate dimensionality contributes to non-classical processing.

INTRODUCTION

A well-documented error in logical reasoning is the 'empirical bias' or the inability to separate logical implications from their truth status in the real world (Braine & Rumain, 1983; Johnson-Laird, 1983; Leevers & Harris, 2000). For example, given the statement *If dogs are made of wood, then the sun will not rise tomorrow* and the premise *dogs are made of wood* the conclusion *the sun will not rise tomorrow* is valid. Most people balk at such a conclusion,

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however, because it is in conflict with their real-world expectations that the sun will in fact rise tomorrow and that dogs are rarely made of wood. Deriving the correct conclusion to the problem above necessitates a logical system, extensional logic, in which logical connectives are processed independently of the contents upon which they operate (Johnson-Laird, 1983).

Reasoning with elements like numbers work well in extensional systems because they are STRUCTURELESS predicates. A structureless predicate cannot be divided into parts and wholes (Sharpe, Cote & Eakin, 1999). For example, the number eight is even and thus cannot be odd. Structureless predicates obey the law of non-contradiction and excluded middle because predication of a characteristic (e.g. odd number) refers to the object as a whole and necessarily eliminates the predication of a related characteristic (e.g. even number).

Several logicians (Anderson & Belnap, 1975) and psychologists (e.g. Johnson-Laird, 1983) suggest that a different logical system underlies human reasoning – intensional or non-classical logic. In non-classical logic, connectives are not processed independently of content but rather are processed in part from the content of the predicates. In intensional logic, operations are interpreted using the meaning of the predicates at both the connective and the propositional level. One example of intensional logical reasoning is that people often reason with objects that are STRUCTURED predicates, or objects that can be predicated into parts and wholes. For example, a *dinner* can be divided into parts such as salad, a main course, and a dessert.

Related to predicate structure is the degree to which an object possesses a predicate, or predicate dimensionality (Lyons, 1977; Sharpe, Purdy & Christie, 1997). If someone says, *My coffee is not hot*, a common interpretation is that the coffee is *cold*. Predicate dimensionality extends meaning along the dimension specified by the content of the predicate. In this case *not hot* specifies the dimension of temperature, on which the opposite is *cold*. Though such an interpretation is not necessarily valid it is often pragmatically supported. Predicate dimensionality is particularly relevant when examining the influence of opposition on negation because oppositionality may not allow for middle ground in interpretations. For example, *tall* is the opposite of *short*, yet one who is not tall is not necessarily short. The middle ground between terms (e.g. average height), however, is often not pragmatically supported, suggesting an excluded-middle collapse in which the opposites are preferred (Sharpe & Lacroix, 1999).

In the case of negations, intensional interpretations require processing a negation while integrating the semantic and pragmatic information associated with it. While many studies of intensional semantics suggest that adult logical reasoning performance is influenced by content (e.g. Johnson-Laird, 1983; Rychlak, 1994), little research has examined the prevalence of intensional semantics in young children's processing of negative operators. This is

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relevant because young children may not be able to produce the same type of semantic content as adults. If not, then either a child's semantic or pragmatic knowledge is insufficiently developed or this knowledge is not integrated with their knowledge of negation. The present studies examine these issues by investigating the role of a specific type of semantic content – oppositional predicate dimensionality – in children's processing of negations.

The dimensionality of opposition

Opposites are terms dependent on dichotomization. Lyons (1977) specifies three types of opposites: antonymous, converse and directional. ANTONYMOUS opposites are gradable in that they differ in the degree to which they ascribe a certain property. For example, a person can be described as *tall* if they exceed the average height of a population or as *short* if they are below this average height. Thus, the two terms are defined as points that occupy widely different positions on the same dimension. With antonymous opposites, the predication of one implies the negation of the other, yet the converse is not true (Lyons, 1977). For example, if Bill is tall, this implies that Bill is not short, however, stating that Al is not short does not necessarily imply that Al is tall.

CONVERSE items are dichotomous subsets in which the presence of an attribute implies the negation of another. For example, if Sue is a wife, this implies that Sue is not a husband because classification as one term prohibits classification as its opposite. Converse opposites represent different kinds, rather than differences in the extent to which they ascribe a specified characteristic.

DIRECTIONAL opposites imply motion in opposed directions given a specified location (Lyons, 1977). For example, *up* and *down* are locational opposites that imply motion in different directions from a specified position. Within directional opposition is a finer distinction: ORTHOGONAL and ANTIPODAL opposition. Orthogonal refers to perpendicular oppositions while antipodal refers to diametric opposition. For example, the direction set [north, south, east, west] contains both types of directional opposites. North and west are orthogonal opposites while north and south are antipodal opposites. Directional oppositionality can also be extended to colour terms (Lyons, 1977). Colour terms such as *black* and *white* are considered opposites because they demonstrate similar locational properties when arranged in three-dimensional space consistent with antipodal oppositionality (Berlin & Kay, 1969; Lyons, 1977).

Intension, opposition and negation

Intensional interpretations make use of predicate meanings at the semantic and pragmatic level. When processing negations on the semantic level, the dimensionality of the predicate suggests a range of possible responses sharing the predicate yet differing in their position on this dimension. A WEAK negation makes use of middle terms as well as extreme terms thus utilizing the full range of possibilities. For example, in a weak negation coffee that is *not hot* may be warm, tepid, lukewarm or cold.

Pragmatics refers to a set of learned, evaluative conditions induced from experience (Lyons, 1977). In such a pragmatic rule, particular positions in any given context on a specified dimension (e.g. extremes) are more appropriate than other positions. A STRONG negation follows such a rule by a middle-excluding collapse in which non-extreme values are eliminated. For example, in a strong negation *not hot* would only imply cold.

Two related lines of research suggest that adults' interpretations of negations are intensional and that adults favour strong rather than weak interpretations (Brewer & Lichtenstein, 1975; Gross, Fischer & Miller, 1989; Rychlak & Barnard, 1996). The first line of research involves choosing the opposite of a given phrase. A representative task examines meaning-preserving errors, or recall errors where the meaning recalled is not that of the actual wording. For example, when given a sentence such as *the tea is not hot* adults frequently made meaning-preserving errors recalling the sentence as a strongly interpreted negation such as *the tea is cold* (Brewer & Lichtenstein, 1975). When given the sentence *Mary was not happy* and the choices *sad* and *angry*, adults overwhelmingly chose the preferred opposite: *sad* (Rychlak & Barnard, 1996). A second line of research examined response times when recalling oppositional terms. When given a series of words, adults recognized opposites more rapidly than any other type of relation (e.g. synonyms) (Gross *et al.*, 1989). What is clear from this work with adults is that, when given an item with a well-known opposite (i.e. a commonly used pair of opposite terms), a common interpretation of a negation is as the opposite of the element negated. However, it is unclear if young children use a similar interpretation by attending to predicate dimensionality.

LOGICAL LEARNING THEORY (Rychlak, 1994) explains the findings presented above by suggesting that the CONTENT of oppositionality provides direction by extending meaning between the class of objects of which the object in question is not a member and the opposite class of meanings. Although the adult literature suggests non-classical interpretations of negation, the developmental literature has not focused on the influence of such content.

The development of negation

The concept of negation is central to higher-order reasoning as it allows evaluation of propositions (Pea, 1980). Negation (broadly defined to include *not* and *no*) appears early in development, demonstrated by the fact that *no* is often one of the first words comprehended and produced by young children

(Dale & Fenson, 1996). Previous research examining the acquisition and early use of negation can be characterized in three broad areas of focus: (1) the syntax of negation, (2) the semantics and pragmatics of negation, and (3) the role of negation in the evaluation of truth-values.

Age-related changes in the syntax of negation can be summarized in three areas: (a) changes in the types of syntactic constructions, (b) universality of these changes, and (c) how structural relations influence comprehension. The syntactic constructions in which children produce negations are initially restricted to a simple set of structural relations (i.e. a negation placed before or after an object, person, or action as in *Mommy no*) (Klima & Bellugi, 1967). Over development, children begin to produce a larger set of structural combinations, including additional semantic elements such as auxiliary verbs (Klima & Bellugi, 1967; Bloom, 1970). Klima & Bellugi (1967) described these changes as occurring over three stages that are invariant across all languages. Although the evidence used to support their stages remains valid, later linguistic theorists questioned the invariance and universality of the stages. Hyams (1994) has suggested that although the initial parameters of the syntax of negations may be set innately, language-specific input might reset the parameters. For example, although English- and Irish-speaking children may begin with the same syntactic frame (SVO), children produce slightly different constructions over the course of development, perhaps due to language input (Hyams, 1994).

Children also appear to recognize early on that the position of the negative operator is crucial to their interpretation. By 4;0, children use syntactic clues about the position of the negation relative to the noun phrase to limit the scope of a negation (de Boysson-Bardies, 1977). By 6;0, children use the presence of definite and indefinite articles to determinate the appropriate referent of a negation (Rumain, 1988).

Two related changes characterize the semantics and pragmatics of negation. The first general change is the production of increasingly sophisticated functions from simple refusals around 1;0 (e.g. *No*!) to more complicated constructions such as denying propositions (e.g. *Is that a horse? No, that is a tapir*) (Wode, 1977; Park, 1977; Pea, 1980). However, because Bloom (1970) provided evidence for multiple functions at early ages, this change may reflect differences in the frequency of use for any given function rather than evidence for the acquisition of new functions. The second general change is a progression from desire-based, immediate reactions (around 1;0) to imagining future states (around 4;0 or 5;0) and making judgments on the truth or falsehood of statements based on available information (Bloom, 1970; Wode, 1977; Pea, 1980; Kim, 1985).

By age 4;0 or 5;0, children can correctly evaluate the truth status of a negated statement as either true or false (Pea, 1980; Kim, 1985). Evaluations are more accurate for affirmed than negated statements and for true negated sentences (*This is not a banana* while seeing the apple) than false negated sentences (*This is **not** an apple* while seeing an apple) (Kim, 1985).

Thus, by age 4;0 or 5;0 children (1) are capable of producing a number of structural formulations with negations and use their knowledge of syntax to specify meanings and limit the scope of negations; (2) communicate a range of semantic and pragmatic concepts when producing negations (e.g. denial and disappearance); and (3) accurately evaluate the truth-value of negated statements. One area, however, in which there is little research, is *how* semantic properties (e.g. predicate dimensionality) influence children's processing of negation.

The development of non-classical negation

As mentioned earlier, previous research (e.g. Rychlak, 1994; Rychlak & Barnard, 1996) shows that in the interpretation of negation, adults use the semantic properties of objects (e.g. object structure and predicate dimensionality). The small number of studies examining children's use of these semantic properties suggests that children may make use of object structure (rather than classical structure) and predicate dimensionality when processing negations (e.g. Sharpe *et al.*, 1997).

Late in his career, Piaget (Piaget & Garcia, 1991) reformulated his theory of logical development and suggested that negations were interpreted based on meaning. Rather than focusing on processing connectives in a classical sense (i.e. regardless of content), Piaget suggested that the contents upon which a negation operates contributes to its interpretation and that a 'negation is meaningful only with respect to an inclusion (or inherence of meaning)' (Piaget & Garcia, 1991, p. 77). Although taking into account intensional logic changed Piaget's theory, little empirical evidence was provided on how the TYPE of content makes use of the dimensions along which meaning is extended.

Sharpe and colleagues (Sharpe, Eakin, Saragovi & Macnamara, 1996; Sharpe *et al.*, 1997) have demonstrated that children use object structure and predicate dimensionality when processing negations. In one study, three-year-old children realized that objects can be structured into parts and wholes and that attributes of a part of an object might not be extended to the whole object. For example, children (as well as adults) are able to resolve apparent contradictions (e.g. *my dinner was good and bad*) by shifting their interpretation from the whole object (dinner) to a separate examination of its parts (*the salad was good but the wine was bad*).

Sharpe *et al.* (1997) examined children's and adult's use of predicate dimensionality with antonymous opposites. In the study, each subject was given a series of apparent contradictions based on the presentation of (or descriptions of) objects such as a toy elephant. Subjects were then asked to comment on apparent contradictions such as *I asked my friend if the elephant was tall and she replied: Yes and No*. The results indicated that adults and children made use of object structure and predicate dimensionality to process contradictions non-classically.

Children use semantic (e.g. predicate dimensionality) and pragmatic properties when processing negations, yet several unresolved issues remain. One issue is that a common dimension, directional oppositionality, has not been explored. While a single study (Sharpe *et al.*, 1999) has examined dimensionality in children, this study did not look at how children process and evaluate dimensional oppositionality. Thus the following questions remain: a) When processing negations, do preschool children make use of oppositional predicate dimensionality? b) Are children's responses evenly distributed among all positions on the dimension (weak negation) or do the responses cluster at extreme ends of the predicate dimensions (strong negation)? c) When given a negation with dimensional opposites, do preschool children make use of this information to create antipodal or orthogonal referents? And d) Can children correctly evaluate the truth-value of negations regardless of its semantic content?

Three experiments were conducted to examine these questions. The first experiment investigated four- and five-year-old children's notions of opposites to determine if they respond to items from common oppositional pairs. The materials included a series of items that were dimensional and converse opposites. Experiments 2 and 3 were restricted to dimensional opposites for two reasons: a) these opposites are present by age 4;0 (Dale & Fenson, 1996) and b) dimensional opposites are structured such that they do not overlap with object structure (Sharpe *et al.*, 1999). Experiment 2 examined whether children preferred antipodal or orthogonal representations for negated terms from pairs of directional opposites. In this experiment children were asked to create pictures corresponding to a statement phrased as a negation of a common directional opposite (e.g. up/down). Experiment 3 examined whether children would accept orthogonal as well as antipodal pictorial representations of a negative statement based on items from oppositional pairs. Experiment 3 used the same materials and negated statements as Experiment 2 but asked children to evaluate representations made by 'another child.'

EXPERIMENT 1

The purpose of Experiment 1 was to examine if preschool-aged children can produce an opposite when given one term in an oppositional dyad. Because the other studies presume oppositional category structure, Experiment 1 simply investigates the extent to which children possess such structure. Children were shown 12 pictures: four colours (red, black, white,

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blue), four directions (up, down, right, left), and four magnitudes (dark, light, small, big). Colours and directions are considered directional opposites while magnitudes are considered converse opposites. Each child was shown a series of pictures and asked to name its opposite. While ten of the items had a well-known opposite, two of the stimulus items did not (these items did not represent a lexical gap in English) and were presented to determine if such terms would generate a stable response pattern (as in the case of well-known opposites).

METHODS

Participants

Fifty-seven children participated: 37 four-year-olds (mean age 4;8 years; 14 girls, 13 boys) and 20 five-year-olds (mean age 5;9; 10 girls, 10 boys). Participants were enrolled in two preschools in Pittsburgh, PA and were selected on the basis of returning a parental consent form.

Materials

Seventeen pictures (each approximately 5 × 7 inches) associated with the targeted term were created using Microsoft clip art. Five pictures were used in the warm-up phase and 12 were used in the experimental phase.

Procedure

A female experimenter tested each participant individually. The child and experimenter sat across from each other at a small table. The experimenter read a brief introduction that included five warm-up trials to familiarize children with the general procedure. Children were first given an 'explanation of the word opposite'. Children were told the following: *We are going to play a game called 'Opposites.' An opposite is something that is unlike something else. So, the opposite of tiny is big. So when I say a word I want you to say a word that means the opposite. We play it like this: I have some pictures on the table that will go along with the word I will say. After I say the word I want you to think of a word that would be the opposite of mine. Let's try one.* Each child was then given five warm-up tasks and prompted to give an opposite of that term. For example, children were shown a picture of a person who was smiling and jumping into the air. The child was told *This person is happy, Can you think of a word that is the opposite of HAPPY?* If necessary, children were given prompts for warm-up questions only such as *Now remember that an opposite is something very unlike another word. So can you think of a word that is very unlike happy?*

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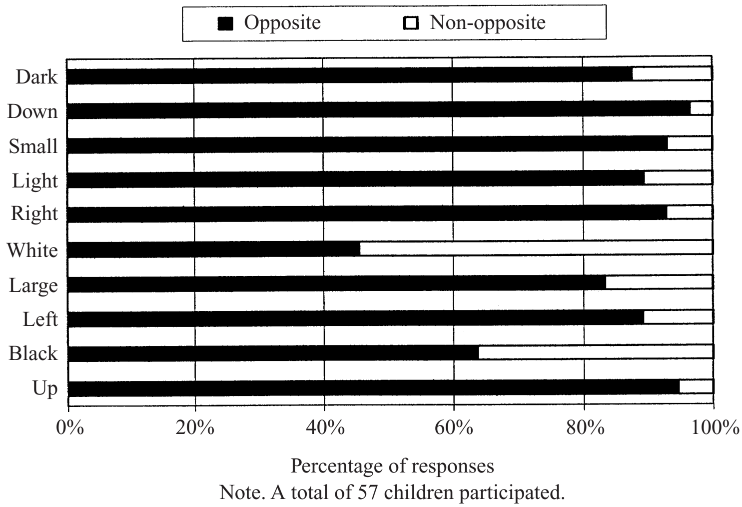

Fig. 1. Percentage of 'opposite' responses.

The experimental task consisted of 12 pictures with corresponding terms. Ten of the items had well-known opposites (e.g. up-down) and two were filler items that had no well-known opposites (e.g. blue-orange) that were not included in coding. On each trial the experimenter presented one picture, clearly stated the term in a sentence (e.g. *The circle is black*) and repeated the targeted term. Once children understood the term, they were asked *What is the opposite of black?* Children's responses were recorded and later coded as either opposites or non-opposites. All children gave a response for each item. In this experiment (as in all studies) presentation orders were counter-balanced so that each child saw one of two possible orders of presentation.

RESULTS

The purpose of Experiment 1 was to see if children were able to produce items from common oppositional pairs. Preliminary chi-square analyses found no age, order or gender differences ($p > 0 \cdot 10$), so all were combined for further analysis. Figure 1 displays the number of children who produced an opposite for each target word. Individual response patterns were compiled to determine the consistency with which children gave opposite responses. A child who gave an opposite on at least 8 of 10 trials was considered consistent. This threshold was used since the two non-opposites were eliminated because their response patterns were not stable across participants. Using this Goodness-of-fit criterion, 39 of the 57 children (68%) consistently produced well-known opposites. A chi-square that compared the number of children who gave consistent opposite responses to the number of children who did not give consistent opposite responses indicated that the distribution of responses was significantly different than chance ($\chi^2(1, 50) = 34$, $p = 0{\cdot}001$). Children provided opposites most frequently on the up/down pair (52 children) and least frequently on the black/white pair (30 children) with other categories falling in between (left/right- 50, dark/light- 49, large/small- 45). A second individual analysis eliminated the black/white items and calculated that 50 of 57 (88%) children gave an opposite response on at least 7 of 8 trials.

DISCUSSION

The results provide evidence that four- and five-year-old children are able to spontaneously produce opposite terms. Individual analysis of each set of pairs indicates a difference in the number of children who provided well-known opposites to both items. One possible explanation for this finding is that opposite category structure is more clearly established for directional and comparative items than for colour terms.

EXPERIMENTS 2 & 3

INTRODUCTION

The purpose of Experiment 1 was to demonstrate that preschool children could produce opposites for well-known terms. Given that children have access to oppositional structure, Experiments 2 and 3 examine how predicate dimensionality influences processing and evaluating negations.

In Experiment 2, children's preferences for weak or strong negations were examined when given dimensional opposites. In Experiment 3, children's evaluations of the truth-values of strong and weak negations were examined with negations that used dimensional opposites. For example, given the statement *The arrow is not pointing up* will children accept strong, antipodal opposites (arrow pointing down) or weak, orthogonal opposites (arrow pointing to the side)?

The children participating in Experiments 2 and 3 were not the same as those used in Experiment 1. The same participants were used for 2 and 3, so two counterbalanced orders were created for each set of materials. The order in which 2 and 3 were presented was randomly determined for each child.

EXPERIMENT 2: METHOD

Participants

Fifty children participated: 27 four-year-olds (mean age 4;8; 14 girls, 13 boys) and 23 five-year-olds (mean age 5;9; 11 girls, 12 boys). Participants

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were enrolled in one preschool in Pittsburgh, PA and were selected on the basis of returning a parental consent form.

Materials

Each child was given one 3×5 inch unlined card during each of 15 trials (3 warm-up, 12 experimental). After the child was provided with the blank card, he or she was given a sticker array that corresponded to possible responses for each trial. There were two types of sticker arrays per trial: a) one sticker for questions of position or direction (arrows and squares) and b) four stickers for questions of colour choice (4 circles that were of four different solid colours). All stickers were approximately the same size.

Procedure

A female experimenter tested each participant individually. Child and experimenter sat across from each other at a small table. The experimenter read a brief introduction that included three warm-up trials to familiarize children with the general procedure. The protocol for the warm-up phase is provided in Appendix A. In each warm-up trial, children were asked to make a picture using the card and stickers to represent a statement read by the experimenter. The warm-up was also designed to eliminate any children who were unable to follow the directions by erring on 2 of 3 trials. None of the children had difficulty with the warm-up tasks.

The experimental task consisted of 12 statements phrased as negations, 10 statements with well-known opposites and 2 filler statements (i.e. terms without well-known opposites) that were not included in the analysis. Children were instructed to make pictures that represented each statement. Statements concerned two topic areas: colour and direction. The materials are as follows: colour (black/white; orange/blue), and direction (above/below; right/left; up/down; left/right). Each topic area had four possibilities that corresponded to one incorrect and three correct answers. The three correct answers represented two orthogonal options and one antipodal option.

Each of the 12 trials involved the experimenter reading a statement to the child and presenting them with one 3×5 inch card and a sticker array to make a picture of the statement. After children made a picture, they were asked why they chose or placed the sticker as they did. Responses were recorded on audiotape and transcribed. An example of the directions each child was read on an experimental trial is provided in Appendix A.

Coding

Two coding systems were used, one for coding pictures and the second for coding explanations. The first coded the placement/choice of the

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TABLE 1. *Stimuli and opposite responses*

Statement	Picture
not up (arrow)	down
not above	below
not black	white
not left	right
not below	above
not down	up
not right	left
not white	black
not right	left
not left	right
not blue	?*
not orange	?*

* Not included in coding and analysis.

TABLE 2. *Coding explanations for picture creation*

Code	Explicit v. implicit	Number of possibilities	Explanation	Example
Other options	Explicit	>1	Mentions other possibilities	*It could be sideways or down*
Opposites	Explicit	1	Gives opposite as reason	*It is the opposite of up*
Restate	Implicit	1	Repeats directions	*You said not up*
Association	Explicit	0	Linked to choice	*Green is like red*
Non-informative	Implicit	0	Gives no information	*Because I felt like it* *It's pointing at you*

sticker from the directions. Table 1 displays the stimuli and opposite responses.

Three codes were used to evaluate the pictures: correct/antipodal, correct/orthogonal, and incorrect. Responses to the statement *The sticker is* ***not*** *above the square* were coded as follows: correct/antipodal – a sticker below the square; correct/orthogonal – a sticker beside the square; incorrect – a sticker above the square. Each child's responses to the problem set were compared to Table 1. As in Experiment 1, the two non-opposite items were not included in coding, leaving 10 possible responses. A child that produced at least 8 of 10 responses of the same type (e.g. antipodal or orthogonal) was considered to be using a consistent strategy because the conditional probability of randomly selecting any response on 8 of 10 trials was less than 0·05.

The second coding system was used to categorize explanations for the placement/choice of stickers. The coding categories were created after the data were collected and covered five different rationales for placement/choice

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TABLE 3. *Distribution of explanations*

Code	Explanation	Number of responses* (percentage of responses)
Other options	Mentions other possibilities	4 (<1)
Opposite	Gives opposite as reason	19 (3)
Restate	Repeats directions	147 (30)
Association	Thematic links between items (e.g. dog and bone)	33 (6)
Non-informative	Gives no information	256 (51)
No answer	Did not respond	41 (9)
Totals		500 (100)

* Two non-opposite responses were eliminated. Each child ($N = 50$) saw 10 trials (500 explanations).

involved in picture creation that differed on two dimensions: explicitness of explanation (explicit v. implicit) and the number of possibilities considered (more than 1, 1, or 0). In order to establish reliability, two coders categorized approximately 30% of the responses with an inter-rater reliability of 93%. The categories are outlined in Table 2.

RESULTS

Picture creation

If children do not have a preference for either type of dimensional opposite, then the types of pictures created should be randomly distributed among all three correct response types (33% antipodal, 66% orthogonal). If children have a preference for a particular type of response, then the pictures should be created at a level exceeding chance (i.e. greater than 33 and 66% for antipodal and orthogonal, respectively). Initial analyses indicated no effects of order, gender or age, so these categories were combined for further analysis. No children produced any incorrect pictures. Nearly all pictures created were correct/antipodal representations (88%). Forty-six of 50 children used an antipodal strategy on at least 8 of 10 trials indicating considerable within-individual consistency. A goodness-of-fit analysis, with expected values set at chance, indicated that significantly more children used this strategy than was expected by chance ($\chi^2(1, 50) = 53.4$, $p < 0.001$). Unlike Experiment 1, there were no significant differences between types of materials such as colours and directions ($p > 0.10$).

Explanation of picture creation

After creating a picture corresponding to the statement, children were then asked to explain why they had chosen a particular representation. Once coded, the number of times each type of explanation was used was compiled across participants and is displayed in Table 3.

Explicit references to more than one possibility (i.e. antipodal explanations) were quite rare (less than 4%). The lack of explicit antipodal explanations was much lower than the high number of antipodal pictures created. The most common type of explanation was non-informative. This suggests that although children often created pictures conforming to an antipodal interpretation, they were unable to explain why they made pictures as they did. The next most common response, restatement, did not explain why a child created a particular picture but merely repeated the instructions.

DISCUSSION

Four- and five-year-old children used an antipodal strategy to create representations corresponding to STRONG negations, based on predicate dimensionality. In the picture creation task, 46 out of 50 children created antipodal representations on at least 8 of 10 trials, demonstrating a considerable level of consistency. In addition, children's responses suggested a pragmatic interpretation in which an excluded middle collapse favoured interpretations at the extreme ends of the predicate dimension. That is, instead of viewing a negation as any response that represents the absence of a characteristic (e.g. *not above* may mean *to the side*), children preferred its diametric opposite (e.g. *not above* means *below*). Children's explanations suggested that they were unable to explain why they chose this strategy. The analysis indicated that two categories (Non-Informative and Restatement) accounted for over 75% of the explanations.

Children seem spontaneously to create antipodal opposites rather than orthogonal opposites when processing negations. But are children CAPABLE of making a fine distinction between antipodal and orthogonal interpretations for a negation or will they accept only antipodal responses? For example, given the statement 'The arrow is **not** pointing up' will children accept an orthogonal, yet correct option (arrow pointing to the side) or will they reject such an option? Experiment 3 addresses this question by asking children to evaluate 'another child's picture' of a negated statement.

EXPERIMENT 3

Experiment 3 examines the extent to which children will accept logically correct options that have been derived from antipodal *or* orthogonal opposites. Children evaluated pre-made pictures corresponding to negated statements. The children were told these pictures were made by 'another child', then were asked to judge the pictures as either *OK* or *SILLY* and asked to explain why they had evaluated the picture as they did. For example, given the statement *The arrow is NOT pointing up*, will children accept an arrow pointing to the side? If so, then children are using a WEAK EVALUATION STRATEGY in which the logical structure takes precedence over antipodal structure. If not, then children are using a STRONG EVALUATION STRATEGY. If children are using a weak evaluation strategy, then they should correctly evaluate all pictures. If children are using a strong evaluation strategy, then they should correctly evaluate only those pictures that represent antipodal opposites.

METHOD

Materials

Fifteen pictures were created on 3×5 cards using the negated statements and stickers from Experiment 2. As in Experiment 2, three pictures were used in the warm-up phase and 12 were used in the experimental phase of the Experiment. The pictures were based on 12 negated statements: 5 antipodal/correct and 5 orthogonal/correct and 2 incorrect options. The incorrect options were given to serve as a control for the tendency to give affirmative responses.

Procedure

The procedure was similar to Experiment 2 but instead of picture creation, children were asked to evaluate pre-made pictures.

Warm-up. Each warm-up trial asked children to evaluate a picture that 'another child made' when given the statement read by the experimenter. An example of the instructions for the warm-up task is provided in Appendix B. The warm-up was also designed to eliminate any children who were unable to follow directions (erring on 2 of 3 warm-up trials). None of the children had difficulty with the warm-up tasks.

Experiment. Children were instructed to evaluate pictures as either OK or SILLY. Ten of the twelve pictures represented a logically correct choice; the differences were whether responses represented antipodal or orthogonal opposites. An example of the instructions for the experimental tasks is provided in Appendix B.

Coding

Two coding systems were used. A child evaluating 10 of 12 responses correctly was coded as using a logical interpretation strategy. The second coding system classified children's explanations of their evaluation. The explanation coding categories were created after the data were collected and covered five different rationales for picture evaluation. The categories are similar to those

TABLE 4. *Rationale for evaluating pictures*

Code	Explanation	Example
Other options	Gives other possible options	*It could have been sideways or down*
Opposite	Interpreting negation as opposite	*You said down* (*recalled as an antipodal opposite*)
Followed directions	'Other child' followed directions	*She listened* *She did it right*
Pre-conception	Child states what they believe *should* have happened	*It should have been left*
Non-informative	No information	*Because I don't know*

used in Experiment 2 with two substitutions due to the task demands: FOLLOWED DIRECTIONS and PRE-CONCEPTION were used in the place of RESTATE and ASSOCIATION. Children rarely used the latter codes when evaluating pictures instead providing explanations for why the pictures conformed to the task demands (followed directions) or what they believed the child should have done (pre-conception). In order to establish reliability, two coders categorized 30% of the responses with an inter-rater reliability of 96%. The categories are outlined in Table 4.

RESULTS

Picture evaluation

Preliminary analyses indicated no age, order or gender differences in the overall response patterns so all were combined for further analysis. Aggregated analysis of responses indicated that children had near-perfect performance in evaluation, scoring 97% of the pictures correctly. Individual analyses indicated that 48 of 50 children correctly evaluated each item on at least 10 of 12 trials. The consistency of responses was significantly greater than chance ($\chi^2(1, 50)=99{\cdot}4$, $p<0{\cdot}001$). As in Experiment 2, there were no significant differences between types of materials such as colour or direction (ps $<0{\cdot}10$).

Explanation of evaluation

After evaluating each picture, children were asked to explain their evaluation. Once coded, the number of times each type of explanation was produced is displayed in Table 5.

One type of explanation, antipodal, accounted for the majority of responses for both antipodal and orthogonal items. A one-group variance test indicated that the distribution of responses differed significantly from

TABLE 5. *Distribution of evaluation explanations*

Code	Explanation	Total number of explanations* Antipodal Number (%)	Orthogonal Number (%)
Other options	Gives other possible options	2 (>1)	1 (>1)
Opposite	Interpreting negation as antipodal	188 (75)	170 (68)
Followed directions	'Other child' followed directions	41 (16)	48 (19)
Pre-conception	States what should have happened	6 (3)	12 (5)
Non-informative	No information	6 (3)	5 (2)
No answer	Did not answer	7 (3)	14 (6)
Total		250 (100)	250 (100)

* Each child ($N=50$) saw 10 trials (5 antipodal, 5 orthogonal) resulting in 500 total explanations (250 opposites, 250 non-opposites).

chance for both antipodal ($\chi^2(5, 50)=56$, $p<0{\cdot}0001$) and orthogonal items ($\chi^2(5, 50)=76{\cdot}7$, $p<0{\cdot}0001$). There was no significant difference between the two response patterns ($p>0{\cdot}10$). The large number of antipodal explanations is suggestive of the idea that children may be encoding or recalling negated statements as affirmatives (e.g. *not up* is encoded as *down*). The second most frequent explanation, followed directions, was an implicit approval of the representation given the task demands (i.e. given the directions, the card was correct).

Comparing individual response and explanation patterns

The previous analyses suggested that a large number of children logically interpreted the pictures and gave antipodal explanations for their choices. To test this, an analysis was conducted to examine the extent to which individual children used a weak evaluation strategy AND produced an antipodal explanation for the same test item. A 'combination' response pattern was coded if a child gave both on at least 70% of trials (7 of 10 opposite trials). A total of 40 of 50 children produced the combination response pattern. This suggests that even though children were able to evaluate the negations correctly, their explanations indicated that children were remembering the statement not as a negation but as an antipodal affirmative.

DISCUSSION

The results of Experiment 3 clearly demonstrated that four- and five-year-old children were capable of correctly evaluating negations despite processing predicate dimensionality. Children were given a series of

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pictures in which the majority were logically correct, representing an equal number of antipodal and orthogonal items. Nearly all children correctly evaluated both types of pictures as correct. Additionally, children demonstrated remarkably high consistency in that 48 of 50 used a weak evaluation strategy (correctly rating the picture on at least 10 of 12 trials).

Children gave two primary explanations (antipodal and followed directions) for their ratings that accounted for over 85% of the total responses. Antipodal was the most frequent explanation in which children remembered the statement not as it was stated (in the form of a negation) but as an antipodal, affirmed statement. This result is somewhat surprising because it indicates that even while children correctly evaluated a statement they often recalled the statement as an antipodal opposite. This result mirrors the type of meaning-preserving errors seen in research with adults in which adults remember negated items (e.g. not hot) as their opposites (cold) (Brewer & Lichtenstein, 1975). The 'followed directions' explanation (16%) suggested that the child who made the pictures did what he/she had been told to do. The results indicated that children are capable of correctly evaluating negations even when the task demands call for inhibiting their preference for strong negations.

GENERAL DISCUSSION

The results reported here suggest that preschool age children process negations non-classically making use of oppositional predicate dimensionality. While children use this information to process negations, it appears that children do not simply consider a negation to be an opposite. Although there was a clear preference for interpreting (and recalling) a negation as an antipodal opposite, nearly all children were able to evaluate negations correctly. That is, children could evaluate truth-values correctly despite their preference for antipodal oppositionality.

The findings generally support theories that suggest non-classical logical processing (Rychlak, 1994; Sharpe *et al.*, 1996, 1999). That is, children used information from the predicate, in this case dimensional oppositionality, to process negations. It seems that oppositionality is particularly important in preschooler's interpretations of negation because when such category structure is present, it provides additional information useful for interpreting the intentions of the speaker. However, children's processing of negation extends beyond mere oppositionality. In fact, the results suggest that preschool children's processing of negation is not restricted to responses derived from semantic information. Specifically, the results of Experiment 3 show that children are capable of evaluating the truth-value of a negation even when a correct evaluation is not aligned with a preferred response.

The findings are important because extensional processing of negation (i.e. independent of predicate dimensionality) suggests that what is logically true is not necessarily intensionally true (dependent on predicate dimensionality). That is, formal logical reasoning often involves the suspension of intensional semantics in order to derive a valid conclusion. This inability to separate real-world knowledge from the content presented in a logic problem is frequently cited as a source of error for both children and adults (e.g. Wason, 1965; Leevers & Harris, 2000). Intensional interpretations of connectives like negations may contribute to this effect by creating defective problem representations from which solutions are derived (Evans, 1989). For example, an arrow that is *not pointing up* may point down but also may point to the side. In the context of a logical proposition (in which each connective must be interpreted as well as the proposition as a whole), an intensional inference may contribute to the statement as a whole being incorrectly represented, thus seriously decreasing the likelihood of solving the problem extensionally. That is, the number of intensional representations at the connective level amplifies the degree of deviation from extensional representations at the propositional level.

Future research is needed to examine the relationship between the development of other types of category structure and the processing of negation. For example, research should examine the relationship between other types of semantic content (e.g. similarity) and intensional semantics. Future studies should also examine the relationship between the relative frequencies of oppositional pairs to determine the role of input in their acquisition. Finally, because the four-year-olds in this study were adult-like in their performance, research with younger children seems necessary in order to determine when children begin to make use of predicate dimensionality.

CONCLUSIONS

Four- and five-year-old children interpret negations non-classically by making use of the rules of inference for negation and the predicate dimensionality of the negated item. When given dimensional opposites (e.g. up/down), these children nearly always made use of oppositionality of the predicate (e.g. South), preferring antipodal (North) to orthogonal (East) responses. However, children's processing of negation was not limited to mere oppositionality. They correctly evaluated truth-values for negations even when these truth-values were not aligned with their preferences for strong negations. Finally, they encoded negations using predicate dimensionality often recalling these statements as antipodal opposites. The results suggest that four- and five-year-old children possess the cognitive resources to make fine distinctions in their logical evaluations of negations based on the predicate structure of semantic information.

REFERENCES

Anderson, A. R. & Belnap, N. D. (1975). *Entailment: the logic of relevance and necessity*. Princeton: Princeton University Press.

Berlin, B. & Kay, P. (1969). *Basic Color Terms*. Berkeley: University of California Press.

Bloom, L. (1970). *Language development: form and function in emerging grammars*. Cambridge, MA: MIT Press.

Braine, M. D. S. & Rumain, B. (1983). Logical reasoning. In J. H. Flavell & E. M. Markman (eds), *Handbook of Child Psychology*. Vol. III. Cognitive Development. New York: Wiley.

Brewer, W. F. & Lichtenstein, E. H. (1975). Recall of logical and pragmatic implication in sentences with dichotomous and continuous antonyms. *Memory & Cognition* **3**(3), 315–18.

Dale, P. S. & Fenson, L. (1996). Lexical development norms for young children. *Behavioral Research Methods, Instruments & Computers* **28**, 125–27.

de Boysson-Bardies, B. (1977). On children's interpretations of negation. *Journal of Experimental Child Psychology* **23**, 117–27.

Evans, J. St. B. T. (1989). *Bias in human reasoning: causes and consequences*. East Sussex, UK: Erlbaum.

Gross, D., Fischer, U. & Miller, G. A. (1989). *Journal of Memory and Language* **28**, 92–106.

Hyams, N. (1994). Nondiscreteness and variation in child language: implications for principle and parameter models of language development. In Y. Levy (ed.), *Other children, other languages: issues in the theory of language acquisition*. Hillsdale, NJ: Erlbaum.

Johnson-Laird, P. N. (1983). *Mental models*. Cambridge, MA: Harvard University Press.

Kim, K. J. (1985). Development of the concept of truth-functional negation. *Developmental Psychology* **21**(3), 462–72.

Klima, E. S. & Bellugi, U. (1967). Syntactic regularities in the speech of children. In J. Lyons & R. J. Wales (eds), *Psycholinguistics papers: the proceedings of the 1966 Edinburgh conference*. Edinburgh, UK: Edinburgh University Press.

Leevers, H. J. & Harris, P. L. (2000). Counterfactual syllogistic reasoning in normal 4-year-olds, children with learning disabilities, and children with autism. *Journal of Experimental Child Psychology* **76**, 64–87.

Lyons, J. (1977). *Semantics* Vol. 1. Cambridge, UK: Cambridge University Press.

Park, T. (1977). Some fact on negation: Wode's four-stage developmental theory of negation revisited. *Journal of Child Language* **6**, 147–51.

Pea, R. D. (1980). The development of negation in early child language. In D. Olson (ed.), *The social foundations of language and thought*. New York: Norton.

Piaget, J. & Garcia, R. (1991). *Toward a logic of meanings*. Hillsdale, NJ: Erlbaum.

Rumain, B. (1988). Syntactics of interpretation of negation: a developmental study. *Journal of Experimental Child Psychology* **45**, 119–40.

Rychlak, J. F. (1994). *Logical learning theory: a human teleology and its empirical support*. Lincoln, NE: University of Nebraska Press.

Rychlak, J. P. & Barnard, S. (1996). The role of negation in implication versus inference. *Journal of Psycholinguistic Research* **25**(4), 483–505.

Sharpe, D. & Lacroix, G. (1999). Reasoning about apparent contradictions: resolution strategies and positive-negative asymmetries. *Journal of Child Language* **26**, 477–90.

Sharpe, D., Cote, M. & Eakin, L. (1999). Reasoning about a structured object: three- and four-year-olds' grasp of a borderline case and an unexcluded middle. *Child Development* **70**(4), 866–71.

Sharpe, D., Eakin, L., Saragovi, C. & Macnamara, J. (1996). Resolving apparent contradictions: adults' and preschoolers' ability to cope with non-classical negation. *Journal of Child Language* **23**, 675–91.

Sharpe, D., Purdy, D. & Christie, E. (1997). Acquiring the logical of natural language negation: structured objects and dimensional predicates. In E. Hughes, M. Hughes & A. Greenhill (eds), *Proceedings of the Twenty-first Annual Boston University Conference on Language Development*. Somerville, MA: Cascadilla Press.

Wason, P. C. (1965). The contexts of plausible denial. *Journal of Verbal Learning & Verbal Behavior* **4**(1), 7–11.
Wode, H. (1977). Four stages in the development of L1 Negation. *Journal of Child Language* **4**, 87–102.

APPENDIX A

PROTOCOLS FOR EXPERIMENT 2

Warm-up instructions

(Experimenter directions are bolded, spoken parts are italicized).

We are going to play a picture game where you use stickers to make pictures. We play it like this: I will read something to you and you will finish the picture. Let's try a few. **Place card (with box) and sticker in front of child.** *Listen closely then make a picture of what I said. Ok, in this picture the sticker is beside the box. Where will the sticker go?* **Place the sticker beside the box if child is unable to follow directions.**

Let's try another one. **Place card (circle picture) and four coloured spot stickers in front of child.** *This time I want you to choose a sticker that will make the circle the colour I said (point to circle). Make it so the circle is red.* **Take the red sticker and put it on the circle if child is unable to follow directions.**

Let's try one more. **Place blank card and arrow sticker in front of child.** Remember, listen closely then make a picture of what I said. Ok, in this picture the arrow is pointing up. Where will the sticker go? **Place the arrow so that it is pointing up if child is unable to follow directions.**

Experimental instructions

(Experimenter directions are bolded, spoken parts are italicized).

Place blank card in front of child. Hand sticker to child with arrow pointing up. The arrow is NOT pointing up. Make the picture so that the arrow is NOT pointing up. Why?

APPENDIX B

PROTOCOLS FOR EXPERIMENT 3

Warm-up instructions

(Experimenter directions are bolded, spoken parts are italicized).

I have some pictures that I would like to show you. **Show warm-up pictures.** *Now, we are going to play a picture game. In this game, we are going to look at some pictures that other children made. When we look at the pictures I will* *tell you what the children were supposed to put in the pictures and I will ask you if the picture is OK or if it is SILLY. Let's try a few. Remember to decide if the picture is OK or SILLY.* **Place card (with sticker beside box) in front of child.** *Ok, the child was supposed to put the sticker beside the box. Is the sticker beside the box? So is this picture OK or SILLY? Good.*

Experimental instructions

(Experimenter directions are bolded, spoken parts are italicized).

Ok, the child was supposed to make circle NOT black. **Place white circle card in front of child.** *Is this picture OK or SILLY? Why?*