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The emergence of inferential rules The use of pragmatic reasoning schemas by preschoolers

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Abstract

This study contrasts the pragmatic view with the natural logic view regarding the origin of inferential rules in conditional reasoning. The pragmatic view proposes that pragmatic rules emerge first, and the generalizations of these produce formal rules. In contrast, the natural logic view proposes that the formal rules emerge first and serve as a core that is then supplemented by pragmatic rules. In an experiment, scenarios involving conditional rules in different contexts, permission and arbitrary, were administered to independent groups of preschool children. To rule out the matching bias [Evans, J. St. B. T., & Lynch, J. S. (1973). Matching bias in the selection task. *Br J Psychol* 64, 391–397] as a possible explanation of reasoning performance, children were given conditional rules with a negated consequent. The results show that in the arbitrary context modus tollens (MT) was unavailable, and the use of modus ponens (MP) was unstable. In contrast, children in the permission context reliably used both MP and MT. In addition, they realized that a conditional rule does not imply a definite answer when the consequent holds. These findings suggest that, in their explicit forms, pragmatic rules emerge earlier than formal rules and in particular, even as basic a rule as MP is generalized from a context-specific form to a context-general one in preschool children. © 2000 Elsevier Science Inc. All rights reserved.

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Investigators have been intrigued by the development of children's ability in deductive reasoning since the 1960s. Early research in this field was mainly

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motivated by Piaget's theory of stages (Inhelder & Piaget, 1958) and was done with the hope that the results could be useful in the curriculum planning of mathematics and science (Donaldson, 1963; O'Brien & Shapiro, 1968; Miller, 1969). According to Piaget, deductive reasoning is a cognitively advanced skill that develops during adolescence; in particular, adolescents acquire a complete mental logic that corresponds to standard logic. Experimental evidence on conditional inferences has not supported Piaget's theory: on the one hand, even college students typically do not reason using standard rules of logic as Piaget suggested (see Evans, 1982 for a review); on the other hand, elementary school children already show competence in conditional reasoning (Roberge, 1970; Kodroff & Roberge, 1975; Ennis, 1982).

Other attempts to address this developmental issue include explanations inspired by learning theory (Falmagne, 1980) at one extreme, and those derived from nativism at the other extreme (Fodor, 1975, 1980; Macnamara, 1986). Falmagne (1980) suggested that inferential rules could be learned in the same way concepts are learned. By receiving feedback either from other speakers or the physical world, children abstract the logical structure common to the instances of a given pattern of inference they encounter. She showed that children of 8–11 years could acquire modus tollens (MT; the inference that given the premises *if-p-then-q* and *not-q*, the conclusion *not-p* follows) from examples in which feedback is given. Falmagne's findings argue for the role of learning in deductive reasoning. It is questionable, however, whether learning by generalization could be applied to a basic inferential rule such as modus ponens (MP; the inference that given the premises *if-p-then-q* and *p*, the conclusion *q* follows) (Braine, 1990; Johnson-Laird, 1990).

At the other extreme, Fodor (1975, 1980) and Macnamara (1986) argued that it is simply impossible to learn basic logical notions such as truth and falsity. A truth-functional system of representation must pre-exist before a child begins to learn a natural language. Learning a natural language is essentially learning to map the natural language onto the corresponding language of thought, which is presumably truth-functional.

In between the two extremes are the *pragmatic* view (Cheng & Holyoak, 1985; Cosmides, 1989; Cosmides & Tooby, 1992), and the *natural logic* view (Braine, 1978), the focus of the present paper. The pragmatic view was proposed partly in response to the failure of a formal account of reasoning, according to which people typically use content-independent rules in everyday reasoning. According to the pragmatic view, clusters of generalized inferential rules specialized for types of goal-directed relationships either evolved in the Pleistocene era or are induced from everyday experience early in life. In particular, Cosmides and Tooby (1992) proposed that humans beings have evolved a "look for cheaters" algorithm for reasoning about social contracts or exchanges, whereas Cheng and Holyoak (1985) proposed that people typically reason using pragmatic reasoning schemas induced from everyday life, such as those involving permissions, obligations, and causation. A social contract is a type of permission (for a discussion of the difference

between these variants of the pragmatic view, see Cheng & Holyoak, 1989). In the present paper, our interest is in differentiating the pragmatic view from the natural logic view, rather than contrasting the two variants of the pragmatic view.

We illustrate the natural logic view and the pragmatic view using Wason's (1966) selection task. In the classic version of this task, subjects are given an arbitrary rule in the conditional form *if-p-then-q*, which states "If a card has a vowel on one side, then it has an even number on the other side." Four cards corresponding to the four cases *p*, *not-p*, *q*, and *not-q* are then presented, for example, "E," "K," "4," and "7." Each card has information regarding the antecedent (i.e., *p* or *not-p*) on one side and the consequent (i.e., *q* or *not-q*) on the other side. The subject's task is to indicate those and only those cards that must be turned over to test if the rule is true or false. In solving the task, two relevant inferential rules are MP and MT (see definitions earlier). According to the "standard-logic" variant of the formal view, the cards corresponding to *p* and *not-q* should be examined. However, subjects seldom select this "correct" answer pattern. Instead, they often select the cards "E" (*p*) and "4" (*q*), but omit to select the "7" (*not-q*).

Reasoning errors are much less frequent when the same task is cast in terms of a permission situation in which a regulation is imposed by an authority to achieve some social purpose, for instance, "If one is to drink alcohol, then one must be over 18." One of the pragmatic schemas proposed by Cheng and Holyoak (1985) is the permission schema. Once this schema is evoked, a set of production rules become activated. They are the following: Rule 1: "If the action is to be taken, then the precondition must be satisfied." Rule 2: "If the action is not to be taken, then the precondition need not be satisfied." Rule 3: "If the precondition is satisfied, then the action may be taken." Rule 4: "If the precondition is not satisfied, then the action must not be taken." In the alcohol example, Rules 1 and 4 function as MP and MT, while Rules 2 and 3, respectively, block the fallacy of *denying the antecedent* (DA) and the fallacy of *affirming the consequent* (AC). The former fallacy refers to the inference that given the premises *if-p-then-q* and *not-p*, the conclusion *not-q* follows; the latter fallacy refers to the inference that given the premises *if-p-then-q* and *q*, the conclusion *p* follows. Research has shown that when a permission rule is given, not only adults (Cheng & Holyoak, 1985; Cheng et al., 1986) but even children as young as 3- or 4-years old can reason "correctly" (Giroto et al., 1988, 1989; Light et al., 1989; Harris & Núñez, 1996).

Despite the fact that the pragmatic view can account for content effects that cannot be explained by a purely formal theory, there is consensus that MP is endorsed regardless of context, even by children at an early age (Roberge, 1972; Osherson, 1975; Evans, 1977; Wildman & Fletcher, 1977; Rips, 1983; Romain et al., 1983; Braine et al., 1984; Bryne, 1989). This consensus is consistent with a natural logic view (Braine, 1978).

Emphasizing the relation between language and standard logic, the natural logic view (Braine, 1978) claims that people have a repertory of domain-independent rules of inference, which they can use automatically and effortlessly

from an early age on. These rules of inference are associated with connectives in natural languages, for instance, *and*, *or*, *not* and *if* in English, for expressing the logical notions of conjunction, disjunction, negation, and conditionality. Inferences using these logical operands are presumably innate and universal across all languages (Osherson, 1975; Braine, 1978; Braine et al., 1984; Rips, 1983). Taking a bioevolutionary perspective, Braine and O'Brien incorporated pragmatic factors into the formal view (Braine, 1990; Braine & O'Brien, 1991; O'Brien 1993), claiming that natural-logic rules never contradict pragmatic rules, but instead form a core to which the pragmatic rules are added. With respect to the connective *if-then*, they argued that the formal rule, MP, should be the core initial entry for *if*, and that the entry can be gradually enriched by increasing experiences with particular goals and relationships. In contrast, MT is a secondary inferential rule that may be acquired in later development. Braine and O'Brien (1991) further pointed out that the pragmatic view could pose a challenge to their theory only if it could be shown that subjects cannot understand MP without a pragmatic context.

1. Empirical test of the natural logic view and the pragmatic view

In contrast, the pragmatic view would argue that pragmatic rules emerge first, and formal rules are then generalized from multiple pragmatic rules of the same form. It seems to us that a distinction should be made between explicit rules that reasoners are consciously aware of, and can therefore spontaneously elicit, and implicit rules that they are not consciously aware of, and are elicited only by the stimuli. Whereas we agree with the formal view that basic logical notions are innate, we think that such innate knowledge is implicit. The explicit versions are acquired, with pragmatic rules such as the production rules in the permission schema forming a basis for the acquisition of more general rules such as the explicit form of MP. The rest of this paper concerns knowledge of explicit inferential rules only.

Research in language acquisition shows that children as young as 2 years and 6 months have begun to utter conditional sentences (Bowerman, 1986). Other research in deductive reasoning indicates that preschool children (3- and 4-year-olds) already displayed an understanding of violations of permission rules (Harris & Núñez, 1996), whereas it is not until school-entering age (6 years) do children show appreciation of MP (Ennis, 1982; English, 1993).

These lines of evidence, however, cannot differentiate between the natural logic view and the pragmatic view. First, the research with preschoolers (Harris & Núñez, 1996) and younger children (Bowerman, 1986) did not test any inferential rule: that is, the children were not given premises such as, (1) *if-p-then-q* and (2) *p*, and tested on what these premises imply. Although such a task may be feasible for preschoolers, the children in Harris and Núñez's study were instead merely shown pictures with various combinations of the values of *p* and *q* (e.g., *p-and-q*,

p-and-*not-q*), and asked to select the combination (i.e., picture) that violates a permission rule *if-p-then-q*. This task is not equivalent to a test of the use of inferential rules because it is conceivable, for example, that a child might be able to recognize a violating picture, and yet be unable to *generate* the answer to a question testing MP or MT.

Second, there has not been any research with preschoolers or younger children in which the context is independently varied for conditional inference rules. In Harris and Núñez's study, the children in the non-pragmatic condition were asked a question concerning a "descriptive" rule that may differ from the question in the permission condition in its logical implications. The protagonist in the non-pragmatic scenario describes her own behavior: "If she does some painting, she always put her helmet on," and the children were asked to select the picture in which the protagonist is doing "something different" and is not doing what she said. It seems that painting without wearing a helmet or not painting at all might both be interpreted as doing something *different* from what the protagonist said about herself. In contrast, in the permission scenario, the children were asked to select the picture in which the protagonist is doing "something naughty" and not doing what her mom said ("If she does some painting, she should put her helmet on.") Now, only painting without wearing a helmet could be interpreted as doing something naughty. This difference between conditions renders a comparison between the two conditions uninformative for testing the natural logic view against the pragmatic view.

Finally, even if the inferential rules had been tested and if the pragmatic and non-pragmatic conditions were comparable, the fact that preschoolers already show knowledge of permissions would not constitute evidence against the natural logic view, according to which deductive knowledge is composed of core rules such as MP supplemented by pragmatic rules such as a pragmatic version of MT. As mentioned earlier, only evidence showing that MP fails to work without a pragmatic context would contradict the natural logic view, and none of the studies has reported evidence against the use of this rule (Giroto et al., 1988, 1989; Light et al., 1989; Harris & Núñez, 1996).

If the natural logic view is correct that the use of MP (presumably even in an explicit form) is innate, then as soon as MP is available, it should apply to both arbitrary and pragmatic selection problems because of its domain-independence. On the other hand, if the pragmatic view is correct in that the pragmatic rules develop earlier than MP, then there must exist an age at which the two kinds of rules do not co-exist; in particular, an age at which the child could solve only a pragmatic version of a reasoning task but not the arbitrary one. Because it is unclear exactly when MP would develop from their precursory pragmatic rules and how long this development will take before MP emerges, an experimental comparison of these two views must use children as young as possible to avoid missing a potential threshold of development. In this study we therefore use the youngest children who can understand conditional sentences. Their ages ranged from 3 years and 7 months to 5 years and 4 months.

2. Experiment

In the present study, two types of problems involving negated conditional rules were presented to young children. One type of problem did not refer to any familiar type of goal-directed context; one can only arrive at a solution by using context-independent rules. The other type of problem did refer to a familiar goal-directed context, so that it can be solved by using pragmatic context-specific rules; a permission situation is used for this type of problem because recent research (Harris & Núñez, 1996) indicated that preschoolers display an understanding of actions that violate a permission rule. All other aspects of the problems were closely matched. We adapted the selection task so that the children, unlike the adults, were not given an open task of checking whether a conditional rule holds; instead, they were asked to answer four specific inferential questions regarding a conditional rule using a forced-choice procedure. Superior performance on any of these questions in the permission condition than in the arbitrary condition would suggest that the relevant inferential rule first emerges in a context-specific form. In particular, the earlier use of MP in the permission condition would provide evidence against the natural logic view.

Our use of negated conditional rules was motivated by the results of a pilot study, which showed that given an affirmative rule *if-p-then-q*, children's response pattern for the arbitrary condition coincides with a prevalent response pattern given by adult subjects on the classic selection task, namely, selecting only the *p* and *q* cases. Researchers have argued that the adults' response pattern is a result of a "matching bias" in that reasoners simply selected the cards whose values matched those mentioned in the rule, that is, cards *p* and *q* (Evans & Lynch, 1973; Evans et al., 1993). The same argument applies to our pilot results regarding children using an inference task. For a rule in the form *if-p-then-q*, when a child was given the minor premise *p* in addition, he or she could have selected the right answer, *q*, by simply selecting the option among those given that matched what was mentioned in the rule, without using any inferential rule; similarly, when given the minor premise *q* in addition, those who used the matching strategy would have ("erroneously") selected *p* as the answer. Finally, when the minor premise did not match what was mentioned in the rule (e.g., *not-p*), the children might not have understood the relevance of the rule, and therefore randomly selected their answers, leading to the observed performance at chance level.

To rule out the matching bias as a possible explanation of reasoning performance, negation was introduced in the consequent of the conditional rule, such that *If p, then not-q*. If a child chooses a case whose value matches a linguistic term named in the rule, regardless of any negation, the child's answer to MP would be wrong; he or she would simply select the *q* option when given the minor premise *p*. Likewise, the child's answer to MT would also be wrong; he or she would select the *p* option when given the minor premise *q*.

Another possible explanation of reasoning performance is that subjects may interpret a given conditional rule (*If p, then not-q*) as a biconditional (*If and only*

if p, then not-q). If so, they may answer a question on MT correctly, but for the wrong reason (Romain et al., 1983; Markovits, 1984, 1985). To ensure that a correct answer on tollens is truly based on a conditional interpretation, a secondary conditional premise, *If r, then not-q*, was presented to suppress interpretation of the primary conditional rule as the biconditional.

3. Method

3.1. Subjects

Thirty-two children (18 males and 14 females) with a mean age of 4 years and 7 months (range 43–64 months) drawn from a preschool in Los Angeles participated.

3.2. Procedure and materials

Children were interviewed individually in a small quiet room. They were randomly assigned in equal numbers (16 subjects in each group) to one of two conditions: (1) the negative permission condition and (2) the negative arbitrary condition. In each condition, the child was first presented a scenario in which two negative conditional rules were embedded. The scenario starred two hand puppets resembling Sesame Street characters, who illustrated the rules on relevant concrete toy objects. Children were then asked to help the puppets select the correct answer to each of four inference questions regarding a rule in the scenario. The entire experiment was conducted in 3 consecutive days with a 15-min session on each day. The script for each condition is presented in Appendix A.

3.2.1. Scenarios

In the negative permission condition, the scenario involved the puppets Bert and Ernie, who played in a playground with a slide and a train. The rules were given by the puppets' mother.

1. If the puppet goes down the slide, then he must not have shorts on, because the slide gets very hot under the sun.
2. If it is windy, then he must not have shorts on, because he would get too cold.

The first rule involves permission because it says that in order to take a certain action, a certain precondition must be satisfied. To ensure that our subjects interpreted the rule as a conditional permission, a rationale (the slide is hot) was included. Although research showed that children were not influenced by the explicit mention of a rationale for the permission rule (Harris & Núñez, 1996), providing children with a standardized rationale instead of having them work it out for themselves may help reduce noise.

In the negative arbitrary condition, the scenario involved an initially covered “magic” box, and a magic rule stated the following.

1. If there is a dog sticker on the lid of the box, then there must not be an orange in the box.
2. If it is windy, then there must not be an orange in the box.

In each condition, the first rule, *if p, then not-q*, was the primary rule from which the four inferential questions based on the various premises were derived, whereas the second rule, *if r, then not-q*, was the one used to reduce the possibility of a biconditional interpretation for the first rule.

To alleviate children’s memory problem, the statement of each conditional rule was accompanied by two vertically arranged pictures depicting the rule, with the top and bottom pictures, respectively, representing the antecedent and the consequent (e.g., for the permission rule, the top picture showed a slide and the bottom one showed a pair of shorts with a cross drawn over it). These pictures remained in view throughout the entire experiment to obviate the need for memorizing the rules.

To ensure children’s memory of the rules, they were requested to repeat the primary rule before *each* inference question. The secondary rule was only repeated by the experimenter. If a child failed to repeat the rule accurately after being primed three times by the experimenter for each question, the experiment discontinued.

3.2.2. Inference questions

After the scenario, four inference questions were asked, accompanied by the relevant pair of toy items. Children indicated their answer by picking an appropriate item for the puppet or by indicating that either item in the pair would do. The four questions were the following: (1) MP: *p* is true (e.g., the puppet is going down the slide), which would entail? *not-q*, *q*, or could it be either? (e.g., which pair of pants must he put on? Trousers, shorts, or could it be either?). (2) DA: *p* is not true (e.g., the puppet is not going down the slide), which would entail? *q*, *not-q*, or could it be either? (e.g., which pair of pants must he put on? Shorts, trousers, or could it be either?). (3) AC: *not-q* is true (e.g., the puppet happened to have trousers on), what would entail? *p*, *not-p*, or could it be either? (e.g., what must he do? go down the slide, play with the train, or could he do either?). (4) MT: *q* is true (e.g., the puppet happened to have shorts on), what would entail? *not-p*, *p*, or could it be either? (e.g., what must he do? play with the train, go down the slide, or could he do either?). Note that our adaptation of the task changed its nature from *selecting* the relevant cases for evaluating a conditional, which requires generating the inferences in each of the four possible cases, to merely *evaluating* inferences presented to the reasoner in each of these cases.

In the case of MP and MT, if a child chose a correct answer in response to an inference question, the choice need not imply that the child thought that the other definite option was unacceptable. To confirm that the children

indeed believed that the other option was unacceptable, following their answer to the inference question, the experimenter further asked whether or not a choice opposite to their answer was acceptable. The experimenter did so only if the child selected the correct answer. For example, in the case of MP for the permission problem, the experimenter said to the child: “The puppet is going down the slide. Which pair of pants must he put on? Trousers, shorts, or could it be either?” If a child chose “trousers,” which is the correct answer, the experimenter would further ask whether it was okay for the puppet to wear shorts to go down the slide. If the answer is “yes,” then the child fails the confirmation question. If a child chose “shorts” or “either” in answer to the original inference question, they were considered wrong. A child was considered correct on an inference only if she answered both the inference and the confirmation questions correctly. The purpose of the confirmation questions for MP and MT was to identify subjects who were correct on these inferences in part because they intended to answer “it could be either” but did not understand the expression “could it be either?” or were otherwise unable to generate their actually preferred answer. These subjects would be more likely than those who truly knew the answer to fail on the confirmation question.

For the same reason, the experimenter further confirmed for the DA and AC inferences only if a child did *not* correctly answer “it could be either.” For these children, the confirmation asked whether the answer opposite to their preferred answer was acceptable. The purpose of this question here was to identify children who did realize that the conditional rule does not imply any definite answer to DA and AC, but might have been unable to understand the expression “could it be either?” or to generate the answer “it could be either.” For example, in the case of DA, the inference question was: “The puppet is not going down the slide. ... Which pair of pants must he put on? Trousers, shorts, or could it be either?” Suppose “trousers” was the initial answer; the child would then be further asked whether the puppet could wear shorts. If the answer was “no,” indicating the commitment of the fallacy of DA, then the child fails the confirmation question. For DA and AC, there were two groups of “correct” subjects: those who answered “it could be either” and those who first selected a definite answer (e.g., *q*), but judged that the opposite answer (*not-q*) was also acceptable when asked the confirmation question. These were subjects who showed evidence that they did not commit the DA and AC fallacies.

Two inference questions (followed by their respective confirmation questions) were asked on each of the first 2 days of the experiment. The two questions given in a session were either the pair MP and DA or the pair AC and MT. Order effects were controlled by counterbalancing the question pairs across children. Half of the subjects were asked MP and DA as a pair first, the other half were asked AC and MT as a pair first. The order of asking either question in each pair was also counterbalanced. To control for response bias, the presentation order of the

choices to each inference question was counterbalanced across subjects for each of the four inference questions. The two puppets were used in turn for the two inference questions in each session to minimize potential confusion. For example, if Bert was used in one question, then Ernie was used in the other.

3.2.3. Logical-necessity questions

In addition to the inference questions, a question directly testing whether the child realized the logical necessity of the right answer was asked. Four logical-necessity questions regarding the respective possible cases were asked on the last day of the experiment. For MP and MT, the question asked whether the answer opposite to the correct one was acceptable. For example, for MP in the permission condition, given the rule: *If the puppet wants to go down the slide, then he must not wear shorts (if p, then not-q)*, this question was: *the puppet's going down the slide; can the puppet wear shorts?* (given *p*, is *q* acceptable?) If the children realized the logical necessity of the right inference given the premises, their answer should be “no.” For MP and MT, children were considered correct if they rejected the answer opposite to the correct one.

For DA and AC, this question asked whether an option that contradicted the corresponding fallacies was acceptable. For instance, for DA in the permission condition, given the minor premise, *the puppet is not going down the slide (not-p)*, the question was: “Can the puppet wear trousers? (is *not-q* acceptable?)” If the children realized that there is no logical necessity to either conclusion (*q* or *not-q*) given the premises, their answer would be “yes.” But, if the child interpreted the rule as a biconditional, *If and only if the puppet wants to go down the slide, then he must not wear shorts*, then they would commit the fallacies of DA and AC, and their answer would be “no.” Children who accepted the alternative option were counted as correct.

3.3. Apparatus

Hand puppets Bert and Ernie were employed throughout. For the negative permission condition, each puppet was shown with a pair of trousers and a pair of shorts that were in the same fabric. In addition, there were a wooden slide and a toy train. For the arbitrary condition, there were two pieces of cloths in the same fabric and two boxes with a dog sticker and a cat sticker on the lid, respectively. Two apples, two oranges and another copy of the dog and cat stickers were also used. For each condition, there were two pairs of pictures for the two conditional rules with each pair representing one rule.

4. Results and discussion

Table 1 presents the percentage of responses to the four inference questions in the negative permission and the negative arbitrary scenarios on MP, DA, AC, and MT.

Table 1

The percentage of responses to the inference questions in the negative permission and the negative arbitrary scenarios for MP, DA, AC, and MT given the rule *if p, then not-q* ($N = 16$ in each)

	Inferences				Confirmation		Confirmed inferences
<i>Permission</i>							
	<i>not-q</i>	<i>q</i>	either	others	yes	no	
MP (<i>p</i>)	<u>100</u>	0	0	0	0	<u>100</u>	<u>100</u> ^a
DA ($-p$)	<u>56</u>	44	<u>0</u>	0	<u>44</u>	56	<u>44</u>
	<i>p</i>	<i>not-p</i>	either	others			
AC ($-q$)	63	12	<u>19</u>	6	<u>50</u>	25	<u>69</u> ^a
MT (<i>q</i>)	0	<u>94</u>	0	6	0	<u>94</u>	<u>94</u> ^a
<i>Arbitrary</i>							
	<i>not-q</i>	<i>q</i>	either	others			
MP (<i>p</i>)	<u>81</u>	6	6	6	19	<u>63</u>	<u>63</u>
DA ($-p$)	<u>31</u>	38	<u>31</u>	0	<u>31</u>	44	<u>63</u>
	<i>p</i>	<i>not-p</i>	either	others			
AC ($-q$)	63	19	<u>12</u>	6	<u>25</u>	31	<u>38</u>
MT (<i>q</i>)	12	<u>69</u>	19	0	25	<u>31</u>	<u>31</u>

Correct answers are underlined.

^a Indicates results that are reliably different from chance. The primary negative permission rule is: If the puppet goes down the slide (*p*), then he must not have shorts on (*not-q*), because the slide gets very hot under the sun. The primary negative arbitrary rule is: If there is a dog sticker on the lid (*p*), then there must not be an orange in the box (*not-q*).

4.1. MP and MT

4.1.1. Inference questions

Recall that the children were considered correct on this measure only when they answered both the inference and the confirmation questions correctly (see the column labeled “Confirmed inferences” in Table 1). We collapsed incorrect answers and atypical answers (e.g., “I do not know”) into one category, as opposed to correct answer, and analyzed the data in two ways: (a) whether subjects reliably selected the correct answer to a question at an above-chance level, and (b) whether the pattern of answers to a question varied with problem context. The chance level was one-third for each inference, because there were three possible logical options, which we assessed in our two-step questions. For MP and DA, these logical options were (1) *not-q* only, (2) *q* only, and (3) either (i.e., *not-q* or *q*); for MT and AC, these options were (1) *p* only, (2) *not-p* only, and (3) either (i.e., *p* or *not-p*). The confirmation questions served to disambiguate which of the three options the child truly intended.

For the use of MP, all children in the permission condition chose the correct answer *not-q* to the inference question and rejected *q* as an option upon confirmation, $\chi^2(1) = 16.0$, $p < 0.001$, whereas children in the arbitrary condition did not choose the correct answer on the inference question more frequently than would be expected by chance, $\chi^2(1) = 2.73$, $p > 0.05$. The difference between

Table 2

The percentage of responses to the logical necessity questions in the negative permission and the negative arbitrary scenarios for MP, DA, AC, and MT given the rule *if p, then not-q* ($N = 16$ in each)

Logical necessity questions		Yes	No	Others
<i>Permission</i>				
MP (p)	Can puppet wear shorts (q)?	0	<u>100^a</u>	0
DA ($-p$)	Can puppet wear trousers ($not-q$)?	<u>94^a</u>	6	0
AC ($-q$)	Can puppet go play with the train ($not-p$)?	<u>100^a</u>	0	0
MT (q)	Can puppet go down the slide (p)?	0	<u>100^a</u>	0
<i>Arbitrary</i>				
MP (p)	Can there be an orange in the box (q)?	12	<u>88^a</u>	0
DA ($-p$)	Can there be an apple in the box ($not-q$)?	<u>50</u>	44	6
AC ($-q$)	Can there be a cat sticker on the box ($not-p$)?	<u>56</u>	44	0
MT (q)	Can there be a dog sticker on the box (p)?	44	<u>56</u>	0

Correct answers are underlined.

^a Indicates results that are reliably different from chance. The primary negative permission rule is: If the puppet goes down the slide (p), then he must not have shorts on ($not-q$), because the slide gets very hot under the sun. The primary negative arbitrary rule is: If there is a dog sticker on the lid (p), then there must not be an orange in the box ($not-q$).

conditions was reliable, $p = 0.018$ by Fisher's exact test. Similar results were found on MT: children selected the correct answer reliably above chance only in the permission context, $\chi^2(1) = 12.6$, $p < 0.001$, but not in the arbitrary context, $\chi^2(1) = 0.01$, $p > 0.50$. The difference between conditions was also highly reliable, $p = 0.001$ by Fisher's exact test. Note that these differences between conditions were obtained despite the close match in the procedure and the format of the questions across conditions.

4.1.2. Logical-necessity questions

Table 2 presents the percentage of responses to the logical-necessity questions in the negative permission and the negative arbitrary scenarios on MP, DA, AC, and MT. The answers to the logical-necessity questions revealed a somewhat different pattern for MP. Children in either condition reliably rejected the wrong answer for MP, $\chi^2(1) > 9$, $p < 0.005$, indicating that they realized the necessity of the correct answer to the question.

The difference between conditions was not reliable, Fisher's exact test, $p = 0.484$. For MT, however, responses in the two conditions reliably differed, Fisher's exact test, $p = 0.007$. All children in the permission condition rejected the wrong answer, $\chi^2(1) = 16.0$, $p < 0.001$. In contrast, the responses to the arbitrary problem was at chance level, $\chi^2(1) = 0.25$, $p > 0.05$. The chance level was 0.50 for each logical-necessity question, because there were two possible options: "yes" or "no."

4.1.3. Consistency across the two measures

We analyzed the consistency of a child's response across the two measures to assess the robustness of each inferential rule. Children might

for various reasons be inconsistent in their answers to an inference question and a logical-necessity question. For example, they might have satisfied the criterion for correctness for a particular measure simply by chance. Or, the attention and memory demands for one measure (e.g., due to its clarity or simplicity) might be less than those for the other (note that whatever differences there might be between measures, these differences were equated across conditions).

All children in the permission context consistently chose the correct answer for MP, whereas only 63% of subjects in the arbitrary context were consistent across the two measures. The difference between conditions was reliable, $p = 0.017$ by Fisher's exact test. These results strongly suggest that MP is a more robust rule in the permission context than in the arbitrary context.

Likewise, children were reliably more consistent on MT for the permission context than in the arbitrary context, Fisher's exact test, $p < 0.001$. Fifteen out of 16 children in the permission context (94%) were consistent across the two measures; in contrast, only 19% of subjects in the arbitrary context were consistent across the two measures.

In summary, these results strongly suggest that young children have already developed pragmatic rules for MP and MT. The abstract form of MP is emerging but not yet robust, and MT is not yet available.

4.2. *DA and AC*

4.2.1. *Inference questions*

For DA, children's performance did not differ from chance in either the permission or arbitrary condition, $\chi^2(1) < 2.7$, $p > 0.05$ for either condition. No difference between the two contexts was found, Fisher's exact test, $p = 0.479$. For AC, the children in the arbitrary condition did not perform reliably above chance level, $\chi^2(1) < 0.50$, $p > 0.50$. In contrast, the children in the permission condition were correct more often than can be explained by mere chance, $\chi^2(1) = 4.02$, $p < 0.05$. No context effects, however, were found, Fisher's exact test, $p = 0.156$.

4.2.2. *Logical-necessity questions*

Recall that subjects were asked whether an option opposite to the one indicating the fallacy of DA or AC was acceptable. Table 2 shows that, for DA, all the subjects except one in the permission condition thought that the option in question was acceptable, $\chi^2(1) = 12.3$, $p < 0.001$ (indicating that they did not commit the fallacy of DA), whereas the response pattern in the arbitrary condition was at chance level. The difference between conditions was reliable, Fisher's exact test, $p = 0.02$. Similar results obtained for AC: All subjects in the permission condition accepted the option in question, $\chi^2(1) = 16.0$, $p < 0.001$, whereas the response pattern in the arbitrary condition was at chance level. Fisher's exact test revealed a highly reliable

difference between the two conditions, $p = 0.007$. In short, these results indicate that children in the permission condition did not commit the fallacy of DA or AC, but children in the arbitrary condition did not show evidence against committing them.

4.2.3. Consistency between the two measures

No context effects were found in the consistency of answers between the inference question and the logical necessity question for DA or AC, $\chi^2(1) \leq 3.14$, $p > 0.08$.

Taken together, our results indicate that when given a permission context children clearly show an understanding that a conditional does not imply a definite answer for DA and AC. This understanding, however, is not yet robustly sustained for DA. In contrast, when given an arbitrary context, children do not show any such understanding.

5. General discussion

5.1. Summary

The present results strongly support the view that pragmatic reasoning rules emerge earlier than explicit formal rules. Preschool children have already developed context-sensitive rules for explicit deductive reasoning in their everyday life. When given a permission context with a conditional rule that contains a negated consequent to rule out their possible use of a matching strategy (Evans & Lynch, 1973), virtually all children consistently used MP and MT across two dependent measures: inference questions and logical necessity questions. In addition, most of these children showed unambiguous evidence for the emergence of the understanding that a conditional implies no definite answer for DA and AC, although this understanding was not sustained across measures for DA. The less prevalent or robust use of DA and AC, on one hand, than of MP and MT, on the other, is consistent with research on relational inferences in adults showing that, when there is indeterminacy in the representation of the problem, reasoners were less likely to make correct inferences (see Evans et al., 1993 for a review). This is probably due to the difficulty of constructing more than one representation (Johnson-Laird et al., 1992).

In contrast, when given an arbitrary context, there is no evidence for the explicit use of any of the inferential rules in preschool children. Even MP was not used robustly; the children correctly used it in answer to the logical-necessity question but not to the inference question. MT was almost never used according to either measure. Likewise, performance on DA and AC remained at chance level according to either measure, offering no evidence for an ability to avoid the corresponding fallacies.

5.2. *The natural logic view versus the pragmatic view*

Proponents of the natural logic view might argue that our results support their view instead, as performance on MP was quite high on the logical necessity measure (88% correct) in the arbitrary condition. This argument raises the question: For MP, why did our subjects perform better on the logical necessity measure than on the inference measure (only 63% correct)?

Two related reasons may account for this difference. The first is that the logical necessity measure has a lower cognitive demand than the inference measure (with the latter providing a closer match to the demands of a standard MP), and the second is that this measure is less stringent. Note that for the logical necessity measure, following the rule repeated by the child (if there is a dog sticker on the lid, then there must *not* be an orange in the box), the child was asked, “There is a dog sticker on the lid. Tell me, can there be an orange in the box?” The question was directly about an orange in the box, requiring a yes–no answer. In contrast, for the inference question, following the same rule repeated by the child, he or she was asked, “There is a dog sticker on the lid. Tell me, what must be inside the box?” The more open-ended question here corresponds to MP more closely than does the logical necessity question. In answer to this question, the child was offered three options, one of them indefinite, “an apple, an orange, or could it be either?” The logical necessity question in effect partially constructed the answer to the inference question by condensing the various possibilities, including the indefinite one, into a yes–no choice. As a result, the probability of guessing correctly differed across the measures. Whereas this probability for the logical necessity question is 0.50 (there were two possible answers), this probability for the inference question is 0.33 (there were three possible answers). Thus, for both cognitive and statistical reasons, being correct on the logical necessity measure provides weaker evidence for the use of MP.

In short, the findings from our two dependent measures converge and strongly favor the pragmatic view over the formal logic view: MP and MT first emerge as pragmatic rules in young children and a context-free MP develops later. Even if one ignores that the logical necessity measure is a weaker one, the natural logic view would still be unable to explain why MP, a presumably cognitively primitive rule that is the core entry for *if*, was used less robustly than subsequently developed pragmatic rules.

5.3. *The social contract model*

Another possible explanation of our findings comes from a variant of the pragmatic view, the social contract model (Cosmides, 1989). A permission rule is also a social contract as long as it implies a cost–benefit structure. Thus, it may be argued that the action to be taken in our permission rule (going down the slide) was seen by the child as a benefit and the precondition (wearing long pants) as a

cost. This argument holds only if one stretches the definition of a social contract to include the case in which the “cost” involved is no longer a price paid to someone, but simply a “requirement.” This broadened definition of a social contract coincides exactly with the definition of permission (see Cheng & Holyoak, 1989 for a discussion and an empirical test of the social contract view and the pragmatic schemas view).

5.4. *Relevance and the pragmatic view*

Sperber et al. (1995) conducted a series of experiments with adults demonstrating that by manipulating the relevance of information regarding a conditional rule, it is possible to improve adults’ performance greatly on versions of the selection task that were previously thought difficult even to college students (for example, with an accuracy of 57% as compared to 10% in the past literature). They distinguish between deontic (e.g., permission) versions of the selection task and descriptive versions that roughly correspond to what we have labeled “arbitrary” versions. They argue that the inferential process for the deontic and descriptive versions are not psychologically different as long as the information given can evoke comprehension mechanisms that indicate relevance, which then determines subjects’ selections. The key to making subjects select the right cards (the *p* and the *not-q* cards) is to construct the information in such a way that the *p*-and-*not-q* cases are easy to represent and “richer in cognitive effects” than the *p*-and-*q* cases (see Sperber et al., 1995, p. 61). The relevance theory provides a parsimonious explanation for past results on the selection task, deontic or descriptive.

How is the relevance theory related to the pragmatic view? We concur with Sperber et al. (1995) that in the selection task, domain-specific competences such as pragmatic reasoning schemas and relevance-guided comprehension procedures are confounded, so that any efforts to separate the two using this task are futile. But, a comprehension mechanism based on relevance does not seem to apply to performance on MP in our inference task—it is not clear how relevance differs for MP in a permission context and in an arbitrary context. If relevance is indeed equated across these contexts in our task, then our results provide evidence for domain-specific reasoning skills.

6. Conclusion

In conclusion, our study, which used an inference task analogous to the selection task (Wason, 1966) but is much less demanding, provides evidence for domain-specific reasoning skills in preschool children. Pragmatic rules emerge earlier than explicit formal rules. Particular explicit formal rules either do not exist at all yet at a certain age, or are used less robustly than pragmatic rules across procedural and linguistic variations.

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Appendix A.

Condition	Negative permission condition	Negative arbitrary condition
<i>Inference questions</i>		
Setting	a playground with a train and a slide	a box covered with a piece of cloth, a dog sticker, a cat sticker, an apple, and an orange
Scenario	Bert and Ernie wear either trousers or shorts (showing trousers and shorts). They like to play in the playground, where they can either play with the train, or go down the slide (pointing to the train and the slide) But their moms say to them:	Bert and Ernie have a magic box. On the lid of the box, there can be either a dog sticker or a cat sticker (showing the two possibilities by alternately placing a dog sticker and a cat sticker on the lid of the covered box). Inside the box, there can be either an apple or an orange (showing the two possibilities by opening the box without removing the cloths and alternately placing an apple and an orange in the box). The box follows a magic sticker rule:
	<i>If you go down the slide (p), then you must not have shorts on (not-q); because the slide gets very hot under the sun. (showing a picture of p above a picture of not-q)</i>	<i>If there is a dog sticker on the lid (p), then there must not be an orange in the box (not-q). (showing a picture of p above a picture of not-q)</i>

	<p>Bert and Ernie are going to play in the playground. They have to do what their moms told them to do. To be sure that they remember their moms' rule, can you tell them again what their moms said about going down the slide? (After kid repeats the first rule)</p> <p>Well, their mom has another rule. She tells them. <i>If it is windy (r), then you must not have shorts on (not-q); because you will get too cold.</i> (showing pictures of <i>r</i> and <i>not-q</i> vertically arranged)</p>	<p>Bert and Ernie are going to play with the magic box. They have to figure out what happens with the magic box according to the sticker rule. To be sure that they remember this rule, can you tell them the rule again? (After kid repeats the first rule)</p> <p>Well, there is another rule, the magic-weather rule: <i>If it is windy (r), then there must not be an orange in the box (not-q).</i> (showing pictures of <i>r</i> and <i>not-q</i> vertically arranged)</p>
MP	<p>Bert and Ernie have already decided what to play right now. Please help them figure out what to put on</p>	<p>(Asking kid to close eyes briefly before starting) Now, Bert and Ernie already know what is on the lid. Please help them decide what is in the box.</p>
	<p><i>Bert (or Ernie) says, "I am going down the slide (showing the puppet going toward the slide). Tell me, what must I put on? Trousers, shorts (showing trousers and shorts in turn) or could I put on either (showing both shorts and trousers)?"</i></p>	<p><i>Bert (or Ernie) says, "There is a dog sticker on the lid (showing the dog sticker on the box by lifting a cloth cover). Tell me, what must be inside the box? An apple, an orange (showing an apple and an orange in turn), or could it be either (showing both an orange and an apple)?"</i></p>
Confirmation	<p>(Continue to ask the confirmation question only if kid's selection for MP was correct)</p> <p><i>Ernie (or Bert) says, "Do you think it is okay for Bert (or Ernie) to wear shorts (opposite to kid's selection) to go down the slide?"</i></p>	<p>(Continue to ask the confirmation question only if kid's selection for MP was correct)</p> <p><i>Bert (or Ernie) says, "Do you think it is okay for there to be an orange (opposite to kid's selection) inside this box with a dog sticker on top?"</i></p>

- DA Now, it is Ernie's (or Bert's) (Primary-rule checking
turn. He may have forgotten procedure)
what his mom told him about
going down the slide. Can
you tell him the rule again?
(Referred to as "primary-rule
checking procedure"
hereafter.)
- (After kid repeats the first (Secondary-rule reminding
rule, experimenter repeats the procedure)
second rule and shows the
pictures of the second rule:
referred to as "secondary-rule
reminding procedure"
hereafter.)
- Ernie (or Bert) says, "I am
not going down the slide. I am
going to play with the train
(showing the puppet going
toward the train). Tell me,
what must I put on? Shorts,
trousers (showing shorts and
trousers in turn), or could I
put on either (showing both
shorts and trousers)?"*
(After kid's selection)
- (Asking kid to close eyes
briefly before starting)
*Ernie (or Bert) says, "There is
no dog sticker on the lid.
There is a cat sticker on the lid
(showing the cat sticker on a
box). Tell me, what must be
inside the box? An orange, an
apple (showing an orange and
an apple in turn), or could it
be either (showing both an
orange and an apple)?"*
(After kid's selection)
- Confirmation *Bert (or Ernie) says, "Do you
think it is okay for Ernie to
wear trousers/shorts
(opposite to kid's selection) to
play with the train?"*
- Ernie (or Bert) says, "Do you
think it is okay for there to be
an apple/orange (opposite to
kid's selection) inside this box
with a cat sticker on top?"*
- AC Remember that you saw Bert (Primary-rule checking
and Ernie yesterday? procedure after warm-up)
Remember that their moms
told them "If . . . , then . . . ;
because . . ." (repeating the
first rule and showing the
pictures). Well, Bert and
Ernie are going to play in the
playground again today. To
be sure that they remember
their moms' rule,

	<p>can you tell them again what their mom said about going down the slide? (Secondary-rule reminding procedure) Today, Bert and Ernie are already dressed. Please help them figure out what to play.</p>	<p>(Secondary-rule reminding procedure) This time Bert and Ernie already know what is inside the box. Please help them figure out what is on the lid. (Asking kid to close eyes briefly before starting)</p>
	<p><i>Bert (or Ernie) says, "I happen to have trousers on today (showing the puppet with trousers on). Tell me, what must I do in the playground? Go down the slide, play with the train (pointing to the slide and the train in turn), or could I do either (pointing to both the slide and the train)?"</i> (After kid's selection)</p>	<p><i>Bert (or Ernie) says, "There is an apple in the box (showing an apple in a box with the lid covered by a cloth and opened). Tell me, what must be on the lid? A dog sticker, a cat sticker (showing a dog sticker and a cat sticker in turn), or could it be either (showing both a dog sticker and a cat sticker)?"</i> (After kid's selection)</p>
Confirmation	<p><i>Ernie (or Bert) says, "Do you think it is okay for Bert to go down the slide/play with the train (opposite to kid's selection) wearing trousers?"</i></p>	<p><i>Bert (or Ernie) says, "Do you think it is okay for there to be a dog/cat sticker (opposite to kid's selection) on this box with an apple inside?"</i></p>
MT	<p>(Primary-rule checking and secondary-rule reminding procedures) <i>Ernie (or Bert) says, "I happen to have shorts on today (showing the puppet with shorts on). Tell me, what must I do in the playground? Play with the train, go down the slide (pointing to the train and the slide in turn), or could I do either (pointing to both the slide and the train)?"</i></p>	<p>(Primary-rule checking and secondary-rule reminding procedures) (Asking kid to close eyes briefly before starting) <i>Ernie (or Bert) says, "There is an orange in the box (showing an orange in a box with the lid covered by a cloth and opened). Tell me, what must be on the lid? A cat sticker, a dog sticker (showing a cat sticker and a dog sticker in turn), or could it be either (showing both a dog sticker and a cat sticker)?"</i></p>

	(Continue to ask the confirmation question only if kid's selection for MT was correct)	(Continue to ask the confirmation question only if kid's selection for MT was correct)
Confirmation	<i>Bert (or Ernie) says, "Do you think it is okay for Ernie to go down the slide (opposite to kid's selection) wearing shorts?"</i>	<i>Ernie (or Bert) says, "Do you think it is okay for there to be a dog sticker (opposite to kid's selection) on this box with an orange inside?"</i>
	<i>Logical necessity questions</i>	
MP	(Primary-rule checking and secondary-rule reminding procedures)	(Primary-rule checking and secondary-rule reminding procedures)
	<i>Bert (or Ernie) says, "I am going down the slide (showing the puppet going toward the slide). Tell me, can I wear shorts?"</i>	(Asking kid to close eyes briefly before starting)
		<i>Bert (or Ernie) says, "There is a dog sticker on the lid (showing the dog sticker on a box). Tell me, can there be an orange in the box?"</i>
DA	(Primary-rule checking and secondary-rule reminding procedures)	(Primary-rule checking and secondary-rule reminding procedures)
	<i>Ernie (or Bert) says, "I am not going down the slide. I am going to play with the train (showing the puppet going toward the train). Tell me, can I wear trousers?"</i>	(Asking kid to close eyes briefly before starting)
		<i>Ernie (or Bert) says, "There is no dog sticker on the lid. There is a cat sticker on the lid (showing the cat sticker on a box). Tell me, can there be an apple in the box?"</i>
AC	Now, it is Bert's (or Ernie's) turn. You must still remember what their mom said: (Instead of asking the children what the primary rule was, the experimenter simply repeats both rules for them by the last day of the experiment to avoid boredom, referred to as "both-rules reminding procedure" hereafter)	(Both-rules reminding procedure)
		(Asking kid to close eyes briefly before starting)

	<i>Bert (or Ernie) says, “I happen to have trousers on (showing the puppet with trousers on) Tell me, can I go play with the train?”</i>	<i>Bert (or Ernie) says, “There is an apple in the box (showing an apple in a box with the lid covered by a cloth and opened). Tell me, can there be a cat sticker on the box?”</i>
MT	(Both-rules reminding procedure)	(Both-rules reminding procedure) (Asking kid to close eyes briefly before starting)
	<i>Ernie (or Bert) says, “I happen to have shorts on (showing the puppet with shorts on). Tell me, can I go down the slide?”</i>	<i>Ernie (or Bert) says, “There is an orange in the box (showing an orange in a box with the lid covered by a cloth and opened). Tell me, can there be a dog sticker on the box?”</i>

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