Cognition, 23 (1986) 43–71

The mismatch between gesture and speech as an index of transitional knowledge*

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Abstract

This study investigates two implications of frequent mismatches between gesture and speech in a child's explanations of a concept: (1) Do gesture/speech mismatches reflect a basic inconsistency in the explanatory system which underlies a child's understanding of a concept? (2) Do gesture/speech mismatches, perhaps as a consequence of this inconsistency, reflect a heightened receptivity to instruction in that concept?

The Piagetian conservation task, which asks children to explain their judgments about quantity invariance, was used to test these hypotheses. Children ages 5–8 were asked to make six conservation judgments and then to explain each of those judgments. All but one of the children were found to gesture spontaneously with their spoken explanations. Children were classified into two groups according to the relationship between gesture and speech in their explanations: "Discordant" children produced many explanations in which the information conveyed in speech did not match the information conveyed in gesture; "concordant" children produced few such mismatched explanations.

Study 1 sought to determine whether discordant children were less consistent in the reasoning underlying their verbal explanations of quantity invariance than were concordant children. Two indices of consistency that were independent of the discordance classifications were devised and applied to the performances of 28 children on the six conservation tasks. The discordant children were found to have significantly lower scores on both indices of consistency than the concordant children. Thus, children who frequently produced mismat-

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*This work was supported by NICHHD Grant #1 RO1 HD18617 and by grants from the Spencer Foundation, the Sloan Foundation, and the Benton Foundation. We thank D. Enerson, E. Eichen, and M. Wagner for their help in establishing the reliability of our coding procedures and in transcribing the videotapes, the members of an ongoing research seminar, M. Perry, C. Mylander, M. Morford, D. Enerson, R. Wodlinger-Cohen, and R. Mayberry, for their help in developing many of the ideas presented in this paper, and J. Huttenlocher, S. Levine, W. Meadow, R. Siegler, J. Stigler, T. Trabasso, and an anonymous reviewer for their insightful comments on earlier drafts of the manuscript. Requests for reprints may be sent to the authors at The University of Chicago, 5835 S. Kimbark Ave., Chicago, IL 60637, U.S.A.

ched information between gesture and speech in their explanations of a concept tended to display other forms of inconsistency with respect to the explanatory systems they used to justify their beliefs about that concept.

Study 2 sought to determine whether this inconsistency reflected knowledge in transition as operationalized by heightened receptivity to training. After participating in a pretest of six conservation tasks, 52 children were exposed to training in conservation. Discordant children were found to show more improvement than concordant children on a posttest containing the same 6 conservation tasks. Thus, gesture/speech discordance appears to be both a useful marker of inconsistency in the explanatory system underlying understanding of a concept and of receptivity to training in that concept.

One of Piaget's contributions to the field of developmental psychology is his observation that young children often give responses to cognitive tasks that are systematically different from those given by adults (Piaget, 1965). Thus, not only are young children frequently incorrect (from the adult point of view), but they also tend to be consistent in their incorrect beliefs. Recent approaches to cognitive development such as Siegler's rule-assessment approach reinforce this point. Siegler has shown that many children who fail to respond as do adults on Piagetian-type tasks appear to be responding according to their own specific rules, i.e., each child appears to be consistently rule-governed in his (misguided) approach to the task (Siegler, 1976, 1981).

Nevertheless, even in Siegler's studies, one typically finds a subset of children who do not perform as adults do on the cognitive tasks and who are also not classifiable as regular users of any single rule (Siegler, 1976, 1981). Thus, there appear to be two ways for a child to be wrong on a cognitive task: (1) the child can be consistently incorrect, a knowledge state Wilkinson (1982) has called "restricted" knowledge in which the child uses a single (incorrect) algorithm on all occasions, or (2) the child can be inconsistently incorrect, a knowledge state Wilkinson calls "variable" knowledge in which the child uses one or more algorithms (either correct or incorrect) in an unsystematic fashion. In the domain of moral understanding, Turiel (1969) has shown that it is the norm rather than the exception for children to respond to moral judgment questions at several different levels of understanding—in Wilkinson's terms, for children to have "variable" knowledge.

Although it is relatively easy to determine when a child is incorrect on a cognitive task, it is more difficult to determine whether a child is consistent or inconsistent in his incorrect beliefs (cf. Wilkinson, 1982). This study represents an attempt, first, to devise a technique for assessing consistency and inconsistency in a child's knowledge of a concept and, second, to assess the power of that technique in predicting a child's receptivity to training in the concept.

Recent work has shown that nonverbal communications can provide insight into a speaker's mental representations during speech (cf. Kendon, 1983). McNeill (in press) has shown that not only can gesture be redundant with the spoken word, it can at times convey information about the speaker's mental representations that differs from the information conveyed in speech. Moreover, researchers on the expression of emotion have noted that certain people frequently produce "mixed messages," i.e., one message in the verbal channel and a different message in the nonverbal channel, and that these people tend to be inconsistent in their emotional beliefs (Ekman & Friesen, 1968, 1969). Study 1 investigates whether a mismatch between the information conveyed in the gestural and spoken channels of a child's explanations of a cognitive belief might also reflect inconsistency—but in a cognitive rather than an emotional domain.

In his discussion of developmental processes in the child's moral thinking, Turiel (1969) hypothesized that consistency characterizes periods of "fixity" while relative inconsistency characterizes periods of transition. A similar relationship between inconsistent (or unstable) understanding and receptivity to training has been hypothesized in discussions of the child's acquisition of Piagetian concepts (cf. Langer, 1969; Strauss, 1972). Study 2 investigates whether mismatch between gesture and speech may serve not only as a useful index of inconsistent understanding of a given concept, but also serve as a marker of a transitional knowledge state and thereby predict receptivity to training in that concept.

Study 1

Methods

Selecting the task

At the outset, an investigation of the hypothesis that gesture/speech mismatch reflects cognitive inconsistency requires a task in which children tend to produce gestures along with their speech. Evans and Rubin (1979) have shown that tasks in which children are asked to give explanations (in their study, explanations of a set of rules) tend to elicit gestural as well as spoken responses. Since informal observation had suggested that the Piagetian conservation task, which requires children to explain their beliefs about quantity invariance, would elicit spontaneous gesture along with speech, we chose to investigate our hypothesis using the Piagetian conservation task. Our goal was to probe the relationship between the information conveyed in the spoken channel of the child's explanations and the information conveyed in the accompanying gestural channel, in order to determine whether frequent mismatches between speech and gesture reflect inconsistent understanding of quantity invariance.

Note that our study investigates a child's knowledge of a concept as reflected in his explanations of that concept. We focus in particular on knowledge of quantity invariance as it is reflected in explanations of the general principle unifying conservation tasks (i.e., the underlying generalization that displacement transformations do not affect quantity). Since our goal is to tap the child's explanatory knowledge of a conservation principle that can apply to a variety of different quantities, our study focuses on explanations produced across a series of six conservation tasks probing three quantities, liquid quantity, length, and number. Although children can solve conservation tasks by developing a separate and unrelated concept for each individual quantity (cf. Inhelder, Sinclair, & Bovet, 1974; Siegler, 1981), it is also possible for children to solve the conservation task by acquiring a concept that is broader than any single concept of quantity (Gelman, 1969; Kingsley & Hall, 1967; Siegler, 1981). For example, Siegler (1981) found that those children who gave conserving judgments for number but not for solid and liquid quantity did not give explanations that invoked a general principle of conservation, i.e., they did not invoke the principle that displacement transformations do not affect quantity in their verbal explanations of their judgments. In contrast, the children who gave conserving judgments on number, solid, and liquid quantity tasks tended also to be able to explain their judgments in terms of a general principle of conservation.

Further evidence for a general principle of conservation comes from training studies that instruct children in two quantities and test their ability to generalize training to yet another quantity (e.g., Brainerd, 1979; Gelman, 1969; Kingsley & Hall, 1967). For example, Gelman (1969) gave nonconservers training in the concepts of length and number and then tested them on conservation tasks of length, number, mass and liquid quantity. Many of the children showed improvement from pretest to posttest not only on length and number but also on mass and liquid quantity, suggesting that they had abstracted out a principle applicable across a series of conservation tasks. It is this general principle that is the arena for our explorations of gesture/speech mismatch.[1]

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[1] Although (as we have just argued) there is a meaningful way in which a general rule applies to the conservations and particular transformations used in this study, this does not rule out the possibility that the generality of the rule is limited when the range of transformations and conservations is expanded (cf. Gelman & Baillargeon, 1983).

Subjects

Twenty-eight children, ages 5–8, from the Chicago area participated in the study. It was assumed (cf. Piaget, 1965; Siegler, 1981; Smedslund, 1968) that three developmental levels (Conservation, Partial Conservation and Nonconservation) would be represented within this age range.

Procedure

Each child was informed that he was going to play some games and was escorted to a room where he was videotaped while participating in a series of Piagetian conservation tasks. The child was first acclimated to the experimental setting and, when he appeared relaxed, the testing session began.

Six Piagetian conservation tasks, presented in a fixed order, were used to test the child's knowledge of three quantity concepts: 2 liquid quantity tasks, 2 length tasks, and 2 number tasks. Each task contained three phases: (1) initial equality, (2) transformation, and (3) final equality. As an example, in the initial equality phase of the first liquid quantity task, two identical drinking glasses were placed in front of the child and filled with the same amount of water. The child was then asked to verify that the two glasses contained the same amount of water. In the transformation phase, water was poured from one of the glasses into a short, round dish placed in front of the child. Two questions were then posed to the child: (1) the Judgment question, "Do the dish and the glass have the same or different amounts of water?" and (2) the Explanation question, "Why?" (Variations of this question such as "How can you tell?" and "Can you explain to me why they are the same/different?" were also used). In the final equality phase, water from the dish was poured back into its original container and the child was asked again if the two identical glasses had the same or different amounts of water.

The remaining five tasks followed the same procedures but used different transformations. In the second liquid quantity task, the water was poured from the glass into two smaller glasses instead of one dish. In the first of the length tasks, one of two sticks of equal length (both positioned horizontally from the child's perspective, 2 inches apart with the ends aligned) was moved to the child's right keeping the sticks parallel. In the second length task, the stick closest to the child was moved so that it was perpendicular to the unchanged stick. In the first of the number tasks, one of two rows of checkers (each containing six checkers arranged in straight horizontal lines of the same length) was spread apart so that the row ends extended beyond the ends of the unchanged row. In the second number task, the checker row farthest from the child was shaped into a small circle (whose width was smaller than the unchanged row's width). When the child had responded to the last question of the second number task, he was told that the games were over and was then escorted out of the play room.

Partitioning the children on the basis of their judgments

Our goal was to assess the child's grasp of a general principle of conservation applicable across quantities. To this end, we partitioned children into three groups on the basis of their "same/different" judgments across the six conservation tasks: (1) If a child answered "same" to all six judgment questions comparing quantity before and after transformation, he was classified as a Conserver; (2) if a child answered "same" to some questions but "different" to others, he was classified as a Partial Conserver; (3) if a child answered "different" to all six judgment questions, he was classified as a Nonconserver. Thus, we follow Langer and Strauss (1972), Beilin (1965), and Murray (1974) in identifying transitional or partial conservers as children who conserve on some quantities but fail to conserve on others. We differ from these researchers however in that, for our classification, success on a conservation task was based solely on the child's judgment response rather than on some combination of his judgment response and his explanation response (cf. Brainerd, 1973).

Coding explanations

We considered all of the responses (gestured as well as spoken) that followed the experimenter's "Why?" question to comprise a child's "explanation." Each explanation was coded in two ways. We first turned off the picture and, listening only to the audio portion of the tapes, categorized the children's speech independently of gesture. We then viewed the tapes a second time, coding the relationship between speech and gesture in terms of the information conveyed in each modality.

Inter-rater reliability was established by having a second trained coder independently transcribe a subset of the tapes of the testing sessions. The second coder transcribed one of the six reels of tape for type of explanation in speech alone (with the picture turned off), and a second reel of tape for the relationship between gesture and speech taken together.

Coding types of explanations in speech alone

Equivalence explanations. Piaget (1965) isolated three explanations used by conservers on his tasks. Each of these explanations decribes why the child believes the task object has not altered in quantity despite the transformation, and thus argues for the *equivalence* between the object's transformed and original states. We identified all three Piagetian equivalence explanations plus a fourth explanation in our children's data: (1) explanations arguing that reversing the transformation can return the transformed quantity to its original state and therefore that the quantity has not changed (i.e., reversibility, see example 1 in Table 1); (2) explanations arguing that the transformed object has the same quantity it had originally simply because variation from the object's original state on one dimension is compensated by variation on a second dimension of the object (i.e., compensation, example 2 in Table 1); (3) explanations arguing that although the transformed and original quantities differ along at least one dimension (the transformed dimension), the relevant dimension on which to compare the objects (i.e., liquid quantity, length, or number, as opposed to height of the containers, orientation of the sticks, or shape of the checker rows) has remained unchanged (i.e., identity, example 3 in Table 1); and (4) explanations arguing that the quantity before the transformation was the same as the quantity after the transformation (example 4 in Table 1).

Table 1. *Examples of types of verbal explanations*

Equivalence explanations

(1) "Because if you pour the water back, you know it's the same" (reversibility)

(2) "Even though the dish is shorter, it is also wider than the glass" (compensation)

(3) "The sticks are the same length no matter how you shape them" (identity)

(4) "Before you put it [the water] in those [the two small glasses] it was the same amount"

Nonequivalence explanations

(5) "Because you put them in a circle"

(6a) "The glass is thin and the dish is short"
(6b) "This stick is long and sideways"

(7) "That [transformed] stick is going down and the other [untransformed] stick is going across"

Noncomparative explanations

(8a) "The dish is fat"
(8b) "The dish is round and it's mine"

(9) "Because that's a dish and that's a glass"

Nonequivalence explanations. In addition to producing equivalence explanations, the children in our study produced explanations describing why they believed the transformed object had indeed altered in quantity after its transformation; that is, their explanations argued for the *nonequivalence* between the object's transformed and original states. We identified three types of nonequivalence explanations in the children's data: (1) explanations expressing the fact that an action (i.e., the transformation) had been performed (as in reversibility) but failing to note that the action could be reversed (example 5 in Table 1); (2) explanations describing two dimensions (as in compensation), but either the two dimensions were not described on a single object (example 6a in Table 1) or the two dimensions failed to compensate for one another (example 6b in Table 1); and (3) explanations comparing the task objects on a single dimension (as in identity), but a dimension which differentiated between the two objects (example 7 in Table 1).

Noncomparative explanations. The children also produced a type of explanation that did not focus on a comparison of objects at all, explanations which we have called *noncomparative.* Two types of noncomparative explanations were identified in the children's data: (1) explanations containing attribute information about a task object but either including only one attribute on one of the task objects (example 8a in Table 1), or including one or more attributes which were irrelevant to the quantity concept tested (example 8b in Table 1); and (2) explanations indicating the existence of the task objects without further elaboration (example 9 in Table 1).[2]

Reliability for assigning verbal responses to these equivalence, nonequivalence, and noncomparative explanation categories was 88% (N = 36) agreement between two coders.

Coding the relationship between speech and gesture

We employed the criteria developed in Goldin-Meadow (1979, see also Feldman, Goldin-Meadow, & Gleitman, 1978, and Goldin-Meadow, & Mylander, 1984) to isolate gestures from the flow of manual behaviors and to describe those gestures.[3] The children in our study were found to produce

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[2] Occasionally (6% of the 168 explanations in Study 1 and 4% of the 312 explanations in Study 2), the children qualified the nonequivalence and noncomparative explanations they produced with "all you did" or "just" (e.g., "all you did was put them in a circle," "you just poured the water from the glass to the dish," or "it's just wide"). Qualifications of this sort might suggest that the child is aware that the displacement transformation or the perceptual difference between the transformed and the untransformed objects is irrelevant to the quantity under scrutiny. These qualified explanations might therefore be legitimately classified as equivalence rather than nonequivalence or noncomparative explanations. It is important to note, however, that these qualified explanations were infrequent in our data base, and that reclassifying them as equivalence explanations does not alter the pattern of results reported either for Study 1 or for Study 2.

[3] Further details on our coding categories can be obtained by consulting R.B. Church, "Speech and gesture discordance as an index of transitional knowledge," doctoral dissertation, University of Chicago, expected 1986, or writing to the authors at the University of Chicago, 5835 S. Kimbark Ave., Chicago, IL 60637.

two types of iconic gestures (in addition to producing points at the task objects): (1) action gestures that portrayed either the motion the experimenter used to transform a task object (e.g., a pouring motion from the glass to the dish), or a motion one might use to return the object to its original state (e.g., a pouring motion from the dish to the glass); and (2) attribute gestures that portrayed characteristics of the task objects, either characteristics that changed in appearance during the transformation (e.g., a "C" hand with the fingers 2–3 inches from the thumb representing the thinness of the glass vs. a "C" hand with the fingers 4–5 inches from the thumb representing the wideness of the dish), or characteristics that remained the same after the transformation (e.g., two palms demarcating the length of the horizontal stick and the length of the vertical stick). Inter-rater reliability ranged between 87% and 100% agreement between two coders for isolating and describing the gestures.

To examine the relationship between gesture and speech within an explanation, we focused on the match (concordance) and mismatch (discordance) between the action and attribute information conveyed in the two modalities.

Concordant explanations. A gesture-plus-speech explanation was categorized as concordant if gesture expressed the same information about the task objects as was expressed in speech, as in a description of reversing the pouring action in the water task, "If you poured the water back," said while gesturing the same information (see also examples of concordant responses in Table 2). Concordant explanations also included those in which gesture conveyed a subset of the information conveyed in speech, as in "The glass is tall and thin," said while gesturally representing only the thinness of the glass.

Discordant explanations. Explanations were categorized as discordant if gesture contained different information about the task objects from that contained in speech. For example, a response in which speech described an action performed on the objects while gesture described a dimension (or dimensions) of the objects, as in "You poured water from the glass into the dish," said while gesturally representing the tallness of the glass and the shortness of the dish was categorized as discordant (see also examples of discordant responses in Table 2). Discordant explanations also included those in which gesture conveyed more information than was conveyed in speech, as in "The dish is wide," said while gesturally representing the shortness as well as the wideness of the dish. Note that the information conveyed in gesture of a discordant explanation was not necessarily contradictory to the information conveyed in speech—it was merely different and, in this limited sense, discordant.

Explanations in which only one modality was used (i.e., spoken explana-

Table 2. *Examples of verbal explanations with matching gestures (concordant responses) or with mismatching gestures (discordant responses)*

Type of verbal explanation	Concordant responses		Discordant responses	
	Speech	Matching gesture	Speech	Mismatching gesture
Equivalence	"Turn it [the vertical stick] the other way" (i.e., rotate the vertical stick back to original position)	Small "C" hand pivots from vertical to horizontal orientation (i.e., rotate the vertical stick back to original position)	"Push them [the horizontal and vertical sticks] close together" (i.e., return the sticks to original position)	Point moves from end to end on the vertical stick and from end to end on the horizontal stick (i.e., indicating length on both sticks)
Nonequivalence	"You poured my glass in there [the dish]"	Pouring motion from the *glass* to the *dish*, point at the dish	"Because you poured water in that glass in there [the dish]"	Pouring motion from the *dish* to the *glass*, point at the dish
Noncomparative	"You have two glasses"	Holds two fingers in air toward two glasses	"Just in two cups"	Pouring motion toward glasses

tions with no gesture [14% of the 168 responses] or gestured explanations with no speech [3% of the responses]) were not analyzed for concordance and discordance. Explanations in which gesture and/or speech were uncodable (i.e., speech was codable but gesture was not [2% of all responses] or gesture and speech were both uncodable [<1% of responses]) were also not coded for concordance and discordance.

Reliability for coding concordant and discordant explanations was 88% (*N* = 34) agreement between two coders.

Results

Partitioning the children into judgment groups

Using the "same/different" judgments each child gave on the six Piagetian tasks, we identified 5 Nonconservers, 9 Partial Conservers, and 14 Conservers in our sample. As expected, Nonconservers were found to be younger on average than Partial Conservers who were, in turn, younger on average than Conservers (Table 3). None of the 9 Partial Conservers produced a "same" judgment on all three quantities (i.e., none conserved across quantities) but

Table 3. *Number of gesture-plus-speech explanations produced by each judgment group*[a]

Judgment group	Number of children	Age (yrs; mos.) Mean	(S.D.)	Number of gesture-plus-speech explanations Total	Mean	(S.D.)
Nonconservers	5	5;2	(0.5)	26	5.2	(0.84)
Partial Conservers	9	6;6	(1.1)	45	5.0	(1.12)
Conservers	14	7;2	(1.1)	67	4.8	(1.81)

[a] The maximum number of gesture-plus-speech explanations each child could produce was six.

6 produced two "same" judgments on at least one quantity (i.e., they conserved within a quantity, usually number).

Types of explanations expressed in speech

Previous studies of conservation have found that conservers tend to produce equivalence explanations while children who fail to conserve rarely do so (e.g., Brainerd, 1973; Gelman, 1969; Gelman & Weinberg, 1972; Siegler, 1981). The children in our study, like children in other studies of quantity conservation, showed this expected pattern of production across judgment groups. Conservers expressed a relatively large percentage of equivalence explanations (62% of their 84 explanations), fewer nonequivalence explanations (29%), and extremely few noncomparative explanations (8%). Partial Conservers produced few equivalence explanations (17% of their 54 explanations), a large percentage of nonequivalence explanations (65%), and few noncomparative explanations (11%). Nonconservers produced no equivalence explanations (out of 30) and relatively equal percentages of nonequivalence (47%) and noncomparative (40%) explanations.[4]

The relationship between speech and gesture and consistency of knowledge

All but one of the 28 children were found to produce gestures along with at least some of their verbal explanations. Table 3 presents the total number and

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[4] The percentages do not sum to 100 because the children failed to produce verbal explanations or produced uncodable verbal explanations on a small percentage of responses: 1% for the Conservers, 7% for the Partial Conservers, and 13% for the Nonconservers.

mean number of explanations containing both gesture and speech produced by children in each judgment group. The table indicates that gesture-plus-speech explanations were quite common: On average children in the three groups produced between 4.8 and 5.2 (out of 6) explanations containing both gesture and speech, accounting for 82% of all explanations.

Looking next at the relationship between the information conveyed in gesture and in speech within an explanation, we found that 40% of the 168 explanations (50% of the 135 explanations containing both gesture and speech) produced by all of the children were found to be discordant (i.e., the information conveyed in gesture failed to match the information conveyed in speech). Across judgment groups, discordant explanations accounted for 47% of the Nonconservers' 30 explanations, 44% of the Partial Conservers' 54 explanations, and 36% of the Conservers' 84 explanations.

We next looked at the production of discordant explanations by individual child and found that the children varied considerably in the numbers of discordant explanations they produced: Some children produced as many as five (out of six) discordant explanations while others produced no discordant explanations at all. We suggest that gesturing one thing while saying another (a discordant response) might be an indication of inconsistent thinking. We hypothesize that those children who produced a large number of discordant explanations might be less consistent in their beliefs about quantity invariance (independent of what those beliefs actually were) than were those children who produced few such mismatched explanations.

To investigate this hypothesis, we first classified the children in each judgment group as either concordant or discordant on the basis of the proportion of discordant responses each child produced. We then established two measures of consistency—measures that were independent of our criteria for classifying concordant and discordant subjects and independent of our criteria for classifying judgment groups—in an attempt to determine whether discordant children were indeed more inconsistent in their explanations of their conservation beliefs than were concordant children.

Classifying children as concordant and discordant. For each judgment group, we used the proportion of discordant responses produced by each child to classify the children as "concordant" or "discordant." We classified those children who produced discordant responses in fewer than 50% of their 6 explanations as concordant subjects (2 Nonconservers, 4 Partial Conservers, and 9 Conservers) and those who produced discordant responses in 50% or more of their 6 explanations as discordant subjects (3 Nonconservers, 5 Partial Conservers, and 5 Conservers). Table 4 displays the mean ages of the concordant and discordant children in each judgment group, as well as the number of discordant responses each group produced.

Table 4. *Characteristics of concordant and discordant children in Study 1*

	Concordant children					Discordant children				
Judgment group	Number of children	Mean age	Number of discordant responses			Number of children	Mean age	Number of discordant responses		
			Mean	(S.D.)	Range			Mean	(S.D.)	Range
Nonconservers	2	5;0	1.50	(.71)	1–2	3	5;4	3.67	(.58)	3–4
Partial Conservers	4	6;0	1.25	(.50)	1–2	5	6;11	3.80	(1.10)	3–5
Conservers	9	7;0	1.11	(.78)	0–2	5	7;7	4.00	(1.00)	3–5

Establishing indices of consistency of knowledge. We established two indices of consistency of knowledge that were independent of our criteria for classifying concordant and discordant subjects and independent of our criteria for classifying judgment groups. Following traditional analyses of explanations in conservation tasks which look only at verbal responses, we chose indices that involved analyses of the children's spoken responses only, ignoring for this analysis information contained in the children's gestures.

(1) *Consistency between judgments and their explanations.* In our experimental protocol, each child was asked to give six judgments and then to explain each of those judgments. We reasoned that one way to probe consistency of conservation understanding might be to analyze whether the level of conservation understanding reflected in the *judgment* is consistent with the level of conservation understanding reflected in the verbal *explanation* for that judgment. For example, a consistent judgment/explanation pair would be a "same" judgment (which reflects a belief that quantity has not changed after transformation) and an equivalence explanation (which also reflects a belief in the unaltered quantity of the object). In general, a judgment/explanation pair was considered to be consistent if a (spoken) equivalence explanation followed a "same" judgment or if a (spoken) nonequivalence explanation followed a "different" judgment. We measured judgment/explanation consistency in two ways: (1) by calculating the number of consistent judgment/explanation pairs produced by each child, and (2) by calculating the number of children who produced at least four out of six consistent judgment/explanation pairs.

(2) *Consistency across explanations.* Even if a child did not produce explanations consistent with his judgments, the child still might have produced explanations which were consistent in level of reasoning across the six tasks. Consequently, we devised a second index of consistency analyzing solely

verbal explanations without their associated judgments. We measured this second index of consistency in two ways: (1) by calculating the maximum number of explanations at a single level (either equivalence, nonequivalence, or noncomparative) produced by each child on all 6 tasks, and (2) by calculating the number of children who produced at least 4 out of 6 explanations at a single level (4/6 equivalence explanations, or 4/6 nonequivalence explanations; none of the children produced as many as 4 noncomparative explanations).

Discordance as an index of inconsistent knowledge

Our next step was to compare the performance of the concordant and discordant subjects using these two indices of consistency. Table 5 presents the data for the two consistency indices, each measured in terms of number of explanations (5a) and number of subjects (5b), for both concordant and discordant children. Concordant subjects achieved higher consistency scores than discordant subjects on both measures of the "consistency between judgment and explanation" index ($t(26) = 2.32, p < .02$, one-tailed, for number of explanations; $\chi^2(1) = 3.51, p < .05$, one-tailed, for number of children) and on both measures of the "consistency across explanations" index ($t(26) = 1.87, p <$

Table 5. *Indices of consistency for concordant and discordant children*

a. Mean number of consistent responses (out of six) produced by concordant and discordant children

Consistency indices	Concordant children	Discordant children
Judgment/explanation consistency	4.1 (1.39)[a]	2.9 (1.50)**
Across explanation consistency	4.3 (0.98)	3.6 (1.12)*

b. Proportion of concordant and discordant children producing four or more consistent responses

Consistency indices	Concordant children	Discordant children
Judgment/explanation consistency	.73 ($N = 15$)	.31 ($N = 13$)*
Across explanation consistency	.80 ($N = 15$)	.38 ($N = 13$)*

*$p < .05$.
**$p < .02$.
[a] The number in parentheses is the standard deviation.

.05, one-tailed, for number of explanations; $\chi^2(1) = 3.31, p < .05$, one-tailed, for number of children). In other words, the children who produced a relatively high proportion of responses with gesture/speech discordance in their explanations (discordant subjects) were less consistent in their (spoken) answers to the conservation questions than were children who produced relatively few responses with gesture/speech discordance (concordant subjects).

When the data in Table 5 are analyzed by judgment group, the same pattern arises, although the numbers are too small to test for statistical significance. Table 6 presents data on the two measures of each consistency index

Table 6. *Indices of consistency by judgment group*

a. Mean number of consistent responses (out of six) produced by concordant and discordant children

Judgment group	Concordant children	Discordant children
Judgment/explanation consistency		
Nonconservers	3.5 (0.7)[a]	2.3 (1.2)
Partial conservers	4.0 (1.4)	3.4 (1.3)
Conservers	4.2 (1.6)	2.8 (1.9)
Across explanation consistency		
Nonconservers	3.5 (0.7)	3.0 (0.0)
Partial conservers	4.5 (0.6)	3.8 (1.3)
Conservers	4.4 (1.1)	3.8 (1.3)

b. Proportion of concordant and discordant children producing four or more consistent responses

Judgment group	Concordant children	Discordant children
Judgment/explanation consistency		
Nonconservers	.50 ($N = 2$)	.00 ($N = 3$)
Partial conservers	.75 ($N = 4$)	.60 ($N = 5$)
Conservers	.78 ($N = 9$)	.20 ($N = 5$)
Across explanation consistency		
Nonconservers	.50 ($N = 2$)	.00 ($N = 3$)
Partial conservers	1.00 ($N = 4$)	.60 ($N = 5$)
Conservers	.78 ($N = 9$)	.40 ($N = 5$)

[a] The number in parentheses is the standard deviation.

for concordant and discordant subjects divided into judgment groups (Conservers, Partial Conservers, and Nonconservers). Within each judgment group, concordant subjects were more consistent than discordant subjects on both measures of the two indices of consistency.

Equivalence explanations in discordant responses

To begin to understand the nature of the discordant children's inconsistency, we examined the types of information conveying equivalence in the children's discordant responses. We found that the children were able to use their gestures to express the central elements in all three Piagetian equivalence explanations. To convey reversibility, the children produced gestures that reversed the action the experimenter used to transform the object, e.g., in the number task in which the experimenter spreads out a row of checkers, the children used a squishing motion (two palms approaching each other several times over the spread-out row) to indicate reversing the action. To convey compensation, the children produced gestures that represented two compensating dimensions on a single object, e.g., in the liquid quantity task in which the experimenter pours the water from the glass to a dish, the children indicated the height (a horizontal palm held at the top of the glass) and width (two vertical palms held at the sides of the glass) of the glass. To convey identity, the children used gestures that represented an identical dimension on the two task objects, e.g., in the length task in which the experimenter moves one stick over so the ends are no longer aligned, the children indicated length on stick 1 (two vertical palms held at the ends of stick 1) and the same length on stick 2 (two vertical palms held the same distance apart over stick 2).

In discordant explanations, the children used gestural representations of equivalence in three ways with respect to speech. (1) Gesture *complemented* speech so that together gesture and speech formed an equivalence explanation, e.g., the child said "the glass is tall" but indicated the thinness of the glass gesturally, thereby creating a compensation explanation. (2) Gesture *surpassed* speech, e.g., the child said "the glass is tall" which is a noncomparative explanation, but represented reversibility, which is an equivalence explanation, in his gesture (i.e., a pouring motion from the dish to the glass). (3) Gesture *equalled* or was *less* than speech, e.g., the child produced an equivalence explanation in speech and a different equivalence explanation in gesture ("the glass is tall and skinny" said while producing a pouring motion from the *dish* to the *glass*), or an equivalence explanation in speech and a nonequivalence explanation in gesture ("the glass is tall and skinny" said while producing a pouring motion from the *glass* to the *dish*).

Overall, we found that the discordant children conveyed equivalence in the gesture and/or speech of their discordant responses somewhat more often than the concordant children did: 56% of the discordant children's 50 discordant responses conveyed equivalence vs. 44% of the concordant children's 18 discordant responses. However, if we ignore gesture for the moment and analyze the proportion of equivalence explanations conveyed in the children's spoken responses, we find that the discordant children were *less* likely to convey equivalence in speech alone than were the concordant children: 26% of the discordant children's 78 verbal responses conveyed equivalence vs. 46% of the concordant children's 90 verbal responses. Note that the discordant children showed more equivalence understanding when both gesture and speech were considered in their discordant responses (56%) than when speech alone was considered in all responses (26%). In contrast, the concordant children showed no such disparity between their discordant reponses (44%) and their spoken responses taken as a whole (46%).

Turning next to the ways in which the children conveyed equivalence in their discordant responses, we again find differences between the discordant and the concordant children: in 67% of the 28 discordant responses the discordant children used to convey equivalence, gesture either complemented (21%) or surpassed (46%) speech, compared to 13% of the 8 discordant responses the concordant children used to convey equivalence. Thus, the discordant children were more likely than the concordant children to use gesture in ways that enhanced speech. These data suggest that the improved performance the discordant children showed in their discordant responses (compared to their performance in speech alone) was, not surprisingly, due to the way in which they used gesture.

In sum, we have found that the concordant children (the children who produced few discordant responses) used those few discordant responses to express a level of reasoning that was comparable to the level expressed in their verbal explanations taken as a whole. In contrast, the discordant children (the children who produced many discordant responses) expressed a higher level of reasoning in their discordant responses, particularly in the gestural component of those discordant responses, than in their verbal explanations overall. The discordant children thus appeared to have some understanding of elements central to the equivalence explanation that were not yet integrated into their verbal explanations. This unintegrated information may, in fact, have been the source of the discordant children's inconsistency.

Given that the discordant children appeared to have pieces of information that they had not yet consolidated into a coherent explanatory system (hence the high proportion of discordant responses and the inconsistent performance on the conservation task), we might predict that instruction in equivalence would be particularly beneficial to discordant children, assisting them in consolidating their knowledge of equivalence. In other words, we might expect that discordant children, no longer convinced of nonequivalence but not yet masters of equivalence, would be more responsive to training in equivalence than concordant children, who gave no evidence of being in such an unstable knowledge state. Study 2 tested this hypothesis.

Study 2

The goal of Study 2 was to assess whether discordance could serve not only as an index of inconsistent knowledge, but also as an index of transitional knowledge and thus as a predictor of susceptibility to training. To meet this objective, we exposed concordant and discordant Partial Conservers to two different types of training in quantity conservation, and assessed the effects of that training via a conservation posttest.

Methods

Subjects

106 children participated in six Piagetian conservation tasks. Children who gave six "different" judgments (i.e., Nonconservers) or six "same" judgments (i.e., Conservers) on these tasks, 54 children in toto, were eliminated from the study. The remaining 52 children who gave both "same" and "different" judgments on the tasks (i.e., Partial Conservers) comprised the subjects for the study. Partial Conservers were chosen as the focus of the training study because, as a group, they have been shown to benefit from instruction in conservation (e.g., Brainerd, 1972). Moreover, most training studies find that the effects of training are variable within groups of Partial Conservers, i.e., some Partial Conservers benefit from training while others do not (e.g., Beilin, 1965; Brainerd, 1972; Langer & Strauss, 1972; Strauss & Rimalt, 1974).

Procedure

The children participated in a series of three consecutive videotaped sessions, each lasting approximately 15 minutes.

(1) During the pretest, each child was given the six Piagetian conservation tasks described in Study 1 (2 liquid quantity tasks, 2 numbers tasks and 2

length tasks). As in Study 1, for each task the child was asked to judge whether an object was the "same" or "different" in quantity after undergoing a transformation and then to explain that judgment.

(2) During training, the child was exposed either to a condition in which explicit instruction in equivalence was given (cf. Beilin, 1965), or to a condition in which the child was given experience in manipulating the task objects but no instruction or feedback. An experimenter who was not at the pretest and was therefore blind to the child's status as concordant or discordant randomly assigned the child to one of the two training conditions on the basis of a coin flip.

In the *instruction* condition, the experimenter who was not at the pretest presented two identical containers and filled them with equal amounts of water. She then poured water from one of the containers into a flat pan and told the child that she thought the container and the pan had the same amount of water. The experimenter asked the child if he wanted to know why she believed the amounts to be the same and proceeded to provide examples of each of the three Piagetian equivalence explanations, i.e., a reversibility explanation ("I could think about pouring the water back into the container and it would be the same amount"), a compensation explanation ("The pan is shorter than the container but it is also wider than the container"), and an identity explanation grounded in the fact that the experimenter neither added nor subtracted water ("I didn't take any water away so we don't have less water and I didn't add any water so we don't have more water; so the pan still has to have the same amount of water"). The experimenter then poured the water back into the original container and told the child that it was his turn. She had the child pour the water into yet another container and asked the child if the two containers had the same or different amounts of water, and why. The experimenter gave the child feedback on his judgment (i.e., she verified a "same" judgment and corrected a "different" judgment) and provided any of the three equivalence explanations that the child did not spontaneously produce (e.g., if the child produced only a reversibility explanation, the experimenter provided a compensation and an identity explanation). Thus, each child heard all three equivalence explanations on every trial, produced either by himself or by the experimenter. After the two liquid quantity tasks, the experimenter repeated this process with two number tasks. The child received no training in length.

In the *manipulation* condition, the experimenter who was not present during the pretest placed the same two containers used in the instruction condition in front of the child and filled them with equal amounts of water. She then requested the child to pour water from one of the containers into a flat pan and asked if the pan and the container had the same or different amounts of water. Thus, the child was asked to give a judgment but not to explain that judgment. The child received no feedback on his response. This procedure was repeated with the objects used in the second liquid quantity task and with the objects used in the two number tasks of the instruction condition.

(3) During the posttest, each child was again tested on the six conservation tasks used in the pretest by the original experimenter who was not present during training.

Coding the pretest

Pretests were coded first for judgments and then for explanations. Children were included in the study only if they produced some "same" and some "different" judgments on their pretests (i.e., if they were Partial Conservers). The explanations the children gave for their judgments on the pretest were coded for type of reasoning (i.e., equivalence, nonequivalence, and noncomparative) expressed in speech alone, and for the relationship between the information conveyed in gesture and in speech (i.e., concordance and discordance), as described in Study 1. The only coding difference between Study 1 and Study 2 was that the children in Study 2 produced a fifth type of equivalence explanation arguing that the quantity was the same because the experimenter neither added to nor subtracted from the original quantity (e.g., "You didn't take any away or put any in"). As in Study 1, children who produced 50% or more discordant explanations on the pretest were considered discordant; those who produced fewer than 50% were considered concordant.

Coding the posttest

Posttests were also coded for judgments and explanations. The number of "same" judgments a child produced on the posttest was noted and evaluated in terms of the number of "same" judgments he produced on the pretest. Explanations on the posttest were coded for type of reasoning expressed in speech alone and were evaluated in terms of the types of explanations each child expressed in speech during the pretest.

Results

Characteristics of concordant and discordant children

Using the criteria established in Study 1 for concordant and discordant children, we found that on the basis of the explanations they produced during the pretest, 16 of the children in the instruction condition were classified as concordant and 14 were classified as discordant. Similarly, in the manipulation condition, 12 children were classified as concordant and 10 were classified as discordant. Table 7 presents the mean ages of the children in each of these four groups, as well as the number of discordant responses produced by the groups. Note that the mean number and range of discordant responses for the concordant and discordant children in Study 2 were comparable to these measures for the children in Study 1, with the exception that some of the discordant children in Study 2 produced 6 discordant responses while none of the children in Study 1 did.

Improving to full conservation

We first looked at posttest performance in terms of the most stringent criterion for attributing conservation understanding to the child: "same" judgments on all six tasks and an equivalence explanation produced to justify each of those six judgments. None of the 22 children in the manipulation condition met this criterion on their posttests while 20% of the 30 children in the instruction condition did. Moreover, within the instruction condition, the discordant children were found to achieve full conservation more often than the concordant children: 36% of the 14 discordant children achieved full conservation while only 6% of the 16 concordant children did ($p = .05$, one-tailed, Fisher Exact). Thus, as hypothesized, the discordant children were more likely to benefit from instruction than were the concordant children, using this stringent criterion of success.

Table 7. *Characteristics of concordant and discordant partial conservers in Study 2*

	Concordant children					Discordant children				
Training condition	Number of children	Mean age	Number of discordant responses			Number of children	Mean age	Number of discordant responses		
			Mean	(S.D.)	Range			Mean	(S.D.)	Range
Instruction	16	6;11	1.38	(.81)	0–2	14	7;5	3.79	(.97)	3–6
Manipulation	12	7;4	1.25	(.97)	0–2	10	7;5	3.70	(1.06)	3–6

Improving on judgments

We next considered whether the children, although not necessarily achieving full conservation, might still have shown improvement from the pretest to the posttest on either the judgment or the explanation components of the conservation task. Considering judgments first, we found that 63% of the 30 children in the instruction condition improved on judgments (i.e., they produced more "same" judgments on the posttest than they did on the pretest), compared to 27% of the 22 children in the manipulation condition ($\chi^2(1) = 5.25$, $p < .025$, one-tailed). Moreover, in both the instruction and the manipulation conditions, discordant children were no more likely to improve on judgments than were concordant children: 57% of the 14 discordant children in the instruction condition improved on judgments, compared to 69% of the 16 concordant children ($\chi^2 = .08$, n.s.) and 30% of the 10 discordant children in the manipulation condition improved on judgments, compared to 25% of the 12 concordant children (n.s., Fisher Exact). Thus, concordant children were just as likely to increase their production of "same" judgments on conservation tasks after training as were discordant children.

Improving on explanations

We found two ways in which children showed improvement in explanations from the pretest to the posttest: (1) a child might generalize an equivalence explanation he produced on the pretest to a new quantity on the posttest (e.g., a child who produced an identity explanation only on a number task in the pretest might generalize that identity explanation to a length or liquid quantity task on the posttest), or (2) a child might produce an equivalence explanation on the posttest that he had not produced on the pretest (e.g., a child who produced no equivalence explanations on the pretest might produce any one of the three equivalence explanations on the posttest).

Children in the instruction condition were more likely to improve on explanations than were children in the manipulation condition (67% vs. 27%, $\chi^2(1) = 6.38$, $p < .01$, one-tailed). However, in each of the two training conditions, the discordant children showed greater improvement on explanations than the concordant children. Table 8 presents the proportion of concordant and discordant children as a function of their type of improvement on explanations in the posttest, i.e., no improvement, generalizing an old equivalence explanation only, or adding a new equivalence explanation (with or without generalizing an old explanation). In the instruction condition, the discordant children were significantly more likely than the concordant children to add a new equivalence explanation to their repertoires after training

Table 8. *Proportion of concordant and discordant children classified according to improvement on explanations in the posttest*

	Instruction condition		Manipulation condition	
Posttest improvement on explanations	Concordant children ($n = 16$)	Discordant children ($n = 14$)	Concordant children ($n = 12$)	Discordant children ($n = 10$)
No improvement	.50	.14	.83	.60
Generalizing an old equivalence explanation to a new quantity	.13	.00	.16	.00
Adding a new equivalence explanation	.37	.86**	.00	.40*

*$p < .05$, comparing concordant and discordant children within each condition.
**$p = .03$.

($p = .03$, one-tailed, Fisher Exact). Moreover, despite the fact that they did not receive explicit training in explanations, the discordant children in the manipulation condition were also significantly more likely than the concordant children to add a new equivalence explanation to their repertoires ($p <$ .05, Fisher Exact, one-tailed).

It is worth noting that these differences in posttest improvement between the concordant and discordant children were not due to an unequal performance on the pretest in either training condition. In the instruction condition, the discordant and the concordant children produced comparable mean numbers of equivalence explanations on the pretest (2.1 vs. 1.5 [out of 6], respectively, $t(28) = 1.12$, n.s.) and comparable mean numbers of different types of equivalence explanations on the pretest (1.8 vs. 1.4 [out of 5], respectively, $t(20) = .73$, n.s.). Similarly, in the manipulation condition, the discordant and concordant children were comparable in their mean number of equivalence explanations on the pretest (1.4 vs. 1.1, respectively, $t(28) = .78$, n.s.) and their mean number of types of equivalence explanations on the pretest (1.3 vs. 1.2, respectively, $t(20) = .34$, n.s.).

Recall that the children in the instruction condition received training on liquid quantity and number but not on length. To determine whether the children were extending the knowledge they had gained during training to a new task, we calculated the proportion of discordant and concordant children who improved on explanations in the length tasks. 43% of the 14 discordant children in the instruction condition improved on explanations in the length tasks (half generalized to length an equivalence explanation previously offered on another quantity in the pretest and half added a new equivalence explanation on the length task), compared to 25% of the 16 concordant children (all of whom generalized an equivalence explanation only).

We next examined whether the new equivalence explanations the children added on the posttest were related in some way to the knowledge they exhibited in the explanations they produced on the pretest. Specifically, we looked at the types of equivalence explanations each child added on the posttest in relation to the type of equivalence reasoning that child conveyed in the gestural component of the discordant responses he produced on the pretest. 23 children added equivalence explanations on the posttest (6 concordant and 12 discordant children in the instruction condition and 5 discordant children in the manipulation condition). For 61% of those children, the equivalence explanation added on the posttest could be found somewhere in the gestural component of the children's discordant responses on the pretest (39% were expressed in gesture alone and 22% were expressed in gesture and speech in combination). Interestingly, the percentage of explanations added on the posttest that could be found in discordant responses on the pretest was higher for the 5 discordant children in the manipulation condition (80%) than for either the 12 discordant or 6 concordant children in the instruction condition (58% and 50%, respectively).

Matching for age

Note in Table 7 that the children in the instruction condition differed in age; in particular, the discordant children were on average six months older than the concordant children. To control for the effects of age, we matched as many concordant children as we could with a discordant child who was within three months of the age of that child. We arrived at a sample of nine concordant children and nine discordant children who did not differ in age (mean age was 6;10 for both groups). We then recalculated our measures of posttest improvement on this matched sample.

We found the same effects in the matched sample as we found in the larger population taken as a whole. In terms of improving to full conservation, 44% of the discordant children achieved full conservation, compared to none of the concordant children (p = .05, one-tailed, Fisher Exact). In terms of improving on judgments, 67% of the discordant children and 78% of the concordant children produced more "same" judgments on the posttest than they produced on the pretest (n.s., Fisher Exact). In terms of improving on explanations, 78% of the discordant children added a new equivalence explanation to the repertoires compared to 11% of the concordant children ($p <$ .01, one-tailed, Fisher Exact). Thus, the differences in patterns of posttest performance between the discordant and the concordant children appear to be independent of age.

Discussion

The present study suggests that in a situation where children are asked to give explanations, they are likely to produce gestural responses along with speech (cf. Evans & Rubin, 1979). McNeill (in press; McNeill & Levy, 1982) and others (Kendon, 1983; Slama-Cazacu, 1976) have shown that information conveyed in gesture can reveal what the speaker knows about a given concept; i.e., the gestural channel can provide insight into the mental representation of the speaker. The data from our study suggest that gesture can be used not only to index what the child knows, but also to index how consistently he knows it. The relationship between the information conveyed in gesture and the information conveyed in speech—in particular, the match (concordance) or mismatch (discordance) between the information conveyed in the two modalities—appears to index the consistency of the explanatory system underlying the child's understanding of a given concept.

Moreover, our study has shown that the relationship between gesture and speech can also index transitional knowledge and thus a child's readiness to make use of instruction in a concept. Children who produced many gesture/speech mismatches in their explanations (discordant children) were more likely to acquire new equivalence explanations of conservation after training than were children who produced few mismatches (concordant children). Note that the training provided in the instruction condition explicitly told the children which answers to give when asked for explanations on the conservation task. The point to stress, however, is that it was only the discordant children who were able to benefit from such explicit instruction. Moreover, even when given only practice in manipulating and transforming the objects used in the conservation task and no explicit instruction whatsoever, the discordant children (but not the concordant children) were able to benefit from the experience and add equivalence explanations to their repertoires. These findings suggest that the discordant children already knew a fair amount—however implicitly—about the invariance of length, number, or liquid quantity with respect to displacement transformation and thus could assimilate and benefit from general or specific input.

Further evidence that the children who added explanations on the posttest had an implicit understanding of quantity invariance before training comes from the fact that many of the explanations added after training could be found somewhere in the gestural component of the children's discordant responses in the pretest. Thus, the gestural component of the children's explanations appeared to reflect implicit knowledge of equivalence, knowledge that the training (no matter how minimal) helped to make explicit (see Gelman & Baillargeon, 1983, for a discussion of the role implicit knowledge plays in the development of Piagetian concepts).

Although children who produced many explanations with gesture/speech mismatches were found to be more inconsistent and more trainable in their explanations of the conservation principle than children who produced few such mismatched explanations, we do not mean to suggest that this state of inconsistency and trainability is a general characteristic of the child. Rather, we suggest that inconsistency and trainability describe the child's knowledge state with respect to a particular concept—conservation. We would not expect that the same child who exhibits gesture/speech mismatches in his explanations of conservation, a concept he appears to be in the process of acquiring, would produce many explanations with gesture/speech mismatches while explaining a concept with which he is more familiar.

We hypothesize that gesture/speech discordance may be a general characteristic of the novice learner—an individual who is grappling with a particular concept and has as yet only an inconsistent understanding of that concept and is ready to receive training in that concept. In order to test this hypothesis, we are currently extending our studies of gesture/speech discordance to an older group of children (9- through 12-year-olds) who may be grappling with another concept (one in the symbolic domain—the mathematical concept of equivalence in problems of addition). We are attempting to investigate whether children who produce many gesture/speech mismatches in explanations of their solutions to a series of addition problems are (1) more inconsistent in the explanatory systems they use to justify their solutions than are children who produce few such mismatched explanations, and (2) more likely to benefit from training in mathematical equivalence than children who produce few such mismatched explanations (Perry, Church, & Goldin-Meadow, forthcoming).

Our work on conservation taps knowledge of a concept as it is reflected in explanations of that concept. In particular, we have shown that gesture/speech discordance is associated with inconsistency in verbal explanations of conservation. Moreover, gesture/speech discordance predicts improvement in verbal explanations but not judgments after training in conservation. Both concordant and discordant children learned to produce "same" judgments when asked if a quantity had changed after a transformation, while only discordant children learned explanations that could justify those judgments. Although these data suggest that gesture/speech discordance serves as an index of trainability solely at the level of explanations, we suspect that discordance may in the end turn out be a useful index of trainability at less reflective levels as well. To investigate this hypothesis, our future work will train concordant and discordant children in conservation as in Study 2 but will test the children on a far transfer task that taps understanding of the conservation principle without relying on explanations (e.g., a series of nonverbal conservation tasks testing a number of quantities, cf. Miller, 1976).

Further evidence for the belief that gesture/speech discordance goes beyond the child's reflective knowledge of concepts might be derived from work on a second concept, e.g., mathematical equivalence, which probes knowledge of equivalence at several different levels of understanding. In such studies, if discordant children who benefit from training are able to generalize the instruction they receive on addition problems to problems of the same form but based in a different operation (multiplication), gesture/speech discordance would be demonstrated to predict trainability not only at the level of explanations but also at the less reflective level of actual problem solution (cf. Perry et al., forthcoming).

If gesture/speech discordance is revealed to function as a general index of inconsistent understanding and receptivity to training, the measure could potentially be used in any task in which the subject (child or adult) is asked for explanations. Unlike Siegler's rule-assessment approach in which the experimenter must understand all of the components of a task in order to devise just the right questions to show rule-governed behavior, gesture/speech discordance can, in principle, be spotted in any individual's explanations of any concept. In addition, in the present study, the information conveyed in gesture and speech in a child's mismatched explanations was used to provide insight into the child's partial knowledge about conservation. Thus, gesture/speech discordance may not only be able to index a speaker's inconsistency and trainability with respect to a concept, but may also be able to provide insight into the partial knowledge that contributes to that inconsistency and trainability.

These studies focused on a single developmental phenomenon—conservation. However, as we have tried to argue, the interpretation of these findings may be relevant to learning phenomena more generally. Under any circumstances in which new concepts are acquired, there exists a mental bridge connecting the old knowledge state to the new. Characterization of this mental transition, and description of the mechanisms pushing one forward, are at the heart of developmental and learning research. Our study suggests that the relationship between gesture and speech may be an easily observable and significantly interpretable reflection of knowledge states, both static and in flux.

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Résumé

Ce travail étudie deux implications des discordances entre geste et parole que l'on observe souvent lorsqu'un enfant explique un concept: (1) Ces discordances reflètent-elles une incohérence du système explicatif qui sous-tend la compréhension du concept par l'enfant? (2) Ces discordances reflètent-elles peut-être en tant qu'effet de cette incoherence, une receptivité particulière de l'enfant à l'apprentissage de ce concept?

Une tâche de conservation piagétienne, au cours de laquelle on demande aux enfants d'expliquer leurs jugements sur l'invariance des quantités, a permis de tester ces deux possibilités. On a demandé à des enfants âgés de 5 à 8 ans d'effectuer 6 jugements de conservation et d'expliquer chacun de ces jugements. Tous les enfants sauf un faisaient spontanément des gestes pendant leurs explications orales. On classifia les enfants en deux groupes selon le rapport entre geste et parole qui apparaissait dans leurs explications: les enfants "discordants" produisaient souvent des explications dans lesquelles l'information véhiculée par la parole ne correspondait pas à l'information véhiculée par les gestes; les enfants "concordants" produisaient rarement des explications de ce type.

La première étude a cherché à déterminer si le raisonnement qui sous-tend les explications verbales sur l'invariance des quantités était moins cohérent chez les enfants discordants que chez les enfants concordants. Deux indicateurs de cohérence, indépendants de la distinction entre enfants discordants et concordants, ont été élaborés et appliqués aux performances de 28 enfants au cours de 6 tâches de conservation. Les enfants discordants avaient des résultats significativement moins bons que les enfants concordants pour les deux indicateurs de cohérence. Donc, les enfants qui produisaient souvent des discordances entre geste et parole dans leurs explications d'un concept exhibaient en général d'autres formes d'incohérence par rapport aux systèmes explicatifs qu'ils utilisaient pour justifier leurs croyances sur ce concept.

La deuxième étude visait à déterminer si cette incohérence reflète des connaissances en transition rendues opérationnelles par une receptivité accrue à l'apprentissage. Après avoir été testés au préalable sur 6 tâches de conservation, 52 enfants ont été soumis à un entrainement sur la conservation. Un test ultérieur sur ces 6 mêmes tâches a montré que les enfants discordants faisaient plus de progrès que les enfants concordants. La discordance entre geste et parole semble donc être un indicateur utile à la fois de la cohérence du système explicatif qui sous-tend la compréhension d'un concept et de la réceptivité à l'apprentissage du concept.