JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1990, 53, 21-31 NUMBER 1 (JANUARY)

# TEMPORAL DIFFERENTIATION OF RESPONSE DURATION IN CHILDREN OF DIFFERENT AGES: DEVELOPMENTAL CHANGES IN RELATIONS BETWEEN VERBAL AND NONVERBAL BEHAVIOR

V. POUTHAS, S. DROIT, A.-Y. JACQUET, AND J. H. WEARDEN

LABORATOIRE DE PSYCHOBIOLOGIE DE L'ENFANT (C.N.R.S.) AND UNIVERSITY OF MANCHESTER

Children aged 4.5, 7, or 11 years received an experimental session in which a contingency was placed on button-press duration. Each discrete trial was followed by a brief verbal probe asking a question about the contingency requirement. Other groups of children received an identical task followed by a postexperimental interview. Level of adaptation to the duration contingency tended to increase with age in subjects receiving posttrial verbal probes, but not for those who were interviewed. Eleven-year-olds in the verbal probe condition showed a strong correlation between accurate temporal differentiation and number of verbalizations relating to response duration or timing. The younger subjects, with one exception, showed no association between timing-related verbalizations (which were almost totally absent) and response duration differentiation. This developmental difference occurred even though the younger subjects verbalized after almost every trial. The results suggest that although 11-year-old children apparently produce rule-governed behavior under verbal control as adults do, the behavior of younger children may be controlled directly by reinforcement contingencies even when their verbal repertoires are highly developed.

*Key words:* temporal differentiation, verbal behavior, response duration, button press, children

A number of recent experiments have been concerned with relations between verbal and nonverbal behavior on operant tasks (e.g., Catania, Matthews, & Shimoff, 1982; Lowe, Beasty, & Bentall, 1983), and some arguments in the recent literature have been paralleled in discussion published 20 or more years ago on "conditioning without awareness" (see review by Spielberger & DeNike, 1966). One of the most problematical issues that arises in both sorts of studies is how relations between nonverbal behavior in experimental sessions and measures of verbal behavior (e.g., as revealed by the contents of postexperimental questionnaires—Lippman & Meyer, 1967; for a more recent example see Wearden & Shimp, 1985) should be interpreted. Two theoretically distinct positions have been advanced. The first, "verbal control" (often labeled "cognitive"; Spielberger & DeNike, 1966), proposes that verbal or cognitive changes precede changes in nonverbal behavior, which is generally under the control of verbally expressible rules. The second (labeled "epiphenomenalist" by Wearden, 1988) postulates that nonverbal behavior can change under the direct control of reinforcement contingencies, but that subjects are able to make deductions, a posteriori, from relations they have observed between their nonverbal actions and other events and can express these in postexperimental questionnaires. According to this view, strong relations between verbal and nonverbal behavior may be discovered even though verbal behavior plays no causal role in determining nonverbal operant responding. It should be acknowledged that these possibilities do not exhaust the list of all the different theoretical relations that have been proposed to hold between verbal and nonverbal behavior (see Spielberger & DeNike, 1966, for others).

How can the verbal control and epiphenomenalist positions be distinguished? One possibility (discussed by Wearden & Shimp, 1985) is to use very frequent verbal probes during operant learning sessions to discover the temporal relations between nonverbal and verbal behavior changes. Wearden (1988) described data collected from normal adults using this technique that strongly suggested that changes in verbal behavior were both necessary for, and temporally prior to, adaptation to a response latency differentiation contingency (e.g., see Figures 10.3 and 10.4 in Wearden, 1988). For

The work reported in this article developed out of contacts supported by Twinning Grant 86/45 from the European Science Foundation. Reprints can be obtained from V. Pouthas, Laboratoire de Psychobiologie de l'Enfant, Ecole Pratique des Hautes Etudes, C.N.R.S., 41, rue Gay-Lussac, 75005 Paris, France.

example, almost all subjects produced response latencies closer to a "target" time (which was 2, 4, or 8 s) in the five trials after they produced their first verbalization relating to timing or waiting than in the five trials before such a verbalization. A study using postexperimental questionnaires (Wearden & Shimp, 1985) likewise found that accurate temporal differentiation of responding was associated with verbalizations relating to timing or waiting, but, of course, results from postexperimental questionnaires cannot provide reliable information about the time course of verbal and nonverbal behavior changes during a learning session. Overall, these types of results suggest that, at least in adults, verbal behavior emitted during operant learning sessions plays a causal, rather than noncausal or commentating, role in the determination of action. Such a conclusion is in line with the effects of instructions on behavior (e.g., Buskist, Bennett, & Miller, 1981), in which verbal stimuli can be shown to have powerful effects on the nonverbal behavior that follows them, and with the results of attempts to manipulate the verbal behavior emitted during learning sessions in such experiments as those of Catania et al. (1982). In general, all these lines of evidence suggest that the operant behavior of normal adults in the operant laboratory is often governed by verbally specifiable rules that exert control over nonverbal behavior.

It is obvious, however, that verbal control of behavior cannot be manifested at all levels of development. Preverbal children (e.g., Bentall, Lowe, & Beasty, 1985; Lowe et al., 1983) cannot, by definition, use verbally expressible rules to control their own performance, and it has been suggested that in the absence of such verbal control their behavior is under the direct response-shaping effects of reinforcement contingencies in the same way as is the behavior of nonhumans. Evidence for this comes from the result that the behavior of preverbal children under fixed-interval reinforcement schedules exhibits nonhuman-like features such as within-interval scalloping and sensitivity to the fixed-interval parameter (Lowe et al., 1983). One possible conclusion from this research is that the change from nonhuman-like contingency-shaped behavior to adult-like rule-governed behavior is precisely mirrored by the development of speech, possibly even in an all-or-none fashion such that if children are verbal they show rule-governed behavior under verbal control and if they are pre-verbal they do not and behavior is shaped directly by reinforcement contingencies (see discussion in Bentall et al., 1985, pp. 177–178). However, some evidence exists that verbal and nonverbal behavior may be dissociated to some extent even in children who are well past the preverbal stage.

For example, Pouthas and Jacquet (1987) tested 4.5-year-olds under a differential-reinforcement-of-low-rate (DRL) schedule and found that some subjects were able to adjust their behavior precisely to the schedule requirement but were not able to explain "the rule of the game." Pouthas and Jacquet suggested that 4.5-year-old children did not yet possess the cognitive tools necessary to construct abstract representations of time intervals having a beginning and an end, and were not able to provide explicit rules of action. In more behavior-analytic language, the controlling relation between verbal and nonverbal behavior that would be normal in adults had not yet developed. As a result, the children's behavior was shaped directly by the reinforcement contingencies themselves and was not rule governed.

The present study investigated the development of relations between verbal and nonverbal behavior during learning in children of different ages. Given the results of previous studies, it seemed likely that developmental changes in relations between verbal and nonverbal behavior might be most clearly manifested in comparisons of children of 4.5, 7, and 11 years, and these ages were used here. For all subjects the nonverbal operant response involved temporal differentiation of the duration of a single button press, a modification of the discrete-trial latency differentiation technique used with adults by Wearden (1988). After each trial, subjects in the principal experimental condition received a verbal probe intended to elicit verbalizations concerning contingency requirements. The experiment thus obtained within-session verbal and nonverbal behavior and employed systematic collection of verbal data, rather than the more casual observational methods sometimes used in studies of verbal behavior in children (see some criticisms by Perone, Galizio, & Baron, 1988, for example). In addition, a control condition used with another three groups of subjects of different ages, for whom an identical temporal differentiation contingency was applied, obtained verbal behavior only at the end of the experimental session by means of an interview. This condition could not, of course, provide any information about verbal behavior during response duration training but, by comparison with results from subjects in the experimental condition, might illustrate the effects on response duration of repeated posttrial verbal probing (e.g., the possibility that posttrial probing may suggest that subjects search for the "solution to a problem" when they would not spontaneously do so, and consequently induce behavioral change).

## METHOD

### *Subjects*

Eighteen 4.5-year-olds (9 male and 9 female), 20 7-year-olds (9 male and 11 female), and 20 11-year-olds (10 male and 10 female) were recruited from nursery schools (4.5 years) or primary schools (7 and 11 years) in the Paris region.

### *Apparatus*

Each subject sat at a table on which a white box containing a telegraph key had been placed. A large red button was mounted on the key, and when this was pressed a small red light on the face of the box lit up and remained on until the key was released. The button-press duration was recorded on a noiseless clock that the subject could not see. For children in the two youngest groups posttrial feedback (see below) was accompanied by presentations of one of three clowns. The clowns were drawn on heavy-duty cards, in color, and differed only in facial expression; one was laughing, one had a serious neutral expression, and the third was crying.

### *Procedure*

After having introduced the child into the experimental room, the experimenter gave the instructions which are translated literally below:

*4.5- and 7-year-olds.* "You are going to learn to play with this red button. You will be able to try several times. When you have finished your try the clown will tell you if it was very very good [the child was then shown the laughing clown], if it was moderately good [the child was shown the serious clown], or if it wasn't good at all [the child was shown the crying clown]."

*11-year-olds.* The experimenter did not show the subject the clowns, but instead only said "After each trial, you will be told if it was very very good, moderately good, or not good at all."

The experimental session consisted of 40 discrete trials. The target response duration used for all subjects was 5 s. This value was chosen because it has often been utilized in studies of operant conditioning in children using DRL schedules (Pouthas & Jacquet, 1987; Stein & Landis, 1978) and temporal differentiation of response duration (Macar & Grondin, 1988). The feedback arranged for responses of different durations was as follows: durations of 4.0 to 6.0 s, "very very good"; durations of 2.5 to 4.0 s and 6.0 to 7.5 s, "moderately good"; and duration less than 2.5 s or more than 7.5 s, "not good at all." The experimenter stopped the trial when the response duration reached 10 s.

The subjects were arbitrarily assigned to one of two groups at each age level that differed only in the way verbal data were collected. In the probe condition, subjects received a verbal probe after each trial from an experimenter who always posed the same question, with as far as possible the same intonation. The question was: "What did you have to do to get very very good?" Subjects were allowed 30 s to produce their verbal responses, which were recorded by an observer. From the point of view of the subject, the observer appeared to play no role in the "game" (never looking at the subject and appearing to be engrossed in another task). Thus, the observer did not interfere with the verbal behavior of the subject, nor did the observer have anything more than a partial knowledge of the performance occurring on the trial preceding the verbalization. For example, the observer did not know whether feedback events "moderately good" or "not good at all" followed response durations that were too short or too long.

In the interview condition, subjects were interviewed at the end of the experimental session and were asked the following questions: "What did you have to do to get very very good [or the laughing clown for the younger children]? How did you play? Was the game easy?

Why did you get moderately good or very very good?"

In both conditions experimental trials were separated by 30 s, and when this interval elapsed the experimenter told the child, "You can play." In all conditions the experimenter and the observer were present throughout the experimental session, and all instructions and feedback were delivered verbally.

## RESULTS

Figure 1 shows four different ways of summarizing the nonverbal performance of the different age groups in the probe and interview conditions. The upper two panels show the mean and median number of successful responses, shown as a function of subject age in both the probe and interview conditions. Here, and elsewhere in this article, *successful* responses are defined as those receiving "moderately good" or "very very good" evaluations. Analyses in terms of both means and medians suggest two conclusions: first, that temporal differentiation performance tended to become more accurate with increasing age in the probe condition, and second, that overall performance conformed more accurately to contingency requirements in probe than in interview conditions.

The lower two panels of Figure 1 support the same conclusion in a rather different way. The left panel shows the percentage of subjects in each group producing 50% or more successful responses during the session; that is, the proportion of subjects who exhibited some degree of adaptation to the temporal differentiation contingency. The right panel shows the proportion of subjects who produced 10% or fewer successful responses; that is, subjects showing little or no temporal differentiation. Overall, tendencies for temporal differentiation performance to improve with age and better performance in probe than in interview conditions are evident. Note, however, that the lower two panels of Figure 1 illustrate a strong tendency towards bimodality in within-group temporal differentiation. All groups, including the 11-year-old probe condition group, contained a substantial proportion of subjects whose temporal differentiation was very poor. On the other hand, all groups, including the 4.5-year-olds in the interview condition, contained some subjects who showed accurate behavioral adjustment to the contingency. This bimodality of temporal differentiation performance precluded any meaningful statistical analysis of group data, even with nonparametric tests, in spite of the fact that the various summary measures presented in Figure 1 (as well as individual subject data to be discussed later) all suggest overall probe/interview differences and a marked trend with age in the probe condition.

To assess relations between verbal and nonverbal behavior, a detailed analysis was carried out on the trial-by-trial verbalizations produced by subjects in the probe condition. Verbalizations were grouped into 13 categories, which permitted an exhaustive classification of the verbalizations produced by children in all three age groups. Table 1 shows the verbalization categories and gives examples, translated from French, of each.

Category 1 was used when no verbalizations were produced (which occurred on 4% of trials for the 4.5-year-olds, 6% for the 7-year-olds, and 4% for the 11-year-olds), Categories 11, 12, and 13 expressed verbalizations related to duration (and will be referred to as timing categories below, see also Wearden, 1988). The other categories are self-explanatory. Figure 2 shows a general relation holding between verbal and nonverbal behavior in subjects of different ages by plotting the number of successful responses against the number of verbalizations in timing categories for individual subjects. A maximum score of 40 was possible for both measures.

The results in Figure 2 show a clear developmental trend in relations between verbal and nonverbal behavior on the response duration differentiation task. Consider first data from the 11-year-old subjects, shown in the lowest panel of Figure 2. From these it is clear that there was a strong association during the experimental session between timing verbalizations and successful temporal differentiation. Subjects whose behavior was clearly adjusted to the contingency requirement all produced a large number of verbalizations in timing categories; those whose temporal differentiation performance was poorer produced fewer or no timing verbalizations.

As shown in the upper two panels of Figure 2, the relations between verbal and nonverbal behavior in the 4.5- and 7-year-old subjects apparently were completely different from

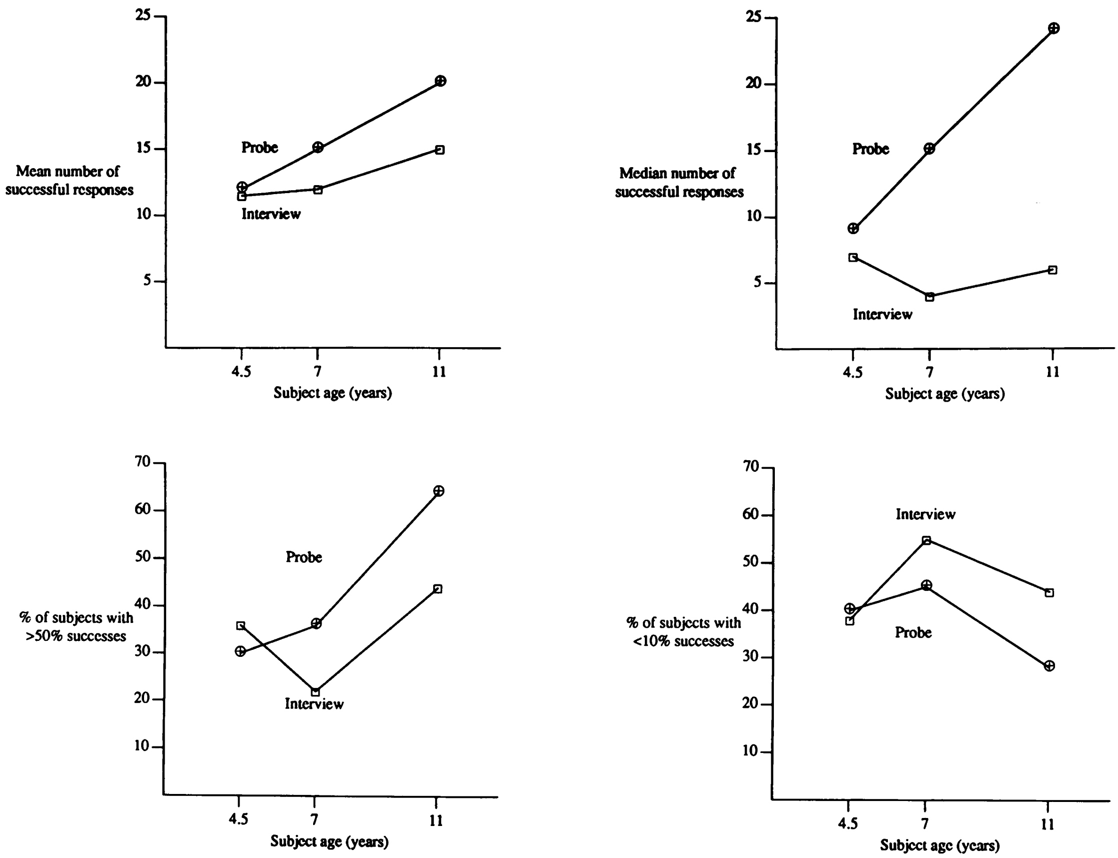


Fig. 1. Summary of nonverbal behavior produced by the different groups as a function of age. Upper left panel shows mean number of successful responses for each group; upper right shows group medians. Lower left panel shows proportion of subjects with 50% or more successful responses during the experimental session; lower right panel shows proportion of subjects with 10% or fewer successful responses. Circles show data from the probe condition; squares data from the interview condition.

those obtained from the 11-year-old group, as timing verbalizations were almost totally absent (with the exception of those from AU in the 7-year-old group). Subject AU said "I count to 10 . . . ," but in spite of having this constant verbalization exhibited performance fluctuations between the "very very good" and "moderately good" ranges. It appeared that this subject varied the rate of counting as a consequence of the evaluation received for the response duration on the previous trial, but this behavior was never described in a verbalization. The other younger subjects did not produce any verbalizations relating to temporal features of the task. There were, however, some consistent differences in the verbalizations produced at the two younger ages. For example, the 4.5-year-olds tended to use the simple rule "press on the button," whereas the 7-year-olds described more complex rules, often relating to the force with which the button was pressed (Category 8). In pressing harder or less hard, the subjects varied the duration of their button presses without any timing-related verbalizations.

One obvious question that arises is whether the timing verbalizations of 11-year-olds played a causal role in determination of nonverbal behavior or whether they were "rules of action" deduced a posteriori on the basis of the subject's observation of his or her performance. Table 2 attempts to address this question by describing trial-by-trial changes in button-press duration and verbalizations from subjects in the 11-year-old group who produced 50% or more successful response during the experi-

Table 1

Description of, and examples from, verbalization categories. The impersonal French construction that expresses necessity (il faut) is translated as "you must."

| Category | Example of verbalization |
|---|---|
| 1. No verbalization | |
| 2. No idea/don't know | I don't know; I've no idea; I'm going to try |
| 3. Repetition of consequence | You must have the laughing clown; you must win |
| 4. Verbalization without any relation to the task | You must call; you must catch a red fish |
| 5. Press the button | You must press the button |
| 6. Manipulation of button | You must turn the button to the right/left; you must pull the button up |
| 7. Localization of response | You must press on the middle/side of the button |
| 8. Response force | You must press hard/very hard/less hard |
| 9. Response sequences | You must press so many times with the left hand and so many times with the right hand |
| 10. Repeated responses | You must press several times on the button; press a (specified) number of times |
| 11. Response duration | You must press for a while on the button; press as long as possible |
| 12. Limited response duration | You must press for a while but not too long |
| 12+/12−. | Hold the button down for longer/less long than on the previous trial |
| 13. Chronometric counting | You must count up to *n* (specified) |

mental session. Support for the hypothesis that verbal behavior played some controlling role in determining nonverbal actions would come from the finding that verbalizations in timing categories temporally preceded changes in button-press duration (cf. Wearden, 1988, Figures 10.3 and 10.4, for comparable data from adults), whereas the opposite temporal relation between verbalizations and nonverbal behavior would suggest that verbalizations were epiphenomenal.

The data in Table 2 come from the trials preceding the trial after which the first timing-related verbalization (Categories 11, 12, or 13) was emitted and from the 10 trials following this verbalization. Also shown are response durations and verbalizations from the last five trials of the experimental session.

For all subjects whose data are shown in Table 2, it appeared that the formulation of a rule relating to response duration (Categories 11 and 12) appeared in the course of the first 10 trials and preceded a modification of response duration. The use of a timing verbalization immediately followed by accurate adjustment of nonverbal behavior was shown by RO, who emitted a timing-related verbalization after Trial 5 and then produced accurately adjusted nonverbal behavior on most subsequent trials (as well as timing-related verbalizations). For most other subjects, adoption of verbalizations in timing-related categories preceded consistently accurate nonverbal adjustment of performance by a number of trials (e.g., AL, GO, LI). There was no evidence of accurate temporal differentiation of nonverbal behavior followed by the use of verbalizations in timing-related categories.

Another trend that was usually present in relations between verbalizations and nonverbal behavior was that the evolution of response duration towards the "very very good" duration was often controlled by more and more precise verbalizations about the duration of the button press. First, subjects verbalized that it was necessary to wait a certain time (Category 11), then, as a result of receiving "moderately good" and sometimes "very very good" feedback, their verbalization changed to express the rule "press for a time, but not too long or too short." Some subjects stated that they had to press for a longer or shorter time than on the preceding trial (classified as Categories 12+ for press longer, or 12− for press shorter; e.g., AL in Table 2). In other words, Category 11 verbalizations, where they occurred, usually preceded Category 12 responses, which in turn preceded Category 13 (chronometric counting). Such a sequence suggests a progressive refinement, or even shaping, of verbalizations more and more precisely adjusted to the contingency requirements. The final performance of 3 subjects was associated with a chronometric counting rule (Category 13; see data from the last five trials for AL, RO, and AN). The temporal differentiation performance of

4 other subjects (GO, LI, GE, and JU), who produced a verbalization relating to response duration but did not consistently count, was more variable than that of subjects who produced counting verbalizations. One subject (GE) resembled the others in originally acquiring good temporal differentiation of responding after adoption of timing-related verbalizations (see *v* values, Trials 6 to 14, in Table 2), but appeared later to be able to perform well on the task without such verbalizations (see data from the last five trials).

The data of some subjects suggested that production of successful responses tended to occur in an all-or-none fashion. One way of illustrating this is to calculate the proportion of successful responses occurring in the trials after the first successful response. If the shift to accurate adjustment of behavior was all-or-none, this calculation should produce a value of 1.0. The values actually obtained from the subjects whose data are shown in Table 2 were .81 (AL), .97 (RO), .76 (AN), .69 (GO), .92 (LI), .91 (GE), and .60 (JU).

There was a clear developmental trend in verbal behavior of subjects who were unsuccessful on the task and whose temporal differentiation performance was poor. The 4.5-year-old children often did not give any rule, frequently saying that they did not know or describing the consequences of pressing (Category 3). On the other hand, the majority of unsuccessful subjects in the two older groups expressed and applied incorrect rules (usually in Categories 6 and 10). However, there was a difference between the two older groups. The 7-year-olds adopted, from the earliest trials of the experiment, a rule with which they persisted even though it was associated with negative evaluations of temporal differentiation performance. In contrast, 11-year-old subjects produced a number of different, and frequently changing, verbalizations, and although verbalizations in timing categories were used, these were abandoned rapidly when the response durations which followed them did →

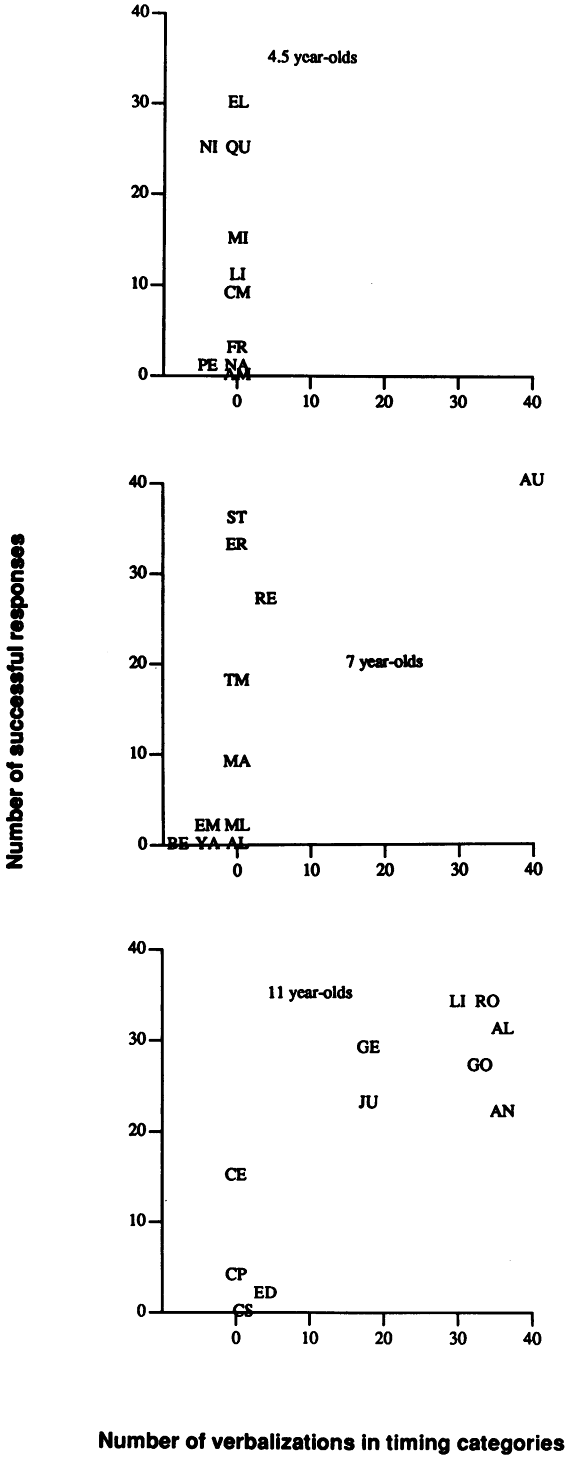


Fig. 2. Number of successful responses plotted against number of verbalizations in timing categories (11, 12, and 13 in Table 1) for individual subjects who are identified by initials (e.g., Subject EL, upper panel). Maximum value for both measures is 40. Upper panel shows data from 4.5-year-olds, center panel 7-year-olds, lowest panel 11-year-olds. All subjects were in the probe condition. Some subjects who produced zero timing-related verbalizations tied with others in number of successful responses, so their data points have been displaced below zero for clarity (e.g., NI in upper panel).

Table 2

Response durations (*d*, value in seconds) and verbalization categories (*v*) on selected trials for 11-year-old subjects in the probe condition who produced 50% or more successful responses (*d* = 2.5–7.5 s) during the session. Trial numbers (*t*) correspond to the response durations; the indicated verbalizations directly followed these trials. Data come from the five trials (where five were available) preceding the trial that was followed by a verbalization in a timing category (11, 12, or 13) and from the 10 trials following this verbalization. The trial that was followed by the first timing verbalization is underlined. Also shown are response durations and verbalization categories for the last five trials of the session.

| AL | | | RO | | | AN | | | GO | | | LI | | | GE | | | JU | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *t* | *d* | *v* | *t* | *d* | *v* | *t* | *d* | *v* | *t* | *d* | *v* | *t* | *d* | *v* | *t* | *d* | *v* | *t* | *d* | *v* |
| 1 | 1.7 | 5 | 1 | 2 | 8 | 1 | 1.8 | 12− | 1 | 1.1 | 11 | 1 | 10.0 | 5 | 1 | 0.6 | 10 | 1 | 6.6 | 4 |
| 2 | 0.7 | 11 | 2 | 1.1 | 8 | 2 | 0.8 | 12 | 2 | 2.6 | 10 | 2 | 0.4 | 11 | 2 | 0.6 | 5 | 2 | 0.8 | 12 |
| 3 | 3.6 | 12 | 3 | 2 | 10 | 3 | 0.9 | 12 | 3 | 0.5 | 12 | 3 | 10.0 | 2 | 3 | 0.4 | 5 | 3 | 9.0 | 12 |
| 4 | 6.1 | 4 | 4 | 0.8 | 10 | 4 | 1.9 | 11 | 4 | 3.7 | 12 | 4 | 2.5 | 12 | 4 | 0.4 | 5 | 4 | 1.6 | 10 |
| 5 | 0.7 | 2 | 5 | 1.3 | 11 | 5 | 0.5 | 1 | 5 | 3.8 | 4 | 5 | 1.9 | 12 | 5 | 0.3 | 5 | 5 | 1.5 | 6 |
| 6 | 7.6 | 1 | 6 | 4.2 | 11 | 6 | 1.9 | 1 | 6 | 4.0 | 5 | 6 | 4.6 | 2 | 6 | 0.9 | 11 | 6 | 3.5 | 4 |
| 7 | 2 | 11 | 7 | 4.4 | 8 | 7 | 0.8 | 1 | 7 | 5.9 | 11 | 7 | 4.3 | 2 | 7 | 1.3 | 11 | 7 | 6.9 | 11 |
| 8 | 10 | 12− | 8 | 4.4 | 10 | 8 | 1.9 | 5 | 8 | 5.8 | 11 | 8 | 2.7 | 2 | 8 | 0.6 | 11 | 8 | 7.5 | 12 |
| 9 | 7.8 | 12− | 9 | 4.4 | 11 | 9 | 1.4 | 12 | 9 | 10.0 | 11 | 9 | 2.4 | 2 | 9 | 2.5 | 12 | 9 | 10 | 11 |
| 10 | 2.7 | 12+ | 10 | 4.8 | 11 | 10 | 0.6 | 12 | 10 | 4.6 | 11 | 10 | 4.1 | 8 | 10 | 3.5 | 11 | 10 | 3.5 | 12 |
| 11 | 3.6 | 12+ | 11 | 3.3 | 12 | 11 | 1.6 | 11 | 11 | 4.2 | 12 | 11 | 3.0 | 2 | 11 | 10.0 | 10 | 11 | 4.6 | 8 |
| 12 | 4.8 | 13 | 12 | 4.5 | 11 | | | | | | | 12 | 4.0 | 2 | 12 | 1.2 | 10 | 12 | 4.9 | 4 |
| | | | 13 | 5 | 11 | | | | | | | | | | 13 | 1.7 | 11 | | | |
| | | | 14 | 6.4 | 12 | | | | | | | | | | 14 | 5.1 | 13 | | | |
| | | | 15 | 4.6 | 11 | | | | | | | | | | 15 | 3.4 | 13 | | | |
| | | | | | | | | | | | | | | | 16 | 2.9 | 13 | | | |
| 36 | 5.2 | 13 | 36 | 8.1 | 12 | 36 | 4.9 | 13 | 36 | 7.8 | 11 | 36 | 7.0 | 2 | 36 | 4.0 | 2 | 36 | 1.6 | 11 |
| 37 | 5.5 | 13 | 37 | 4.9 | 13 | 37 | 5.1 | 13 | 37 | 10 | 12 | 37 | 7.2 | 12 | 37 | 3.8 | 4 | 37 | 3.1 | 8 |
| 38 | 5.1 | 13 | 38 | 4.9 | 13 | 38 | 4.9 | 13 | 38 | 7.2 | 12 | 38 | 9.8 | 12 | 38 | 4.1 | 2 | 38 | 6.2 | 4 |
| 39 | 5.3 | 13 | 39 | 5.4 | 13 | 39 | 5.4 | 13 | 39 | 5.6 | 12 | 39 | 4.0 | 12 | 39 | 3.7 | 2 | 39 | 2.2 | 12 |
| 40 | 4.9 | 13 | 40 | 6.1 | 13 | 40 | 5.7 | 13 | 40 | 5.1 | 12 | 40 | 4.6 | 12 | 40 | 4.0 | 2 | 40 | 5.6 | 11 |

not produce "very very good" evaluations (for similar results from adult subjects see Wearden, 1988, Figure 10.3).

Table 3 shows, for each subject in the interview condition, the number of successful responses as well as the verbalization category (or categories, if there were more than one) for the subject's reply to the first question of the interview ("What did you have to do to get very very good?").

Table 3

Number of successful responses in the experimental session (*N*, maximum = 40) and verbalization category or categories (*v*, see Table 1 for details) of verbal responses produced after the session for subjects in the interview groups. S = subject number.

| Subject age (years) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 4.5 | | | 7 | | | 11 | | |
| S | *N* | *v* | S | *N* | *v* | S | *N* | *v* |
| 1 | 30 | 8, 11 | 1 | 32 | 13 | 1 | 32 | 13 |
| 2 | 21 | 8 | 2 | 37 | 13 | 2 | 37 | 13 |
| 3 | 24 | 12 | 3 | 16 | 6 | 3 | 29 | 13 |
| 4 | 3 | 5 | 4 | 4 | 7 | 4 | 31 | 6, 8 |
| 5 | 8 | 5 | 5 | 13 | 7 | 5 | 6 | 8 |
| 6 | 6 | 1 | 6 | 2 | 6 | 6 | 0 | 6, 7, 8 |
| 7 | 2 | 2 | 7 | 0 | 5 | 7 | 0 | 2 |
| 8 | 0 | 5 | 8 | 4 | 7 | 8 | 0 | 7 |
| | | | 9 | 0 | 5 | 9 | 0 | 7 |

Three 4.5-year-olds in the interview condition produced more than 50% successful responses during the experimental session. Of these, Subject 3 produced a timing verbalization during the interview, and the other two produced a verbalization relating to response force (Category 8), although Subject 1 also produced a timing verbalization. The other subjects, who produced far fewer successful responses, generally verbalized in Categories 1, 2, and 5.

Two 7-year-olds who produced more than 50% successful responses gave a chronometric counting verbalization (Category 13) during the interview. The other subjects, who produced fewer successful responses, gave verbalizations relating to manipulation of the button (Category 6), localization of responding on the button (Category 7), or simple repetition of consequence (Category 5).

Results from the 11-year-olds were very similar, with one exception. Subjects 1, 2, and 3, who produced a large number of successful responses, verbalized a chronometric counting rule. Unsuccessful subjects (5 to 9) generally verbalized about response force or localization of response (Categories 7 and 8). Subject 4 presents an apparent exception to the association in 11-year-olds between successful performance and timing-related verbalizations; this subject produced a large number of successful responses and verbalizations in Categories 6 (manipulation of button) and 8 (response force). However, this subject's nonverbal performance was actually somewhat different from that of the other successful responders in the group, as most of the successful responses fell into the "moderately good" category (21/31). For the other subjects (1, 2, and 3) who had chronometric counting verbalizations, most successful responses fell into the "very very good" category (e.g., 21/32 for Subject 1; 29/37 for Subject 2; 22/29 for Subject 3). It is therefore clear that the quality of temporal differentiation of responding in Subject 4 was inferior to that of other successful subjects in this group.

## DISCUSSION

The present experiment provides strong evidence of developmental differences in relations between verbal and nonverbal behavior during operant learning. It appears that only in 11-year-old children (and the exceptional 7-year-old, AU) is there a strong association between successful performance on our temporal differentiation schedule and the use of verbalizations that relate to temporal features of the task. In the younger children, on the other hand, successful temporal differentiation appears possible even without such timing verbalizations. In general, although there are hints of changes in temporal differentiation performance with age (at least for subjects in the probe condition, see Figure 1), it is the relations between verbal and nonverbal behavior occurring during learning sessions that show the most dramatic developmental change (Figure 2).

It is important to dismiss one trivial explanation of the age-related differences in relations between verbal and nonverbal behavior, namely that the younger children produced far fewer verbalizations of any sort than the older ones. This interpretation is not supported by the number of trials without any posttrial verbalization, which was very small (4 or 6%) and differed little at the three different ages. It is therefore clear that the absence of timing verbalizations in the two younger groups was not due to the absence of verbalizations per se.

Another objection to the claim of differences in relations between verbal and nonverbal behavior in children of different ages might be that the characteristics of the verbal probe given could have been influential in determining the form of the verbalizations produced. It is evident that the type of verbal probe used to elicit verbal behavior can change the verbal behavior produced (see Ericsson & Simon, 1984, for example). However, even though younger subjects might have produced timing-related verbalizations if some other type of verbal probe had been used, there are two reasons why the above results still support developmental changes in verbal/nonverbal behavior relations. The first is that the claim that the "appropriate" type of verbal probe was not used is itself difficult to evaluate directly. If the results from any type of verbal probe administered suggest dissociations between verbal and nonverbal behavior, the objection that the "correct" type of verbal probe had not been used could always be raised (e.g., see discussion in Spielberger & DeNike, 1966). Therefore, acceptance of this objection would make it logically impossible to demonstrate any dissociation between verbal and nonverbal behavior. The second relates to the notion of "self-instruction," the idea that experimental subjects frequently control their own behavior by verbal formulation of rules, even when these are not provided explicitly by the experimenter (see Lowe, 1979; Lowe & Higson, 1981). Although it is true that the verbalizations elicited by the verbal probes might have changed had the type of probe been altered, it seems almost inconceivable that the successfully adapting subjects in the two younger groups could have been making extensive use of self-directed verbalizations relating to temporal features of the task, and yet have shown no evidence of timing-related verbalizations when an explicit question was asked after each trial. Moreover, some of the young subjects often expressed primitive "rules" (such as "press on the button," or variations in force of response) while exhibiting accurate temporal differentiation of the nonverbal response. Thus, at the very least, the present experiment seems to show that temporal differentiation of button-pressing duration can occur in younger children in the absence of self-instructions relating to timing, whether or not verbal behavior relating to temporal requirements of the task would be produced in response to more elaborate verbal probes.

One interpretation of the developmental differences in relations between verbal and nonverbal behavior presented above is that they manifest a developmental shift away from contingency-shaped behavior (the primary mode of adaptation in the younger subjects) towards rule-governed behavior (primarily characteristic of 11-year-olds and adults). Attempts to distinguish contingency-shaped and rule-governed behavior in adult subjects have been problematical, because there has not been unequivocal support for the proposal by Skinner (1969, pp. 150–151) that differences in sensitivity to imposed contingencies distinguishes the two types of behavior, with rule-governed behavior being less sensitive (Shimoff, Matthews, & Catania, 1986). Indeed, as with "conditioning without awareness," convincing demonstrations of contingency-shaped acquisition of conventional operant responses such as button pressing in normal adults have been elusive. One criterion that might be useful for defining contingency-shaped behavior is dissociation between verbal and nonverbal behavior, that is, changes in the rate or patterning of responses in the absence of relevant changes in verbal behavior (see discussion in Shimoff et al., 1986, p. 156). As mentioned above, such dissociations have been found rarely in experiments with adult subjects but seem to have been demonstrated in this article with 4.5- and 7-year-olds. It seems likely that the study of contingency-shaped behavior itself, and in particular the processes involved in shifting from contingency-shaped to rule-governed behavior, can be studied most profitably in a developmental context.

The changes in relations between verbal and nonverbal behavior discovered in our experiment parallel previous results from Kendler and Kendler (1962), who noted similar modification of "modes of learning" in a developmental study of discriminating learning. For example, from the age of 7, children, like adults, learned most rapidly in reversal shift situations, whereas younger children, like nonhumans, performed better on nonreversal shifts. Kendler and Kendler interpreted this type of result in terms of a developmental change from nonmediational, nonhuman-like responding to learning mediated by language; that is, they proposed something similar to a shift from contingency-shaped to rule-governed behavior. However, they noted, as we have, that the mere possession of an extensive verbal repertoire is not sufficient to ensure that behavior is rule-governed, as children up to the age of 7 years obviously possess the verbal means to codify and discriminate stimuli. According to Kendler and Kendler, verbal and nonverbal behavior in younger children constitute two different levels of behavior, which occur simultaneously but are independent, whereas later the two are combined into "horizontal processes" in which they interact to produce verbal control of behavior such as is observed in older children and adults. A somewhat similar view of developmental relations between verbal and nonverbal behavior is given by Luria (1961), who states that language initially functions purely for communication. Later in development it serves to regulate performance while remaining closely linked to the activity being regulated, and finally language becomes to some extent independent of current nonverbal behavior, achieving the status of a tool for problem solving.

In our experiment, we can see data relating to all these ideas. For example, in younger children—the 4.5- and 7-year-olds—nonverbal responding appeared to be mostly nonmediational. Eleven-year-old subjects in the probe condition, on the other hand, appeared to use language to control nonverbal responding and sometimes to express general rules for problem solving in terms of chronometric counting.

The experimental analysis of relations between what human subjects say and what they do on operant tasks has made great strides in recent years (e.g., Bentall et al., 1985; Catania et al., 1982; Hayes, 1986; Lowe et al., 1983). The above results suggest that much still remains to be discovered about how humans learn verbal/nonverbal behavior relations and how they develop the verbal control of nonverbal actions that seems so characteristic of adult performance. The 7-year-old and, to a lesser extent, the 4.5-year-old subjects in our own study obviously possess a verbal repertoire of immense complexity, including a mastery of syntax and idiomatic usage that few nonnative learners of the French language will ever achieve. Nevertheless, relations between what they say and what they do seem distinctly different from those found in older children and adults. Whatever the explanation for the developmental changes in saying and doing found above, it seems likely that further investigation of developmental trends in verbal control of nonverbal performance will throw considerable light on verbal/nonverbal behavior relations at all developmental levels.

## REFERENCES

Bentall, R. P., Lowe, C. F., & Beasty, A. (1985). The role of verbal behavior in human learning: II. Developmental differences. *Journal of the Experimental Analysis of Behavior,* **43,** 165–181.

Buskist, W. F., Bennett, R. H., & Miller, H. L., Jr. (1981). Effect of instructional constraints on human fixed-interval performance. *Journal of the Experimental Analysis of Behavior,* **35,** 217–225.

Catania, A. C., Matthews, B. A., & Shimoff, E. (1982). Instructed versus shaped human verbal behavior: Interactions with nonverbal responding. *Journal of the Experimental Analysis of Behavior,* **38,** 233–248.

Ericcson, A. K., & Simon, H. A. (1984). *Protocol analysis: Verbal reports as data.* Cambridge, MA: MIT Press.

Hayes, S. C. (1986). The case of the silent dog—verbal reports and the analysis of rules: A review of Ericcson and Simon's *Protocol analysis: Verbal reports as data. Journal of the Experimental Analysis of Behavior,* **45,** 351–363.

Kendler, H. H., & Kendler, T. S. (1962). Vertical and horizontal processes in problem solving. *Psychological Review,* **69,** 1–16.

Lippman, L. G., & Meyer, H. E. (1967). Fixed interval performance as related to instructions and to subjects' verbalizations of the contingency. *Psychonomic Science,* **8,** 135–136.

Lowe, C. F. (1979). Determinants of human operant behaviour. In M. D. Zeiler & P. Harzem (Eds.), *Advances in analysis of behaviour: Vol. 1. Reinforcement and the organization of behaviour* (pp. 159–192). Chichester, England: Wiley.

Lowe, C. F., Beasty, A., & Bentall, R. P. (1983). The role of verbal behavior in human learning: Infant performance on fixed-interval schedules. *Journal of the Experimental Analysis of Behavior,* **39,** 157–164.

Lowe, C. F., & Higson, P. J. (1981). Self-instructional training and cognitive behaviour modification: A behavioural analysis. In G. Davey (Ed.), *Applications of conditioning theory* (pp. 162–188). London: Methuen.

Luria, A. R. (1961). *Language and cognition.* New York: Wiley.

Macar, F., & Grondin, S. (1988). Temporal regulation as a function of muscular parameters in 5-year-old children. *Journal of Experimental Child Psychology,* **45,** 159–174.

Perone, M., Galizio, M., & Baron, A. (1988). The relevance of animal-based principles in the laboratory study of human operant conditioning. In G. Davey & C. Cullen (Eds.), *Human operant conditioning and behavior modification* (pp. 59–85). Chichester, England: Wiley.

Pouthas, V., & Jacquet, A.-Y. (1987). A developmental study of timing behavior in 4½- and 7-year-old children. *Journal of Experimental Child Psychology,* **43,** 282–299.

Shimoff, E., Matthews, B. A., & Catania, A. C. (1986). Human operant performance: Sensitivity and pseudosensitivity to contingencies. *Journal of the Experimental Analysis of Behavior,* **46,** 149–157.

Skinner, B. F. (1969). *Contingencies of reinforcement: A theoretical analysis.* New York: Appleton-Century-Crofts.

Spielberger, C. D., & DeNike, L. D. (1966). Descriptive behaviorism versus cognitive theory in verbal operant conditioning. *Psychological Review,* **73,** 306–326.

Stein, N., & Landis, R. (1978). Effects of age and collateral behavior on temporally discriminated performance of children. *Perceptual and Motor Skills,* **47,** 87–94.

Wearden, J. H. (1988). Some neglected problems in the analysis of human operant behavior. In G. Davey & C. Cullen (Eds.), *Human operant conditioning and behavior modification* (pp. 197–224). Chichester, England: Wiley.

Wearden, J. H., & Shimp, C. P. (1985). Local temporal patterning of operant behavior in humans. *Journal of the Experimental Analysis of Behavior,* **44,** 315–324.

*Received July 27, 1988*
*Final acceptance September 3, 1989*