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Language and Hand Preference in Early Development

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Although there is a demonstrated bias toward use of the right hand from birth, the meaning of this bias and its stability over time are unclear. Within a longitudinal study of language development at 13, 20, and 28 months, we extracted information about unimanual and bimanual hand preference from videotapes. Both unimanual and bimanual actions on objects were divided into symbolic (e.g., pretend play) and nonsymbolic (e.g., picking up and putting down). A separate count was made of communicative pointing gestures. Children showed a marked right-hand bias (70%) across categories, a bias that did not differ as a function of age, sex, or unimanual or bimanual type. However, preference for the right hand was stronger for symbolic than for nonsymbolic movements in both unimanual and bimanual activity. At 13 and 28 months, there was a significantly greater right-hand bias in pointing than in any other manual activity. Total right-hand bias at 13 months was significantly correlated with analytic/receptive aspects of language development. The same linear correlation did not hold for hand bias at the later stage (although correlations were stronger for girls). At 20 months there was a significant *nonlinear* relationship between nonsymbolic hand movements and language. This combination of linear and curvilinear patterns, together with the greater hand bias for symbolic communicative activities that are compatible with language, led us to consider the contralateral interference hypothesis of Kinsbourne and Hiscock. A temporary instability in hand bias may reflect increased need to use left-hemisphere resources for language whenever a child enters a new stage of language func-

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tioning. This would lead to "cyclic" patterns of hand preference around major milestones in language, particularly for nonsymbolic actions that compete with language.

Although there is no shortage of speculation on the matter, there is still no convincing explanation for the well-known relationship between language and hand preference in adulthood. We know at the left hemisphere plays a dominant role in language processing for the vast majority of right-handed adults and for most left-handers as well. But we don't know why. For one thing, the relationship is purely statistical: There are just enough exceptions to the rule to suggest that a causal relationship must be indirect at best.

A recent surge in developmental research on hand preference is at least partially motivated by a desire to solve this particular puzzle; researchers are tracking the relationship between language and manual specialization back to its origins (Carlson & Harris, 1983; Gottfried & Bathurst, 1983; Ramsay, 1980; Ramsay, Campos, & Fenson, 1979; Young, Lock, & Service, 1985; Young, Segalowitz, Corter, & Trehub, 1983). So far, however, the developmental evidence has only made things more complicated. Contrary to earlier claims (e.g., Lenneberg, 1967), some form of hand preference seems to be established well before language development begins. Indeed, Ramsay's research suggests that stability in hand bias may in fact decline, at least temporarily, around major milestones in language development: between 7 and 9 months (when most children begin to babble in reduplicative syllables), between 12 and 14 months (with the onset of "first words"), and again around 20 months (when many children first begin to put words together into sentences). In other words, some children seem to cycle in and out of a stable lateral bias around the time when (according to group norms) they are trying to solve a new linguistic problem. If the developmental relationship between language and hand preference is in fact nonlinear, we will need much more sophisticated models and considerably more data to handle the issue.

Kinsbourne and Hiscock (1983) and Liedermann (1983) put forward some new ideas about the dynamic relationship between language and hand movements. These ideas may be useful in explaining such nonlinear developmental relationships. First, Liedermann argued that there is no such thing as a single trait called "handedness." A host of disparate and competing factors may facilitate or inhibit use of the preferred hand at any given moment in time. More specifically, Kinsbourne and Hiscock suggested that overt or covert verbal acitivity can facilitate or inhibit movements of the hand contralateral to the hemisphere that is dominant for language. Inhibition is more likely to occur when the manual acitivity is irrelevant to language processing and therefore competes instead of cooperates in the use of left-hemisphere resources. Facilitation (or, at least, lack of inhibition) is more likely when the manual activity is relevant to the ongoing verbal flow—in writing, in hand gestures used to illustrate a point in conversation, or in a language that is literally carried out with the hands (e.g., American Sign Language; Vaid, Moriarty, & Bellugi, 1984). The direction of the relationship between language and hand bias is determined by this dimension of competition versus compatibility between verbal and manual activity. The magnitude of the effect is presumably a function both of the difficulty of the ongoing verbal process and of the difficulty of the manual activity.

According to this kind of dynamic, quantitative model, we should not expect a simple, linear developmental relationship between language and hand preference. Indeed, we should expect the situation to change from moment to moment depending on the nature and difficulty of the task at hand. However, such a model can be used to explain the kind of large-scale developmental fluctuations observed by Ramsay and others (Ramsay, 1980; Ramsay et al., 1979). Such cycles presumably reflect a phase in development in which particular children experience more than the usual amount of moment-to-moment inhibition from language to hand use. This inhibition is greatest when the children are "in the middle" of a new stage in language acquisition (e.g., first words, first sentences). These are points in development when children struggle with some new aspect of language on a regular basis but are still so inefficient that they must draw heavily on left-hemisphere resources.

In our study, we used this interference–facilitation model as a theoretical framework for a reanalysis of manual activity in a sample of 27 children studied longitudinally at three points in development: 13 months (the average onset for first words), 20 months (the average onset for combinatorial speech), and 28 months (the midpoint in a well-known "burst" in the acquisition of grammatical morphology). Bates, Bretherton, and their colleagues have studied the linguistic and gestural abilities of these children in considerable detail (e.g., Bates, Bretherton, Shore, & McNew, 1983; Bates, Bretherton, & Snyder, in press; Bretherton, McNew, Snyder, & Bates, 1983; Shore, O'Connell, & Bates, 1984; Snyder, Bates, & Bretherton, 1981). In our study, we reanalyzed the same videotapes to examine patterns of hand dominance in both unimanual and bimanual activity to determine how hand preference relates to changes in linguistic/symbolic ability.

Applying the interference model to our longitudinal data, we offer the following predictions:

1. *Overall right-hand bias.* Summarizing across the sample around each of these language milestones, we should find a stable "base rate" of right-hand bias. We have no reason to expect this base rate to change as a function of either age or sex, although individual children will vary in the strength of their hand bias at any point in time.

2. *Differences between symbolic and nonsymbolic manual activity.* If contralateral interference between language and hand use pertains primarily to competing manual activity, then we should see less interference (and hence more right-hand bias) in communicative and/or symbolic gestures. These will include two kinds of activities: symbolic play (i.e., use of the hands in "pretend," in enacting conventional activities associated with cultural objects) and pointing. Both kinds of gestures are arguably "language-like": They are sociocultural conventions used to confer meaning on familiar objects and events and are correlated with the onset of meaningful language in the early stages of development (Bates et al., 1983).

3. *Language-handedness correlations.* Children struggling with a new linguistic problem should give more evidence for contralateral interference with nonsymbolic activity; they should appear "less" right-handed at a given point in time.

4. *Nonlinear relationships between language ability and hand use.* We should expect linear correlations between linguistic ability and hand preference for nonsymbolic material when the fastest children in the group solve the problem and the slowest children struggle to find a solution. However, the same dynamic processes of interference and facilitation could produce nonlinear patterns if, for example, (a) the slowest children at a particular age have not even approached the new problem (e.g., they are not even beginning to tackle first words, first sentences, or grammatical morphology), so that they are in fact more stable in their hand preference; or (b) the fastest children at a particular age have already solved the "modal" problem and have moved on into a new set of linguistic developments that depress their hand preference all over again.

METHOD

Subjects

The sample was comprised of 27 children studied at three age levels: 13, 20, and 28 months. Names of potential subjects were drawn from birth announcements in the local paper. Parents of infants with birth weights greater than 5.5 lb and with addresses reasonably near the university were contacted through an introductory letter describing the project; a follow-up phone call was made a few days later. This technique resulted in a 70% acceptance rate. There were 13 boys and 14 girls. Thirteen children were first-born, 10 were second-born, and 4 were third-born or later. Average birthweight was 7.2 lb, with a range from 5.5 to 9.0. At all sessions, children were within 2 weeks on either side of the target range. Although we did not select subjects systematically on the basis of race or socioeconomic level, the demographic characteristics of Boulder, Colorado are such that these selection criteria resulted in a sample of middle-class to upper-middle-class white children (with the exception of one black child from a middle-class family). This was, then, a very homogeneous and privileged group of children, a fact that of course limits the generalizability of our findings.

Procedure

There were two sessions—one in the home and one in the laboratory—at each age level. Parents were in attendance at all times. Hand use was tabulated from videotapes of three different kinds of situations within the sessions at each age level:

1. Free play between mother and child, with a standard set of laboratory toys including objects that lend themselves easily to symbolic or "pretend" play (e.g., Fischer Price people and toy furniture) and toys that could be used for nonsymbolic activities such as stacking and emptying and filling containers (e.g., nesting cups, a shape box).
2. A "multiple-choice" word-comprehension test in which the child was placed in front of a transparent plastic box with three wells. On each of 16 trials, the child was asked to choose between a "target" and two "distractor" objects placed in the wells in randomized positions.
3. An elicited symbolic play task in which the experimenter modeled three familiar scenarios (e.g., having breakfast) and then turned the props over to the children and encouraged them to imitate the scenario.

Scoring

Unimanual and bimanual actions on objects were coded separately. As defined here, *bimanual* refers to a coordinated, asymmetric activity in which one hand is active while the other serves as a base. Symmetrical bimanual activities (e.g., picking up a doll with both hands) were excluded from these analyses. Reaching or intention movements that did not actually make contact with an object were also excluded, except for the particular case of pointing (defined below).

Within both the unimanual and the bimanual categories, we further distinguished between symbolic and nonsymbolic activities. As defined by Bates et al. (1983), symbolic play gestures included all socially derived, conventional behaviors that confer "meaning" on an associated cultural object: putting a toy telephone receiver to the ear, stirring with a spoon in an empty bowl, hugging a doll to the chest, and so forth. Nonsymbolic behaviors included actions such as picking up a doll, banging on the floor with a spoon, moving the toy telephone from one spot on the floor to another.

Within the set of unimanual behaviors were pointing gestures (defined here as an extension of the index finger toward some object or event of interest). These gestures were counted separately and are not reflected in the unimanual totals.

Interrater reliabilities for hand use categories were tabulated from videotapes for nine children, three randomly selected from each age level. The reliabilities were calculated as follows: 100 × [number of categorization agreements / (number of agreements + number of disagreements)]. The average figure across ages and categories was 89%, ranging from 86% at 13 months to 91% at 20 months. Agreements tended to be somewhat lower for nonsymbolic activities (averaging 82%) than for symbolic activities (averaging 94%) because the beginning and end of a nonsymbolic action are often more difficult to establish. However, disagreements were not biased in favor of right-hand or left-hand classifications (reliability for hand use was 93%) and hence did not affect the results reported here.

Language Measures

To obtain measures of language development, we used parental interviews, observations of free speech and free play, and a supplemental set of much more structured and standardized experimental tasks for eliciting particular linguistic/symbolic behaviors. As discussed in detail in Bates et al. (in press), these individual language measures were used to extract a set of theoretically guided factor scores at each age. At 13 and 20 months, we have not only a principal component score for overall language ability but also a pair of factors that reflects the child's relative reliance on different "modes" or "strategies" in language acquisition: (a) an analytic factor that reflects progress in comprehension and productive use of lexical and/or grammatical forms, and (b) a rote/imitative factor that reflects social uses of language with relatively little understanding of lexical and/or grammatical "rules." In terms of the model presented here, we would expect the analytic factor scores to reflect "deep" processing (i.e., the kind of language processing that presumably makes a demand on left-hemisphere resources and hence that should create maximal interference with use of the dominant hand). At 28 months, these two factors no longer provide a good fit to the data, so that the principal component score is probably a better index of deep linguistic understanding at that age.

RESULTS

Because this is a longitudinal design, the analyses below treat age as a repeated measure. This also means that we were forced to reduce cell size to account for missing data at certain points in the design. The number of children with relevant data at every age dictated the sample size for each analysis, as indicated within the following sections.

Overall Hand Preference

Unimanual Hand Bias

An Age × Sex × Right–Left Hand analysis of variance (ANOVA) was carried out on the total number of unimanual movements observed for each child, collapsing across situations and symbolic–nonsymbolic categories (Figure 1). The sample size in this analysis was 24. There was a significant main effect of age $F(2, 44) = 7.32$, $p < .05$, reflecting the fact that children do more with their hands as they get older. There was also a main effect of right–left hand, $F(1, 22) = 31.94$, $p < .001$, indicating that the children used the right hand more than the left across categories of unimanual activity. No interaction between age and handedness was obtained; that is, there is no variation in the amount of right-hand bias as a function of age. No effects of any kind were associated with sex.

Bimanual Hand Bias

A similar Age × Sex × Right–Left Hand ANOVA was carried out on the total number of bimanual movements in which one hand was dominant, again collapsing across situations and symbolic–nonsymbolic categories

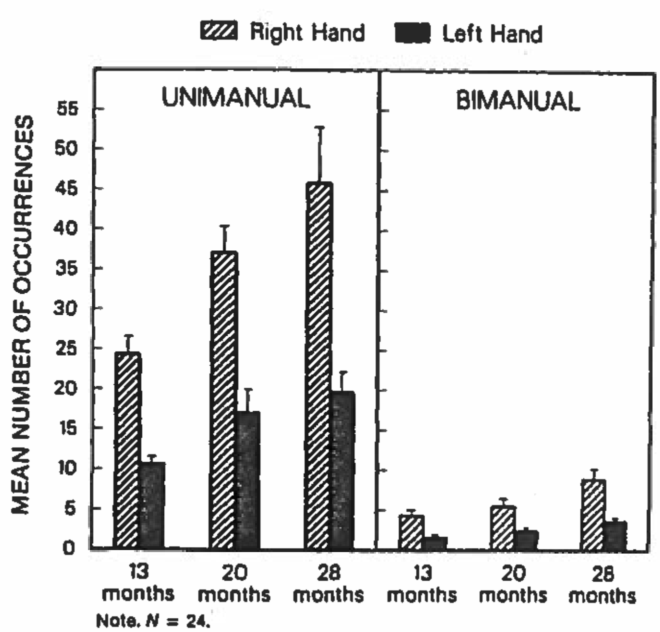

FIG. 1 Asymmetry in overall hand usage.

(Figure 1). Again, the sample size was 24. As in the preceding analysis, there was a main effect of age, $F(2, 44) = 10.34, p < .001$, with total bimanual activity increasing over time. There was also a main effect of hand, $F(1, 22) = 35.23, p < .001$, with significantly more right-dominant actions. There were no effects associated with sex; age and hand bias did not interact. In other words, even though the total amount of bimanual activity increased markedly over time, there was a constant right-hand bias at every age.

Unimanual–Bimanual Comparison

Some investigators have suggested that a right-hand bias may be more evident in bimanual activity insofar as these actions involve greater "planning" and "distribution of labor" between the two hands. We compared the right-hand bias in unimanual and bimanual activity in an Age × Unimanual-Bimanual ANOVA, collapsing over sex. The sample size of 15 for this analysis reflects the number of children with no missing data in any category. Instead of using number of occurrences (as in the above analyses), we used proportion scores to equate unimanual and bimanual activity for the total amount of activity in each category, an amount that was considerably larger for unimanual behaviors. There were no significant effects in this analysis: The proportion of right-hand bias (averaging 70%) was the same at every age and was the same whether the child acted with one hand or two.

Incidence of Right-Hand Bias

Many investigators prefer to look at hand bias as a dichotomous variable: Is the child right-handed or left-handed? From this point of view, use of the right hand was greater than use of the left hand for about 85% of the sample at each age, which corresponds to reports for the adult population. The range in unimanual right-hand proportion scores at each age was as follows: 31% to 92% at 13 months, 53% to 94% at 20 months, 35% to 90% at 28 months. Although some children showed a left-hand preference at one of the three ages, none of the children in this sample was consistently left-handed.

With regard to our first hypothesis, there does indeed seem to be a stable "base rate" bias toward use of the right hand from 13 to 28 months. This bias does not vary as a function of age or sex; in addition, we did not find a difference beween unimanual and bimanual activity in the amount of right-hand bias that children display.

Symbolic and Nonsymbolic Manual Activity and Pointing

Symbolic Play

We already know that the overall amount of symbolic activity displayed by young children increases markedly from 1 to 3 years of age. Hence, in the following analyses, we restricted ourselves entirely to proportion scores. Within each category, the total number of right-hand behaviors was divided by the sum of behaviors with both the left hand and the right hand.

Symbolic versus nonsymbolic activity: Unimanual. We compared the proportion of right-handed unimanual behaviors in symbolic play (e.g., drinking from a toy cup, putting a telephone receiver to the ear) with that of unimanual actions that have no conventional social "meaning" (e.g., picking up a toy cup, moving a toy telephone from one place on the floor to another). Three children who had no entries in one of the relevant categories were dropped from this particular analysis, leaving the sample size at 24. Scores were entered into an Age × Type (i.e., symbolic vs. nonsymbolic) ANOVA. There was no effect of age, and age did not interact significantly with type. There was, however, a main effect of type, $F(1,14) = 13.29, p < .001$: Children were significantly more likely to use their right hand for a unimanual symbolic play activity than for a nonsymbolic action. (See Figure 2.)

Symbolic versus nonsymbolic activity: Bimanual. This was also an Age × Type ANOVA on the proportion of right-dominant bimanual actions. Proportion scores were not calculated for children with no entries in one of the categories; hence, the analysis was based on only 15 children. Again there were no effects associated with age, but there was a significant main effect of type, $F(1,14) = 5.62, p < .05$, with more right-handed action in symbolic play than in nonsymbolic activities (Figure 2).

To summarize, in separate analyses of unimanual and bimanual activity, symbolic acts displayed a significantly greater right-hand bias than non-

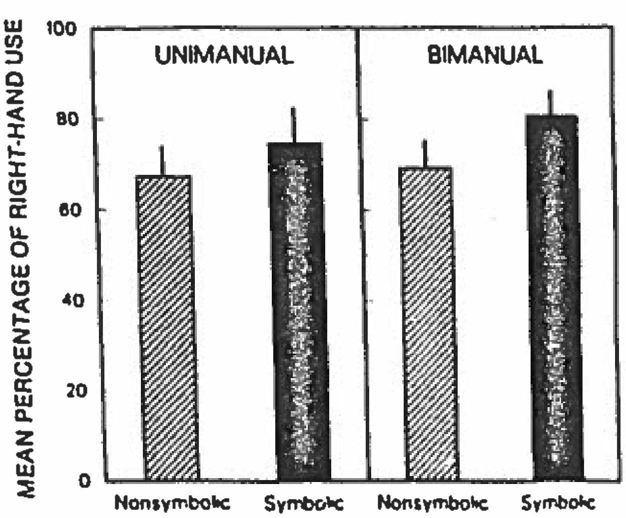

FIG. 2 Right-hand preference as a function of type of hand usage.

symbolic acts. This fits with our prediction that a reduction in right-hand bias will occur for activities that are unrelated to linguistic-symbolic processing. Because these nonsymbolic acts are competing with language for use of left-hemisphere resources, they are more likely to reflect inhibition of use of the right hand.

Pointing

Pointing differs from symbolic play in two respects. It is used more often during direct communication and is almost always compatible with ongoing linguistic activity. For this reason we should expect minimal contralateral interference between language and pointing. However, pointing is also arguably less symbolic than the gestures of pretend play because it is not associated with any particular "content," "meaning," or "referent."

Ten children produced no pointing gestures at all at one or more of the age levels. Hence, right-hand proportion scores could be calculated for only 17 children at all three ages. For these 17 children, we carried out an Age × Type ANOVA on the proportion of right-handedness in pointing, unimanual symbolic play, and unimanual nonsymbolic activity. There was a main effect of type, $F(2, 32) = 6.92, p < .003$, but no main effect of age. This time, however, there was a significant interaction between age and type, $F(4, 64) = 2.80, p < .03$ (Figure 3). Post hoc tests indicated that pointing was significantly more right-biased than the other two categories at 13 and again at 28 months—but not at 20 months. In this analysis, with the reduced sample of 17, the difference between symbolic play and nonsymbolic activity did not reach significance at any age (although the differences at 13 and 28 months were marginal, $p < .10$).

We did not predict the interaction with age and cannot explain it. As several investigators have suggested (e.g., Petitto, 1983), the function of pointing may change from 1 to 3 years of age—with 20 months representing a

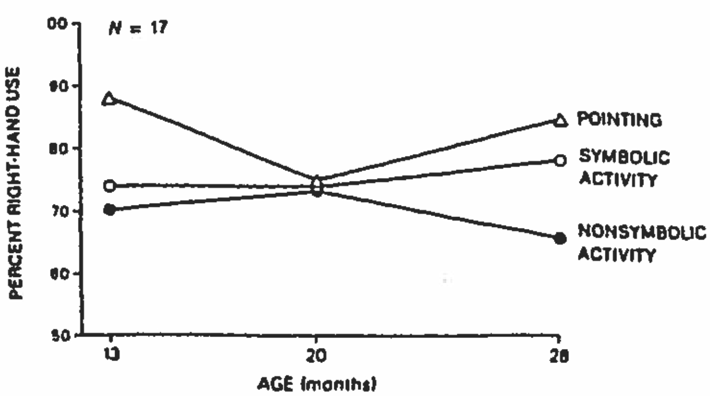

FIG. 3 Right-hand preference as a function of type of hand usage.

TABLE 1
Correlations Between Language and Handedness

	Proportion Right-Hand Bias				
	13 Months				
Language Factors	Overall	Nonsymbolic	Symbolic	20 Months	28 Months
13 months					
Analytic	0.402*	0.325	0.227	0.059	0.223
Rote	0.004	−0.032	0.013	0.284	−0.152
Principal component	0.293	0.215	0.189	0.187	0.017
20 months					
Analytic	0.396*	0.436*	0.046	0.196	0.148
Rote	0.071	0.039	0.075	−0.018	0.096
Principal component	0.403*	0.419*	0.103	0.314	0.130
28 months					
Principal component	0.485*	0.496*	0.109	0.161	0.162

*$p < .05$.

crossover point as children reorganize and reintegrate the relationship between pointing and language. In general, however, the findings for pointing are consonant with the findings for symbolic play: a greater right bias for gestures that are more "language-like" (i.e., for hand movements that are compatible with linguistic processing and hence that do not compete with language for use of left-hemisphere resources).

Correlations Between Language and Handedness

Overall Correlations

Table 1 presents linear correlations between global right-hand bias scores and the language factors at every age. There was a significant relationship between right-hand bias and language ability at 13 months; however, as predicted, this relationship was restricted to the deep analytic factor. This correlation "echoes" from 13-month handedness to analytic language at the later ages as well. We do not find a similar correlation between language and handedness at 20 months or at 28 months.

Correlations Broken Down by Sex

Following Gottfried and Bathurst (1983), we broke the sample down by sex and reran the same correlations. Although the respective samples were now very small, the direction of results was consistent with their findings: positive relationships for both sexes at 13 months; positive relationships only for girls at the later stages. The correlations, however, are too weak ($p < .10$) to warrant further consideration.

13-Month Correlations by Gestural Type

There are now a large number of studies demonstrating a correlational relationship between linguistic ability and both the amount and sophistication of symbolic play from 13 months to 20 months. But this is quite separate from the question of correlations between language ability and degree of handedness in symbolic play. In fact, the interference theory would predict stronger correlations between language level and hand bias in nonsymbolic activity. The basic rationale is: Because symbolic activity is compatible with language it produces no competition and receives no interference. In other words, there should be no dynamic or causal relationship between degree of right-hand bias in symbolic activity and degree of language ability. However, because nonsymbolic activity is very often unrelated to linguistic-symbolic processing, right-handed nonsymbolic acts can produce competition for use of left-hemisphere resources and hence may be subject to interference and suppression by language processing. In other words, there is a dynamic, causal relationship between linguistic processing and nonsymbolic uses of the hands. Hence, if there is a linear correlation between language level and specific categories of hand use, it should involve nonsymbolic activities. Specifically, children who struggle with a new language problem should be more suppressed in right-handed nonsymbolic activities than children who are able to solve the problem.

Correlational analyses by gestural type were consistent with this prediction: There are significant correlations between analytic language and nonsymbolic activity at 13 months, but correlations with a combined score for handedness in pointing and symbolic play hover very close to zero. There are, however, no significant correlations between gesture categories and language ability at the two later ages.

Nonlinearity in Language-Handedness Relations

The relationship between language and handedness is obviously not consistent from one age to another, and the relationship is not terribly strong. Remember, however, that product-moment correlations are sensitive only to linear relationships. The interference theory would predict a host of more subtle (and more fragile) nonlinear effects—depending on how the sample is distributed around a given language milestone at any particular age.

To test for the existence of nonlinear effects, we broke the sample down into fifths or "quintiles" at each age level according to performance on the analytic or deep processing factor at 13 and 20 months and according to performance on the principal component score at 28 months. These groupings were then used as the independent variable in a set of one-way ANOVAs, one at each age, using proportion of nonsymbolic unimanual activity as the dependent variable. With the one-way ANOVA, we could test for the significance of the linear, quadratic, and cubic trends at each age.

At 13 and 28 months, none of the linear or nonlinear effects over quintiles reached significance. However, at 20 months we found a significant quadratic relationship between language level and nonsymbolic hand bias, $F(1, 20) = 5.47, p < .03$ (Figure 4). The highest levels of right-hand use occurred in the middle group—children who are now quite comfortable with two-word speech but who still avoid the problem of grammar. Children at the lowest levels showed the greatest evidence for interference (i.e., the 20-month-olds who still struggled with the problem of stringing two words together). Hand bias dropped again in the higher functioning children who began to launch an assault on the grammar. There is, then, at least some support for the idea that the dynamic relationship between language and hand use is nonlinear, cycling with the difficulty of the language task from the child's point of view at a particular phase in development.

SUMMARY

The results reported here can be summarized briefly as follows:

1. A significant right-hand bias is established by 13 months for both unimanual and bimanual behavior. This baseline bias does not change as a

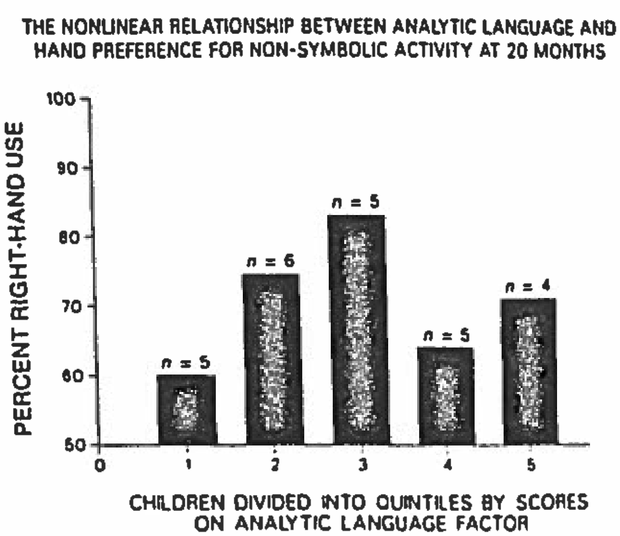

FIG. 4 The nonlinear relationship between analytic language and hand preference for nonsymbolic activity at 20 months.

function of age or sex, although individual children do vary at a given age level.

2. Symbolic play activities show a greater right-hand bias than do nonsymbolic actions in both unimanual and bimanual behavior.

3. Pointing also shows a greater right-hand bias, although the advantage seems to disappear at one age level (i.e., 20 months).

4. There is a significant correlation between language and degree of right-hand bias at 13 months. The relationship pertains primarily to nonsymbolic behaviors in relation to the more analytic aspects of language.

5. Language-handedness correlations are not significant at every age; also, they are not impressively large. A significant nonlinear relationship between language and hand preference at 20 months demonstrates that nonlinear relationships between hand use and language are possible in development—and may be far more common than we know.

These findings are consistent with an interference-facilitation model of the relationship between language and hand use; language interferes with incompatible or irrelevant manual activities that compete for left-hemisphere resources. No such interference occurs when hand use is compatible with language and/or when tasks are too easy to create competition. Apparent "cycles" in hand preference throughout development may reflect increases and decreases in interference with use of the dominant hand as a function of increases and decreases in the difficulty of language processing as the child approaches and subsequently solves each successive problem in language development.

The interference-facilitation model is, however, based on "on-line," real-time dynamic relations between language and hand use. Our data are, instead, summed across many instances of hand use, so that the effects we observe provide only indirect support for the model. We recommend research with larger samples, which would provide more statistical power for an adequate test of the nonlinear relations suggested here at 20 months of age. We also recommend doing more fine-grained studies of the temporal coordination between hand preference and language use (in comprehension or production) to determine how the hypothetical patterns of interference work in real time.

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