A Cost-Effectiveness Analysis of Early Intervention Services in Massachusetts: Implications for Policy

Marji Erickson Warfield
University of Massachusetts Medical Center

This article presents the results of a cost-effectiveness analysis of early intervention services in Massachusetts. The findings indicate that (for a $1,000 investment) children demonstrate different levels of improvement in adaptive behavior and child-mother interaction depending on the severity of their disability and their age of entry into early intervention. Estimates of the number of service hours required to produce maximum gains also varied by outcome measure and child characteristics. Comparisons were made between these estimates and the hours of service received. The implications of these results for policy and future research are discussed.

Part H of the Education of the Handicapped Act Amendments of 1986 (Public Law 99-457) established a discretionary program for states to facilitate the development of comprehensive systems of early intervention services for infants and toddlers with developmental disabilities or delays. Under this statute, early intervention services are mandated for a population of children who vary considerably in terms of the type and severity of their disability (Meisels & Wasik, 1990).

To serve this heterogeneous population, the law requires that an individualized family service plan (IFSP) be developed for each eligible child and family (Education of the Handicapped Act Amendments of 1986). Service providers and the parents of each eligible child are required to work together to determine the specific needs of the child and other family members, set goals, decide on the types and amounts of services necessary to reach those goals, design methods by which to monitor progress, and reformulate the plan periodically as the family's needs change. Thus, early intervention service systems must be able to provide a "broad range of service options, extending from ongoing monitoring and the provision of educational materials to intensive, multidisciplinary team efforts" (Shonkoff & Meisels, 1991, p. 22). Given this amount of variation and limited resources, it is critical for state-level policymakers and directors of early intervention programs to understand how to distribute their resources most efficiently.

Cost-effectiveness analyses are designed to assess the relative efficiency of different interventions. This analytic strategy takes account of both the costs and the effects of different interventions, making it possible to choose the one that either provides the best results for any given amount of resources or minimizes the resources needed for any given outcome (Levin, 1983). The primary goal of this type of analysis is to provide a basis for improving public policy decisions (Barnett, 1986; Levin, 1988).

In general, the cost-effectiveness of any type of intervention is assessed most easily when an experimental or strong quasi-experimental design is used to compare similar groups of individuals who are each assigned to receive a predetermined and unchanging set of services (Barnett, 1988; Levin, 1983). Since early intervention services under Part H are required to be individualized and changeable, however, designing
this type of cost-effectiveness analysis would violate the IFSP mandate. Therefore, researchers must use other methods to analyze these services, which are highly variable across a number of different dimensions.

Cost-effectiveness analyses of both publicly provided mental health services and experimental program models have used multiple regression equations to estimate costs and measures of effectiveness (Beecham, Knapp, & Fenyo, 1991; Hu & Jerrell, 1991). Recognizing that the costs and effects of services are sensitive to the characteristics of the population served, researchers have included demographic variables, measures of pretreatment psychological symptoms and functional status, and service variables in regression models. The results have yielded estimates of the average costs, effects, and cost-effectiveness ratios associated with different groups of service recipients. According to Hu and Jerrell (1991), “Each ratio can be interpreted as the amount of change in outcome as a result of $1 invested” (p. 464).

A similar approach can be taken to compare the costs and effects of individualized early intervention services for children with different characteristics. Age of entry into early intervention and severity of disability are characteristics that are important to examine from a public policy perspective for two reasons. First, studies of service cost have indicated that these characteristics influence the types, amounts, and, therefore, cost of the services provided (Barnett & Escobar, 1990; Erickson, 1992). Second, analyses of the effectiveness of early intervention programs suggest that the benefits derived from these services may differ by age and level of severity. For example, meta-analyses of various intervention studies have produced different findings regarding whether or not providing services to children at younger versus older ages is better (Casto & Mastropieri, 1986; Shonkoff & Hauser-Cram, 1987).

In addition, Farran (1990) reviewed 42 projects in which intervention services were provided to children with various disabilities. For most of these studies, the intervention was provided for less than a 1-year period. Expecting that children with severe disabil-
mother or caregiver begin what Thoman (1975) describes as a three-part cue-response sequence in which the child’s initial cues are followed by a response from the caregiver that, in turn, is followed by the child’s response to the caregiver’s action. This sequence establishes a pattern of interaction thought to be critical to the child’s development in other domains. As Rosenberg and Robinson (1988) suggest, “important elements of children’s social, cognitive, and communicative competence develop through the child’s experience in dyadic interaction with the primary caregiver” (p. 170). Previous research indicates that some children with disabilities display diminished affect and produce cues that can be difficult to interpret (Shonkoff et al., 1992). Therefore, since children will enter early intervention with different adaptive behavior and child-mother interaction skills, analyses are needed to assess the differential gains made by various groups relative to the cost of providing services.

The purpose of this article is to present the results of a cost-effectiveness analysis of early intervention services in Massachusetts. Specifically, the following four questions were addressed: (a) At a set level of resources, do subgroups of children who vary by age at entry and severity of disability demonstrate greater gains in adaptive behavior or child-mother interaction? (b) At a set level of resources, does the amount of improvement made on each outcome differ across subgroups of children who vary by age at entry? (c) At a set level of resources, does the amount of improvement made on each outcome differ across subgroups of children who vary by severity of disability? and (d) How does the number of service hours received compare with the number of service hours necessary to maximize improvement on each outcome for subgroups of children who vary by age at entry and severity of disability?

**Method**

**Subjects**

The children and families included in the sample are part of the Early Intervention Collaborative Study (EICS) being conducted at the Department of Pediatrics of the University of Massachusetts Medical School with the assistance of 29 publicly supported early intervention programs in Massachusetts and New Hampshire. The purpose of this longitudinal research is to assess the impact of early intervention services on a variety of child and family outcomes (see Shonkoff et al., 1992, for an expanded discussion of the EICS methodology).

The type and amount of service provided were determined jointly by early intervention program staff and family members, were designed to meet the individual needs of each child and family, and were not affected by the family’s participation in the research. Since cost data were available only for the early intervention services provided by the 25 Massachusetts programs participating in the study, the present analysis was conducted on the Massachusetts subsample (n = 157) of the total project sample (N = 190). In October 1986, roughly 3,468 children were being served each month in all of the early intervention programs across the state (R. Benjamin, personal communication, October 4, 1990). Thus, the Massachusetts EICS sample constituted roughly 4.5% of the children served statewide on a monthly basis.

By design, the EICS sample included children with Down syndrome, motor impairment, and developmental delays of uncertain etiology. For the Massachusetts sample, the numbers of children in each diagnostic category were 42, 64, and 51, respectively. The mean age of these children at study enrollment was 10.5 months (SD = 6.5, range = 1.3 to 26.9 months). Each diagnostic group was significantly different from the other two in age at entry (F = 91.66, p = .000). The Down syndrome group was the youngest (M = 3.34 months, SD = 1.77); those with motor impairments were older (M = 11.13, SD = 4.16); and the group with developmental delays of uncertain etiology was the oldest (M = 15.70, SD = 5.95). These differences reflect the ages at which children with these disabilities are typically referred to early intervention programs.

The children’s mean Mental Developmental Index (MDI) at study entry was 63.5 on the Bayley Scales of Infant Development (Bayley, 1969). Since the lowest standard
MDI score on the Bayley is 50, this cutoff point was used to create two groups based on level of cognitive impairment: mild (MDI > 50) and severe (MDI < 50). Statistically significant differences were found for diagnostic group by level of cognitive impairment ($\chi^2 = 13.15, p = .001$). Almost all (92.9%) of the children in the Down syndrome group were defined as having mild cognitive impairment, while almost two fifths (39.1%) of those with motor impairment were categorized as more severely disabled. Children with developmental delays of uncertain etiology were mostly (70.6%) defined as mildly impaired.

The majority of the sample mothers were married (79.6%) and White (91.1%), and most listed their primary occupation as homemaker (62.4%). Two thirds (66.9%) of the sample families had a yearly income of $20,000 or more.

**Procedure**

Detailed data on the type, amount, and estimated value of all services received by each sample member, as well as outcome data to assess effectiveness, were gathered from a variety of sources. Families were recruited to the study between December 1985 and January 1988, during their initial intake interview into an early intervention program. The children and families in the sample were assessed in their homes by the EICS staff within 1 month of their entrance into an early intervention program (Time 1) and then again 1 year later (Time 2).

**Outcome data**

Two instruments were used to assess different aspects of social competence. Adaptive behavior was measured by the Vineland Adaptive Behavior Scales (Sparrow, Balla, & Cicchetti, 1984). The Vineland is commonly used to measure social competence in children from birth to 18 years of age (American Association on Mental Retardation, 1992). The interview version was used because it is the most appropriate version for evaluating the effectiveness of early intervention services (Mott et al., 1986). Four domains were assessed: communication, daily living skills, socialization, and motor skills. These scores were combined into an adaptive behavior composite age equivalence score.

The Cronbach alpha reliability coefficient for the adaptive behavior score in this analysis was .95.

The child’s ability to interact with his or her mother was measured by the Nursing Child Assessment Teaching Scales (Barnard, 1978), a 73-item instrument completed by an observer who evaluates the interaction between a mother and child. The observation occurs while the mother teaches her child a task that is above the child’s ability level so that an assessment of adaptive patterns in the child-mother dyad can be made. The behaviors scored are the child’s ability to produce clear cues for the mother and the child’s ability to respond to the mother. The Cronbach alpha reliability coefficient for this outcome was .73.

**Service data**

Early intervention service providers completed 12 monthly service forms for each family by recording the number of hours each of the following types of services was received: (a) home visit, (b) center-based individual visit, (c) child-focused group session, (d) parent support group, (e) screenings, and (f) assessments. For screenings and assessments, the number of professionals involved was also documented.

**Expenditure data**

Since 1985, a unit rate structure has been used in Massachusetts whereby early intervention programs are reimbursed by the Department of Public Health or Medicaid at a set dollar per hour rate for each of the six service types. These rates were determined initially by a unit cost analysis that gathered data on all program operating expenses (Harrison, 1984).

For Fiscal Year 1988 (i.e., when most services received by the EICS sample were provided), the following rates applied: (a) home visit, $53.68 per hour; (b) center-based individual session, $45.28 per hour; (c) child-focused group session, $21.52 per hour; and (d) parent support group session, $14.72 per hour. Screenings and assessments are also reimbursed under the unit rate structure according to the number of working hours involved (the number of hours required to complete the screening or assessment multi-
plied by the number of professionals involved). For Fiscal Year 1988, the following rates applied: (a) screening, $67.84 per working hour, and (b) assessment, $79.16 per working hour.

Data Analysis

Three sets of estimates were calculated to address the four research questions. First, the expenditures associated with services provided over the course of 1 year to subgroups of children that varied by age at entry and severity of disability had to be estimated. A series of regression and tobit equations was constructed; these equations used data on participant characteristics to predict hours of service. The tobit technique is a modified version of regression that is used when the distribution of the dependent variable has a large number of values clustered at one point, usually zero (McDonald & Moffitt, 1980; Tobin, 1958). The coefficients generated from a tobit analysis can be interpreted in the same way as regression coefficients (Amemiya, 1984). Erickson (1992) presented a detailed discussion of how regression and tobit models were used to estimate total hours of service received by different subgroups and how these estimates were converted into expenditures.1

Second, estimates were calculated to measure the amount of change in adaptive behavior and child-mother interaction demonstrated by different subgroups of children per $1,000 worth of services. This occurred in three steps. The first step involved analysis of regression equations that used data on participant characteristics and total service hours received to predict change per hour estimates.2 Table 1 presents the results of the final regression model used to produce change per hour estimates.3 In the second step, total change estimates were calculated by multiplying the change per hour values by the total hours of service received.4 Finally, ratios of change per $1,000 worth of services were calculated by dividing the total change estimates by the total expenditures expressed in thousands of dollars.5 These values were compared to address the first three research questions.

The third set of calculations produced estimates of the level of hours beyond which additional services will not be effective. The regression equations presented in Table 1 were transformed in order to identify the level of hours associated with the point of maximum change.6 These values were used to address the fourth research question.

Results

In order to address the research questions, subgroups of children with specific age and severity characteristics were identified.7 Children in each diagnostic group were classified into one of two age groups (i.e., less than or

TABLE 1
Multiple Regression Coefficients for Change per Hour Measures (N = 157)

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Adaptive behavior</th>
<th></th>
<th>Child's interaction with mother</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b</td>
<td>t</td>
<td>b</td>
<td>t</td>
</tr>
<tr>
<td>Log of preintervention score</td>
<td>-0.030</td>
<td>-1.836</td>
<td>-0.171</td>
<td>-6.631***</td>
</tr>
<tr>
<td>Log of total hours</td>
<td>-0.194</td>
<td>-14.724***</td>
<td>-0.036</td>
<td>-2.110*</td>
</tr>
<tr>
<td>Severe disabilities</td>
<td>-0.388</td>
<td>-3.177**</td>
<td>0.203</td>
<td>1.306</td>
</tr>
<tr>
<td>Motor impairments</td>
<td>0.051</td>
<td>2.063*</td>
<td>0.003</td>
<td>0.107</td>
</tr>
<tr>
<td>Developmental delay</td>
<td>0.080</td>
<td>2.943**</td>
<td>0.038</td>
<td>1.287</td>
</tr>
<tr>
<td>Less than 12 months of age</td>
<td>0.000</td>
<td>0.002</td>
<td>0.059</td>
<td>2.500*</td>
</tr>
<tr>
<td>Yearly income &gt; $20,000</td>
<td>-0.000</td>
<td>-0.042</td>
<td>0.007</td>
<td>0.352</td>
</tr>
<tr>
<td>Log of total hours × severe disabilities</td>
<td>0.079</td>
<td>3.022**</td>
<td>-0.044</td>
<td>-1.296</td>
</tr>
<tr>
<td>Constant</td>
<td>0.985</td>
<td></td>
<td>0.610</td>
<td></td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>.653</td>
<td></td>
<td>.332</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05. **p < .01. ***p < .001.
greater than 12 months of age upon entry into early intervention) and one of two severity groups (i.e., mild or severe cognitive impairment). The distribution of sample members across these categories was examined for each diagnostic group to select those who could be compared to allow an analysis of the influence of age at entry and severity of disability on cost-effectiveness. For example, all of the children with Down syndrome entered early intervention prior to their first birthday, and 92.9% were categorized as having mild cognitive impairments. Therefore, none of the subgroups analyzed included children with Down syndrome.

Given the characteristics of the overall sample, four subgroups were selected with the following diagnostic group, age at entry, and severity of disability characteristics: (a) motor impairment, less than 12 months of age at entry into early intervention, mild disability; (b) motor impairment, less than 12 months of age at entry into early intervention, severe disability; (c) developmental delay, mild disability, less than 12 months of age at entry into early intervention; and (d) developmental delay, mild disability, greater than 12 months of age at entry into early intervention.

The first research question asked, At a set level of resources, do subgroups of children who vary by age at entry and severity of disability demonstrate greater gains in adaptive behavior or child-mother interaction? Table 2 presents the estimated change in adaptive behavior and child-mother interaction demonstrated by each subgroup for a $1,000 investment.

The outcome measure in which the greatest gains were made differed by severity of disability but not by age at entry. Among the two subgroups of children with motor impairments, those with mild cognitive impairments experienced greater improvement in adaptive behavior, while those with severe cognitive impairments experienced greater improvement in child-mother interaction. However, the younger and older subgroups of children with developmental delays both experienced greater gains in adaptive behavior than in child-mother interaction. For the subgroup of older children with mild developmental delays, no gain was measured in child-mother interaction. This subgroup, however, had the highest child-mother interaction score prior to receiving early intervention services. This finding suggests that there may be a ceiling effect that limits the ability of the measure to detect improvement.

The second research question asked, At a set level of resources, does the amount of improvement made on each outcome differ across subgroups of children who vary by age at entry? Among the two subgroups of children with mild developmental delays, those children who entered early intervention prior to their first birthday experienced much greater gains in both adaptive behavior and child-mother interaction than those who entered after 12 months of age.

The third research question asked, At a set level of resources, does the amount of improvement made on each outcome differ across subgroups of children who vary by severity of disability? Among the two subgroups of children with motor impairments, those with mild cognitive impairments demonstrated greater gains in adaptive behavior than those with severe cognitive impairments. In contrast, however, those with severe cognitive impairments experienced greater improvement in child-mother interaction than those with mild impairments.

The final research question asked, How does the number of service hours received compare with the number of service hours necessary to maximize improvement on each

### TABLE 2

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Adaptive behavior</th>
<th>Child's interaction with mother</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor impairments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild, LT12</td>
<td>3.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Severe, LT12</td>
<td>1.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Developmental delay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild, LT12</td>
<td>4.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Mild, GT12</td>
<td>1.9</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*Note.* Mild/severe = level of cognitive impairment; LT12/GT12 = age of child at entry into early intervention as less than or greater than 12 months.
outcome for subgroups of children who vary by age at entry and severity of disability? Table 3 presents the estimates of the hours required to maximize gain as well as the estimates of the total hours of service received.

For the subgroup of children with motor impairments and mild cognitive delays, the estimate of the total number of hours of service received is about equal to the amount of hours predicted to be required to maximize gains in adaptive behavior. For child-mother interaction, however, more hours are required to maximize gain. Thus, if maximizing improvement in interaction skills is a priority, the findings suggest that more hours of service should be provided.

For the subgroup of children with motor impairments and severe cognitive delays, the estimate of the number of hours required to maximize gain in adaptive behavior is smaller than the estimate for total hours. This suggests that if maximizing gains only in adaptive behavior is the primary goal, fewer hours of service could be provided. The number of hours required to maximize gain in child-mother interaction, however, is only slightly higher than the estimated total number of hours of service provided. These findings suggest that any substantial decrease in the hours of service provided may fail to produce maximum improvement in child-mother interaction.

The subgroup of younger children with developmental delays received a slightly higher number of hours of service than required to maximize gain in adaptive behavior. In terms of child-mother interaction, however, improvements were maximized quite quickly. This unexpected finding suggests, perhaps, that child-mother interaction is an intermediate outcome for this subgroup. Improvements in child-mother interaction may promote gains in other domains of development that take longer to occur.

Finally, the subgroup of older children with developmental delays received roughly twice the number of hours of service required to maximize gain in adaptive behavior. Furthermore, no value was calculated for child-mother interaction since no overall gain was measured (see Table 2). Thus, in terms of the outcomes analyzed, fewer hours of service could be provided to maximize improvement. It is not known, however, what gains were made by this subgroup in other important developmental domains or the number of hours required to maximize improvement in those areas.

**Discussion**

This article has presented a cost-effectiveness analysis of early intervention services in Massachusetts. The differences found by age at entry and severity of disability, as well as the comparisons made between the number of hours required to maximize gain and the number of hours received, demonstrate how this technique can provide unique insights to policymakers and service providers.

Age at entry into early intervention was found to influence the level of improvement made on different outcomes. For the two subgroups of children with mild developmental delays, those entering early intervention be-

---

**TABLE 3**

*Hours of Service Required to Maximize Gain and Mean Total Hours of Service Received by Subgroup and Outcome Measure*

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Adaptive behavior</th>
<th>Child's interaction</th>
<th>Mean total hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>with mother</td>
<td></td>
</tr>
<tr>
<td><strong>Motor impairments</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild, LT12</td>
<td>55.1</td>
<td>103.4</td>
<td>59.3</td>
</tr>
<tr>
<td>Severe, LT12</td>
<td>65.6</td>
<td>100.8</td>
<td>93.3</td>
</tr>
<tr>
<td><strong>Developmental delay</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild, LT12</td>
<td>66.4</td>
<td>3.1</td>
<td>76.6</td>
</tr>
<tr>
<td>Mild, GT12</td>
<td>58.4</td>
<td><em>a</em></td>
<td>109.9</td>
</tr>
</tbody>
</table>

*Note: Mild/severe = level of cognitive impairments; LT12/GT12 = age of child at entry into early intervention as less than or greater than 12 months.

*aNo value was calculated since the overall gain was zero.*
before their first birthday made greater improvements per $1,000 investment in both adaptive behavior and child-mother interaction than those who did not receive services until they were more than 1 year old. These findings support the necessity and efficiency of developing an active statewide child find and referral system, as mandated under Part H, coordinated with an ongoing screening and tracking system.

Each state is responsible for creating its own definition of developmental delay and establishing criteria that will determine who is eligible at the point of referral. This assumes that the future developmental status of a child can be determined, accurately, at that one point in time. As King, Logsdon, and Schroeder (1992) note, however, the developmental progress of children between birth and 3 years of age is not stable. Thus, a mechanism for monitoring and assessing the eligibility of children periodically is needed (King et al., 1992; Shonkoff & Meisels, 1991). Tools for accomplishing this have been developed. For example, a standardized telephone interview guide designed to feasibly and efficiently identify children in need of service has been tested (Rojahn et al., 1993). Furthermore, in order to compile a complete list of children who should be monitored over time, the child find system must involve all of the diverse public and private agencies in a state that provide health, education, and social services to children (e.g., Medicaid; Early and Periodic Screening, Diagnosis, and Treatment [EPSDT]; Head Start; Special Supplemental Program for Women, Infants, and Children [WIC]; day-care providers) (Peterson, 1991).

The findings also reveal that the subgroup of children with severe disabilities made gains on both outcomes relative to a $1,000 investment, even though their adaptive behavior and child-mother interaction scores after 1 year of intervention were the lowest of the four subgroups. These results suggest that service providers should not be held accountable for helping all children reach a standard level of performance. Alternatively, as Farran (1990) suggests, "for many children normal development cannot be the goal. Rather, the goal is to improve their adapta-

‡tion within the limits of their disability" (p. 532).

Finally, the comparisons made between the number of hours required to maximize gain and the number of hours received reveal that there is a great deal of congruence between these two estimates for certain subgroups and large differences for other subgroups. This suggests that it is difficult to calibrate the provision of services accurately for all potential outcomes. The delivery of more services will increase costs; however, depending on the subgroup, the additional intervention may result in increasing, decreasing, or sustaining the level of initial improvement.

Knowledge of these trade-offs is important to share with both service providers and family members as they begin to work together to develop IFSPs. Acknowledging that children will move toward different goals at different speeds will help service providers and families set priorities as to the relative importance of achieving certain outcomes and thus setting the level of service provision appropriately. Beckman and Bristol (1991) suggest that the more active families are in the development of the IFSP, the more likely the outcomes will reflect their priorities for their children.

In addition to the implications that the findings have for implementing Part H, the limitations of the present analysis highlight five areas in which more research is needed. First, basic research is needed to define and quantify better the nature and extent of the intervention itself. In this analysis, the intervention was measured simply by assessing the total hours of service received. Data on the other characteristics of service provision included on the EICS database (e.g., where services were provided and whether they were provided to individuals or groups) were not taken into account. Furthermore, no data on the quality of the intervention were available. It is fair to assume that the quality of each hour of intervention was somewhat variable since services were provided by 25 different programs and by providers trained in different disciplines.

Other researchers have described measurements of the early intervention experi-
ence that should be analyzed relative to their influence on effectiveness. LeLaurin and Wolery (1992) suggest that more creative ways are needed to measure the extent of an individual's participation in the intervention and the skill of the interventionist. Guralnick (1988) discusses how intensity should be measured as actual instructional time.

Second, more work needs to be done to develop reliable and valid instruments of child, family, and interaction outcomes that are appropriate for children and families with widely varying aptitudes and skills (Barnard & Kelly, 1990; Hauser-Cram & Shonkoff, 1988; Krauss & Jacobs, 1990). In addition, better ways to assess change on those outcomes are needed (Hauser-Cram & Krauss, 1991; Willett, 1988).

Third, although the overall sample included children from three diagnostic groups, the analysis excluded those with Down syndrome since this group lacked variation in age and severity of disability. Future research should examine whether children with Down syndrome in early intervention programs vary on other dimensions (e.g., presence or absence of medical problems, family characteristics) that may have implications for the way in which resources are distributed. Furthermore, samples including children with a wider variety of diagnosed disabilities should be analyzed as part of a cost-effectiveness analysis to identify the characteristics on which providers should focus when determining the appropriate level of service.

Fourth, the cost-effectiveness of early intervention services should be evaluated for samples that include a greater diversity of families. Since the current cost-effectiveness estimates were computed for children of middle-class families, the results cannot be generalized to low-income groups.

Finally, the results regarding the level of service at which gains are maximized suggest that, for some subgroups, additional service may not result in additional improvement. The present analysis cannot estimate, however, whether additional services are required to sustain the gains already made. Future research, therefore, should include follow-up studies on children once they stop receiving early intervention services. This could be accomplished by placing children on monitoring status instead of discharging them from their early intervention program. Public Law 99-457 requires that programs place children on monitoring status if it is believed that they are at risk but do not require immediate service.

To address these research issues, a comprehensive system for compiling data on early intervention services is needed. This may be accomplished by developing working partnerships among service providers, researchers, and policymakers (Black, 1991). These partnerships should be dedicated to the creation of databases that are sufficiently streamlined for providers to maintain but sufficiently complex to give researchers access to comprehensive information on services and outcomes for large and diverse samples. One way to encourage providers to document critical information is to develop more efficient data-collection tools. For example, some time-consuming data-gathering techniques have been revised so that they can be incorporated into regular pediatric visits. Some of these newer data-collection instruments assess parent-child interaction (Casey, Bradley, Nelson, & Whaley, 1988) and maternal stress and social environment (Orr, James, & Charney, 1989). Furthermore, these partnerships could be enhanced by encouraging researchers to present their findings to providers periodically to generate discussion about the meaning of those findings and how they can best be translated into better and more efficient service delivery.

Notes

I gratefully acknowledge the important contributions of Barry Friedman of Brandeis University, Marty Wyngaarden Krauss of Brandeis University and the Early Intervention Collaborative Study (EICS), Jack Shonkoff of the University of Massachusetts Medical School and EICS, Carole Upshur of the University of Massachusetts at Boston and EICS, and Penny Hauser-Cram of Boston College and EICS. In addition, I wish to thank Helene Fausold, Kathy Antaki, and Ann Steele of EICS, service providers in the Massachusetts early intervention programs collaborating on EICS, and members of the Massachusetts Department of Public Health for their help in data collection.
The equations analyzed for this article differ slightly from those examined by Erickson (1992). First, the dummy variable identifying those with severe versus mild disabilities was defined differently. In the present analysis, two groups were created by using the lowest standard MDI score on the Bayley as the cutoff point between children with mild versus severe disabilities. Erickson (1992) analyzed two groups in which those with mild or moderate cognitive impairments had an MDI score of 52 or above, while those with severe cognitive impairments had an MDI score of 51 or below. Second, the equations used by Erickson (1992) included a dummy variable measuring socioeconomic status. In the present analysis, a dummy variable for income was used. Finally, the previous equations included a dummy variable indicating the geographic location of the early intervention program attended by each child and family. The present analysis did not.

Three types of ordinary least squares regression models were constructed initially to investigate the relation between total hours of service and change in the outcome measures. First, an equation that assumed a linear relation between hours and change was tested. Second, an equation that included the natural logarithms of the interval-level independent variables was evaluated to test whether the relation between hours and change was nonlinear. The third equation also examined the nonlinear relation between hours and change by measuring change in the dependent variable relative to a quantity of service (i.e., 1 hour). The third model was selected for analysis since it produced the highest $R^2$ values and thus represented the best fit to the data. Another approach would have been to evaluate the third model using two-stage least squares since hours of service was included on both sides of the equation. Hours of service, however, only became part of the dependent variable to better assess the nonlinear relation between hours and change, not because change was hypothesized to influence the hours of service received. Thus, since hours of service was considered to be exogenous to the model, ordinary least squares regression was an appropriate technique to use. See Erickson (1991) for a more detailed discussion of how the different regression equations were developed and tested.

Change per hour estimates for children with specific characteristics can be calculated from the regression equations in Table 1 by multiplying a value for each independent variable by the coefficient associated with that variable and adding in the constant term. The value for each independent dummy variable is one if the characteristic is present and zero if it is not present. For interval-level variables, mean values were substituted. The calculations below illustrate how the equation for adaptive behavior in Table 1 was used to estimate the mean change per hour for the subgroup of younger children with mild motor impairments. It is important to note that, despite the negative coefficient on the log of total hours, the calculated change per hour value is positive. This counterintuitive finding is explained by the fact that children with more severe disabilities received more hours of service but demonstrated less improvement on the outcome measures than children with mild disabilities. The importance of this interaction in predicting change per hour was accounted for by including in the equation a variable that multiplies the log of total hours by the dummy variable for severity:

\[
\text{Change/Hour} = k + b_1 \ln T1 + b_2 \ln H + b_3 \text{Sev} + b_4 \text{MD} + b_5 \text{DD} + b_6 \text{LT12} + b_7 \text{High} + b_8 \text{inSevH} + E
\]

\[
= .985 + [-.03][\ln(8.367)] + [-.194][\ln(59.3)] + [-.388][0] + [.051][1] + [.080][0] + [.000][1] + [-.000][1] + [\ln(59.3)][.079][0]
\]

\[
= .985 + -.064 + -.792 + .051 + .000 + -.000
\]

\[
= .18.
\]

The abbreviations used in the above equation are as follows: $K =$ constant term; $b_*$ = regression coefficient associated with each variable; $\ln =$ natural logarithm; $T1 =$ Time 1 score of the dependent variable; $H =$ total hours; $\text{Sev} =$ dummy variable identifying those with severe disabilities; $\text{MD} =$ dummy variable identifying those with motor impairment; $\text{DD} =$ dummy variable identifying those with developmental delay; $\text{LT12} =$ dummy variable identifying those younger than twelve months of age at Time 1; $\text{High} =$ dummy variable identifying families with a yearly income of more than $20,000; $\text{SevH} =$ the interaction variable created by multiplying the dummy variable identifying those with severe disabilities by total hours; $E =$ error term.

The total change in adaptive behavior estimate was derived as follows for the subgroup of younger children with mild motor impairments: $\text{Change} = [\text{Change/Hour}][\text{Hours}] = [1.18][59.3] = 10.67$. The ratio of change per $1,000$ worth of services was derived as follows for the subgroup of younger children with mild motor impairments (this value is presented in Table 2): $\text{Change}/\text{1,000} = [\text{Change}][\text{Expenditures/1,000}] = [10.67][3,152.07/1,000] = 3.4$.
Several computations were required to identify the level of hours associated with the point of maximum change. First, the regression equation had to be multiplied by hours to create a new equation in which change was the dependent variable. As shown below, Equation 1 evaluates the rate of change in an outcome measure with respect to hours of service (see footnote 3 for an explanation of abbreviations).

\[
\text{Change} = k(H) + b_1[H^*\ln T] + b_2[H^*\ln H] + b_3[H^*\text{Sev}] + b_4[H^*MI] + b_5[H^*DD] + b_6[H^*LT12] + b_7[H^*\text{High}] + b_8[H^*\text{SevLnH}] + E(H). \tag{1}
\]

The number of hours at which change is maximized is found by taking the derivative of Equation 1 with respect to total hours.

\[
\frac{d}{dH}C = k + b_1\ln T + b_2\ln H + b_3\text{Sev} + b_4MI + b_5DD + b_6LT12 + b_7\text{High} + b_8 + b_9\text{Sev}. \tag{2}
\]

Next, in order to find the level of hours at which change is maximized, it is necessary to set Equation 2 equal to zero and solve it to compute a value for maximum hours.

\[
0 = b_1\ln H + b_3\text{SevLnH} + k + b_1\ln T + b_3\text{Sev} + b_4MI + b_5DD + b_6LT12 + b_7\text{High} + b_9 + b_9\text{Sev}. \tag{3}
\]

By letting \([A]\) represent the quantity \(k + b_1\ln T + b_3\text{Sev} + b_4MI + b_5DD + b_6LT12 + b_7\text{High} + b_9 + b_9\text{Sev},\) Equation 3 can be rewritten and solved as follows:

\[
b_1\ln H + b_3\text{SevLnH} = -[A] \\
\ln H[b_2 + b_9\text{Sev}] = -[A] \\
\ln H = -[A]/[b_2 + b_9\text{Sev}] \\
\text{Maximum Hours} = e^{-[A]/[b_2 + b_9\text{Sev}]} \tag{4}
\]

Where \(e\) = exponential function.

For example, the hour level at which change in adaptive behavior is maximized for the subgroup of younger children with mild motor impairments is found as follows. First, calculate \([A]\):

\[
= .985 + -.064 + .051 + -.194 \\
= .778.
\]

Then, by substituting \([A]\) in Equation 4, the value presented in Table 3 is calculated: Maximum Hours = \(e^{-[.778]/[.194]} = 55.1\).

Each of the selected subgroups also included only children whose families had a yearly income of $20,000 or more, since two thirds of all sample families were in this income bracket.

References


**Author**

MARJI ERICKSON WARFIELD, Assistant Professor of Pediatrics and Psychiatry, Department of Psychiatry, University of Massachusetts Medical Center, 55 Lake Avenue North, Worcester, MA 01655. *Specializations*: early childhood programs, cost analysis.

Received March 16, 1992
Final revision received October 18, 1993
Accepted October 25, 1993