

Relative Effectiveness of Episodic and Conjugate Reinforcement on Child Operant Learning

Carl J. Dunst, Andrea J. Storck, Melanie D. Hutto, and Donna Snyder

The relative effectiveness of episodic and conjugate reinforcement on child operant learning constituted the focus of this practice-based research synthesis. The synthesis included 35 studies of 672 participants (573 typically developing children and 99 children with disabilities or delays) involved in either episodic ($N = 19$) or conjugate ($N = 16$) reinforcement studies. Comparisons of the time required to double the rate of operant responding indicated that episodic reinforcement was relatively more effective in producing an operationally defined level of operant learning, although both types of reinforcement were effective in increasing operant responding. Implications for practice are described in terms of the types of reinforcement best suited for promoting contingency awareness and mastery.

Purpose

The primary purpose of this practice-based research synthesis is to determine if rapidity of learning differed in contingency studies of infants and young children using either episodic or conjugate reinforcement. Episodic reinforcement paradigms involve the discrete delivery of a stimulus following the child's production of an operant behavior (e.g., Bloom & Esposito, 1975); whereas conjugate reinforcement paradigms involve the availability of a stimulus in amounts proportional to the strength of operant responding (Lipsitt, Pederson, & Delucia, 1966). A secondary purpose of the synthesis is to determine if either type of reinforcement affected contingency learning differently for children with disabilities or delays compared to typically developing children. Effectiveness is measured in terms of a doubled baseline rate of operant responding.

The conduct of the synthesis is guided by a practice-based research framework that focuses on the degree to which different types of reinforcement are associated with variations in rates of operant responding. The synthesis differs from more traditional research reviews by systematically examining the characteristics of practices that are related to differences in behavioral outcomes or consequences. More specifically, this type of analysis focuses on understanding *how* and in what *manner* the

same or similar environmental characteristics exert the same or similar effects on child behavior (see Dunst, Trivette, & Cutspec, 2002, for a detailed explanation of the framework).

Background

Operant Learning

There is considerable evidence that by 2 to 4 months of age infants are capable of learning the relationship between their behavior and its consequences (e.g., Lippman, 2000; Lipsitt & Werner, 1981; Rovee-Collier & Gekoski, 1979; Williams, 2001). In these types of learning situations, the production of an interesting stimulus (i.e., reinforcement) is contingent upon a behavior emitted by a child. These types of learning opportunities are characterized by behavioral-based contingencies (Tarabulsky, Tessier, & Kappas, 1996) where a child's behavior either

Bridges is a publication of the Research and Training Center on Early Childhood Development, funded by the U. S. Department of Education, Office of Special Education Programs, Research to Practice Division (H324K010005). The opinions expressed in this paper are those of the Research and Training Center on Early Childhood Development, an organizational unit of the Center for Evidence-Based Practices at the Orelena Hawks Puckett Institute, and do not necessarily represent the views of the U. S. Department of Education. Copyright © 2006. The Puckett Institute. All rights reserved.

elicits a reinforcing consequence (e.g., touching a roly-poly that then produces movement or sound) or where a child's behavior is reinforced by another person (e.g., a caregiver talking to a child each time the child vocalizes).

Description of the Practice

Studies of response-contingent learning have investigated child learning under generally two types of reinforcement--episodic (e.g., Watson, 1972) or conjugate (e.g., Rovee & Rovee, 1969). (See Ramey, Hieger, & Klisz, 1972, for examples of other types of reinforcement schedules used in infant response-contingent learning studies.) In both types of studies, the contingencies are deliberately arranged or manipulated in order to establish the efficacy of the reinforcement as a determinant of increased operant responding. In other words, both the operant behavior and reinforcement are identified on an *a priori* basis, and the learning opportunity or environmental arrangements are implemented in a manner where the reinforcement is made available or delivered contingent on the child producing the operant behavior.

In *episodic* reinforcement studies, the reinforcement is delivered in both a predetermined manner and amount following the production of an operant behavior (e.g., saying "good baby" contingent on the infant smiling at an adult or having a light stay on for five seconds following a child's panel press). In *conjugate* reinforcement studies, the reinforcement is made available contingent upon a response where the amount or intensity of the reinforcement is proportional to the strength of operant responding (e.g., the harder a child kicks, the more movement and sound there is from a mobile or the brighter a light becomes the louder a child's vocalizations activate a voice-sensitive switch).

A number of investigators have claimed that conjugate reinforcement is more effective than other types of reinforcement, including episodic, in producing rapid learning (e.g., Lindsley, 1963; Lipsitt et al., 1966; Rovee-Collier & Gekoski, 1979). To the best of our knowledge, no studies or analyses have been conducted to support or refute this claim among children first learning response-contingent relationships. This practice-based research synthesis specifically focuses on establishing the relative effectiveness of these contrasting types of reinforcement.

Search Strategy

Search Terms

Identification of relevant studies was accomplished using response-contingent behavior, response-contingent stimulation, response-contingent learning, operant learning, contingency learning, conjugate reinforcement, and episodic reinforcement as search terms, and infants, children, or children with disabilities as delimiters.

Sources

Relevant studies were located using the following databases: Psychological Abstracts on-line (PsycINFO), Social Sciences Citation Index (SSCI), Educational Resources Information Center (ERIC), Health Source: Nursing/Academic Edition, Academic Search Elite, Info-Trac Expanded Academic ASAP, Dissertation Abstracts International, Social SciSearch and SciSearch, ProQuest, Ingenta, and MEDLINE. In addition, on-line searches using Google, Dogpile, and Excite were conducted to identify relevant studies.

A Social Sciences Citation Index search was conducted to identify investigators citing and referencing seminal papers (e.g., Rovee-Collier & Capatides, 1979; Watson, 1972) and to identify noted infant operant learning experts (e.g., Richard P. Brinker, Lewis P. Lipsitt, Phyllis Ohr, Carolyn Rovee-Collier, John S. Watson). The reference sections of all identified studies as well as review articles were hand searched to identify additional investigations.

Selection Criteria

Studies were included in the research synthesis if they met the following criteria: (1) operant learning was the focus of investigation, (2) either episodic or conjugate reinforcement was utilized, (3) the availability of the reinforcement was deliberately arranged or manipulated, (4) both baseline and conditioning phase data were presented, and (5) the minutes to double operant responding from the baseline to conditioning phase were reported or could be determined from data presented in the research report.

Exclusion criteria. Studies were excluded from the analysis for a number of reasons, including insufficient baseline and/or conditioning phase data to calculate the rapidity of learning (e.g., Hanson & Hanline, 1985; Ramey & Watson, 1972; Sullivan & Lewis, 1990), the learning paradigm was not an operant study and/or the reinforcement type was not episodic or conjugate (e.g., Cyrulik-Jacobs, Shapira, & Jones, 1975; Ulrich & Ulrich, 1995), data on the rate of learning was summarized for the entire conditioning phase (e.g., Hitchcock & Rovee-Collier, 1996; Wilk, Klein, & Rovee-Collier, 2001) or the reinforcement type was varied or changed during the conditioning phase or included multiple types (e.g., Doggett, Gans, & Stein, 2000; Young, Krantz, McClanahan, & Poulson, 1994). Additionally, four studies were excluded because operant responding levels never doubled (Gunn, Berry, & Andrews, 1979; Ohr & Fagen, 1994, Down syndrome sample; Watson, 1969; Watson & Ramey, 1972).

Search Results

Thirty-five (35) research reports were located that included studies that met the inclusion criteria. Nineteen

(19) studies (54%) used episodic reinforcement and 16 studies (46%) used conjugate reinforcement. There were 23 studies (66%) of typically developing children and 9 studies (26%) that included either participants with delays or disabilities or children who were at risk for delays, and 3 studies (8%) that included both types of children. Twenty-six (26) studies (74%) utilized group designs, whereas 9 studies (26%) used single participant designs.

Participants

Nearly 700 ($N = 672$) children served as study participants (Table 1). Their ages ranged from 2 to 44 months. Children without disabilities or delays numbered 573 (85%), while 99 study participants (15%) had a disability, developmental delay, or an at-risk condition. The typically developing children ranged in age from 2 to 9 months (Median = 3.5), and the children with disabilities or delays ranged in age from 3 to 44 months (Median = 9). Among the participants with disabilities or delays, the majority had cocaine exposure ($N = 36$), followed by Down syndrome ($N = 28$), prematurity or failure to thrive ($N = 24$), multiple or severe disabilities or delays ($N = 6$), congenital heart disease ($N = 2$), cerebral palsy ($N = 1$), seizure disorders ($N = 1$), and encephalopathy ($N = 1$).

Most studies ($N = 28$, 80%) included information about child gender. Of the 640 participants identified as either male or female, 53% were boys and 47% were girls. For the typically developing study participants ($N = 542$), 54% were boys and 46% were girls. The sample of children with disabilities or delays ($N = 96$) was also almost equally divided between males (52%) and females (48%).

Research Designs

All 35 studies used either experimental or quasi-experimental group or single participant designs for evaluating the effectiveness of the contrasting types of reinforcement (see Table 2). All the investigators used an A_1BA_2 or AB research design, where A_1 is the baseline condition, B is the conditioning phase or phases, and A_2 is the extinction or return to baseline condition. In all but four cases (Alessandri, Sullivan, Imaizumi, & Lewis, 1993; Gekoski, Fagen, & Pearlman, 1984; Ohr & Fagen, 1991; Standley, 2000), the group design studies included typically developing infants as participants, and all the single participant studies included children with disabilities, developmental delays, or conditions placing them at risk for delays.

Practice

In each study included in the synthesis, the experimental arrangements were such that a child producing an operant response was followed immediately by either a social ($N = 2$) or nonsocial ($N = 47$) reinforcement, or some combination of social or nonsocial ($N = 15$) reinforcement,

delivered either episodically or conjugately. The operant behavior that constituted the targets of conditioning included leg kicks, arm pulling, vocalizations, sucking, and head turns. The reinforcements for operant responding included the movement and sound of a mobile, the presentation of a smiling-face slide accompanied by music, the presentation of a slide of colorful visual displays, various types of feedback from toys or music, and adult smiles or vocalizations, among other consequences.

Synthesis Findings

Several different analyses were performed to ascertain if there were differential consequences of episodic and conjugate reinforcement on operant learning. First, the time required to double operant learning between the baseline and conditioning phases of the studies was determined for each study (group design) or participant (single participant designs) based on data available in the research reports. These data were used to ascertain the rapidity of learning (Minutes to Criterion). Minutes to Criterion were calculated using either minute-by-minute data included in the research reports (e.g., Alessandri et al., 1993) or were estimated from blocked data (e.g., Dunst & Lingerfelt, 1985).

Second, we compared Minutes to Criterion for episodic vs. conjugate reinforcement. This was done for all studies combined and for the studies of children with and without disabilities separately. Both t-tests and Cohen's d effect sizes were computed to ascertain the nature of the differences associated with the two types of reinforcement.

Third, we conducted a series of analyses to ascertain if variations in Minutes to Criterion were influenced by child disability status (children without disabilities vs. children with disabilities), by how the Minutes to Criterion were measured (minute-by-minute vs. estimated), and by whether the reinforcement was nonsocial vs. social or a combination of social and nonsocial.

Table 3 shows the findings for the individual studies. The table includes the study sample sizes, child diagnosis, the operant behavior, and both the type of study (group or single participant) and reinforcement (episodic or conjugate). The table also includes the number of minutes to double operant responding and the method used to calculate Minutes to Criterion. The Minutes to Criterion ranged from 1 to 30 for the typically developing children and 1 to 95 for the children with disabilities or those at risk for delays. One study of children with disabilities (Watson, Hayes, & Vietze, 1982) and one study of children without disabilities (Fagen & Rovee, 1976, Group 3) were not included in the analyses because the Minutes to Criterion were both outliers (95 and 30 minutes, respectively).

The average Minutes to Criterion for the typically

developing children was 5.06 (SD = 3.21), and the average Minutes to Criterion for the children with disabilities or delays was 5.64 (SD = 5.94), $t(60) = 0.49$, $p = .62$, $d = .12$. The average Minutes to Criterion for episodic reinforcement was 4.53 (SD = 4.55) and the average Minutes to Criterion for conjugate reinforcement was 6.37 (SD = 4.35), $t(60) = 1.60$, $p < .115$, $d = 0.41$.

A Two Between Group (Children With vs. Without Disabilities) X 2 Type of Reinforcement (Episodic vs. Conjugate) ANOVA produced a main effect for group, $F(1,58) = 9.03$, $p < .01$, a main effect for type of reinforcement, $F(1, 58) = 12.01$, $p < .001$, and a group x type of reinforcement interaction, $F(1, 58) = 5.93$, $p < .05$. Figure 1 shows the patterns of findings for the interaction. Follow-up tests showed that learning occurred more rapidly using episodic reinforcement among both the children without disabilities or delays, $t(34) = 1.59$, $p < .12$, $d = .55$, and the children with disabilities or delays, $t(24) = 2.56$, $p < .02$, $d = 1.29$.

Tests of the influences of the method of measuring rapidity of learning (minute-by-minute vs. estimated) showed that Minutes to Criterion were reached sooner

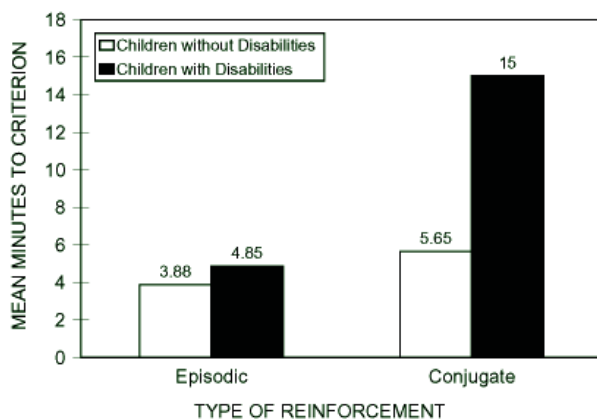


Figure 1. Mean number of minutes to double operant responding between the baseline and conditioning phase of the study.

when minute-by-minute ($M = 3.67$, $SD = 4.57$) data were used to measure learning as opposed to estimating rapidity of learning ($M = 6.47$, $SD = 4.17$), $t(60) = 2.51$, $p < .02$, $d = .64$. This was ascertained for the typically developing children only because too few children with disabilities had data for conjugate learning ($n=2$). The extent to which the method of measuring rapidity of learning influenced the effectiveness of type of reinforcement was assessed using a two way ANOVA. The patterns of findings were nearly identical regardless of how Minutes to Criterion were measured (Figure 2) as evidenced by a nonsignificant type of reinforcement by type of learning measure interaction, $F(1, 32) = 1.10$, $p < .40$. Considering just the

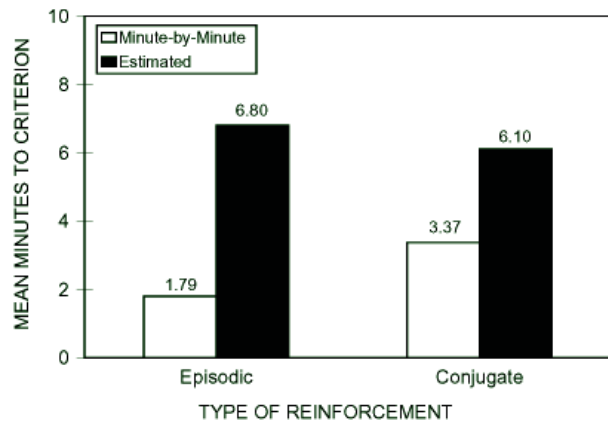


Figure 2. Mean number of minutes to double operant responding as measured by two different methods (minute-by-minute vs. estimated data), for the typically developing children in the studies.

minute-by-minute results, it took almost twice as long to reach Minutes to Criterion for the conjugate compared to the episodic reinforcement condition.

The extent to which reinforcement class affected rapidity of learning was assessed by a 2 Between Group (Children With vs. Children Without Disabilities) X 2 Reinforcement Class (Nonsocial vs. Social + Social/Nonsocial) ANOVA. Results are shown in Figure 3. Rapidity of learning was accelerated when the reinforcement class had a social component, $F(1, 58) = 3.57$, $p < .06$, $d = .57$, where the pattern of differences was the same for children with or without disabilities or delays.

Conclusion

Findings from this practice-based research synthesis indicate that episodic reinforcement is somewhat more ef-

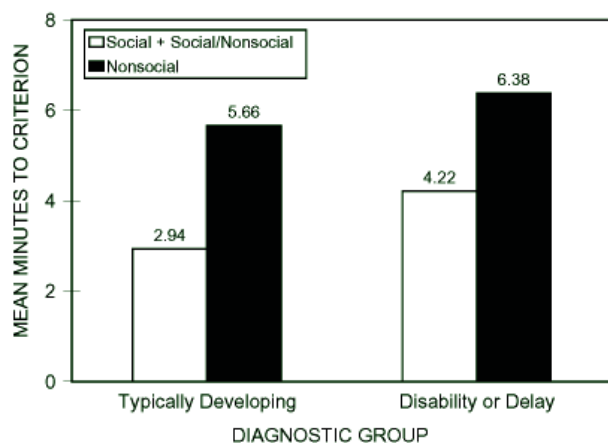


Figure 3. Mean number of minutes to double operant responding for reinforcers having nonsocial or social components.

fective than conjugate reinforcement in affecting rapidity of learning among children with or without disabilities or delays. Despite this difference, both types of reinforcement influenced the study participants' operant learning albeit at different rates. Findings also indicate that social reinforcement or reinforcement including a social component accelerated rapidity of learning. This is especially important in light of the fact that few studies of children with disabilities include social reinforcers.

The differential effectiveness of episodic reinforcement can be explained, in part, by the fact that in these kinds of studies, contingency detection (Tarabulsky et al., 1996) and contingency awareness (Watson, 1966) is so much easier than in conjugate reinforcement studies. In the latter, the child's behavior and the reinforcement tend to occur simultaneously, making it more difficult for the child to "come to understand" (Watson, 1966) the relationship between his or her behavior and its reinforcing consequences. The differences in the temporal response-contingent relations (Watson, 2001) between the two types of studies would therefore seem to explain the findings in this synthesis, although it is the case that other factors such as strength of reinforcement may be operating as well.

Implications for Practice

The use of response-contingent learning opportunities as a type of early intervention has been described for more than 20 years (e.g., Broucek, 1979; Dunst, 1981; Dunst & Lesko, 1988; Lancioni, 1980; Watson et al., 1982). The results from this synthesis add to our understanding of the characteristics of response-contingent learning opportunities that can be used to inform practice to optimize child learning.

First, for children first learning behavioral-based contingency relationships (Tarabulsky et al., 1996), the use of episodic reinforcement learning games or activities would seem warranted as a way of facilitating a child's use and understanding of his or her behavioral capabilities. This would seem especially true for children with disabilities who may have difficulty learning the relationship between their behavior and its environmental consequences (Hutto, 2003).

Second, at the juncture where a child is making the connection between his or her behavior and its reinforcing consequences, the introduction of conjugate reinforcement learning games and materials (e.g., mobiles) would most likely produce both generalization and a stronger sense of mastery (Watson, 1972). Evidence from another practice-based research synthesis of response-contingent learning (Dunst, 2003) suggests that conjugate reinforced learning opportunities are most effective when the amount of reinforcement is not so great that it "confuses" the child or that it has over stimulation effects making it difficult for the child to inhibit responding.

Third, the types of learning games and activities that are used to facilitate operant learning ought to include a mix of learning opportunities that involve interactions with people and interactions with toys and other materials. This would seem especially true for children with disabilities or delays because the kinds of learning activities used with these children mostly involve interactions with toys and other physical objects rather than people (Dunst, Raab, Parkey, Wilson, & Gatens, 1996; Dunst, Raab, Wilson, & Parkey, 1997). For a variety of reasons, learning opportunities afforded children with disabilities often don't include the kinds of social learning opportunities that would strengthen their social interactive competencies. Social learning opportunities are especially indicated because they enhance response-contingent learning and optimizing positive social-emotional benefits and consequences of the learning opportunities (Dunst, 2003).

The companion to this *Bridges* synthesis is a *Bottomlines* (Volume 4, Number 1) report describing the major findings in nontechnical, user-friendly language. The *Bottomlines* summarizes what we know about the effectiveness of episodic and conjugate reinforcement in terms of affecting operant behavior in ways that are more likely to be understood by parents and practitioners.

Both this *Bridges* synthesis and the companion *Bottomlines* are being used to develop practice guides that describe the processes for planning and implementing contingency learning games. These guides will be available to readers in an electronic version at our Web site (www.researchtopractice.info) and in print versions that can be obtained by writing us at the Orelena Hawks Puckett Institute, Research and Training Center, 18A Regent Park Blvd., Asheville, NC 28806.

References

- Alessandri, S. M., Sullivan, M. W., Imaizumi, S., & Lewis, M. (1993). Learning and emotional responsivity in cocaine-exposed infants. *Developmental Psychology, 29*, 989-997.
- Alessandri, S. M., Sullivan, M. W., & Lewis, M. (1990). Violation of expectancy and frustration in early infancy. *Developmental Psychology, 26*, 738-744.
- Angulo-Kinzler, R. M. (2001). Exploration and selection of intralimb coordination patterns in 3-month-old infants. *Journal of Motor Behavior, 33*, 363-376.
- Bloom, K., & Esposito, A. (1975). Social conditioning and its proper control procedures. *Journal of Experimental and Child Psychology, 19*, 209-222.
- Brinker, R. P., & Lewis, M. (1981, April). *Patterns of learning by handicapped infants*. Paper presented at the Biennial Meeting of the Society for Research in Child Development, Boston. (ERIC Document Reproduction Service No. ED232338).

- Brinker, R. P., & Lewis, M. (1982). Making the world work with microcomputers: A learning prosthesis for handicapped infants. *Exceptional Children*, 49, 163-170.
- Broucek, F. (1979). Efficacy in infancy: A review of some experimental studies and their possible implications for clinical theory. *International Journal of Psycho-Analysis*, 60, 311-316.
- Caron, R. F. (1967). Visual reinforcement of head-turning in young infants. *Journal of Experimental Child Psychology*, 5, 489-511.
- Cyrulik-Jacobs, A., Shapira, Y., & Jones, M. (1975). Application of an automated operant response procedure to the study of auditory perception and processing of neurologically impaired infants. In B. Friedlander, G. Sterritt, & C. Kirk (Eds.), *Exceptional Infant: Vol. 3. Assessment and intervention* (pp. 109-136). New York: Brunner/Mazel.
- Doggett, M. S., Gans, D. P., & Stein, R. (2000). Pediatric audiometry: The relative success of toy and video reinforcers. *Infant-Toddler Intervention: The Transdisciplinary Journal*, 10, 73-80.
- Dunst, C. J. (1981). *Infant learning: A cognitive-linguistic intervention strategy*. Allen, TX: DLM.
- Dunst, C. J. (2003). Social-emotional consequences of response-contingent learning opportunities. *Bridges*, 1(1), 1-17. Available at: http://www.evidencebasedpractices.org/bridges/bridges_vol1_no1.pdf.
- Dunst, C. J., Cushing, P. J., & Vance, S. D. (1985). Response-contingent learning in profoundly handicapped infants: A social systems perspective. *Analysis and Intervention in Developmental Disabilities*, 5, 33-47.
- Dunst, C. J., & Lesko, J. (1988). Promoting the active learning capabilities of young children with handicaps. *Early Childhood Intervention Monograph Series*, 1, Number 1. Morganton, NC: Family, Infant and Preschool Program, Western Carolina Center.
- Dunst, C. J., & Lingerfelt, B. (1985). Maternal ratings of temperament and operant learning in two- to three-month-old infants. *Child Development*, 56, 555-563.
- Dunst, C. J., Raab, M., Parkey, C., Wilson, L., & Gatens, M. (1996). *Contingency games played with young children with significant delays and their social-emotional consequences*. Unpublished manuscript, Orelena Hawks Puckett Institute, Asheville, NC.
- Dunst, C. J., Raab, M., Wilson, L., & Parkey, C. (1997, November). *The response-contingent learning capabilities of young children with disabilities and their social-emotional concomitants*. Presentation made at the International Division for Early Childhood Conference on Children with Special Needs, New Orleans, LA.
- Dunst, C. J., Trivette, C. M., & Cutspec, P. A. (2002). Toward an operational definition of evidence-based practices. *Centerscope*, 1(1), 1-10. Available at: <http://www.evidencebasedpractices.org/centerscope/centerscopevol1no1.pdf>.
- Enright, M. K., Rovee-Collier, C. K., Fagen, J. W., & Caniglia, K. (1983). The effects of distributed training on retention of operant conditioning in human infants. *Journal of Experimental Child Psychology*, 36, 209-225.
- Fagen, J. W., & Rovee, C. K. (1976). Effects of quantitative shifts in a visual reinforcer on the instrumental response of infants. *Journal of Experimental Child Psychology*, 21, 349-360.
- Gekoski, M. J., Fagen, J. W., & Pearlman, M. A. (1984). Early learning and memory in the preterm infant. *Infant Behavior and Development*, 7, 267-276.
- Glenn, S. M., Cunningham, C. C., O'Brien, Y., & Schofield, R. (2005). *Violation of expectancy in contingency learning situations in 3 month old infants*. Unpublished manuscript, Liverpool John Moores University, School of Health, Liverpool, UK.
- Greco, C., Hayne, H., & Rovee-Collier, C. (1990). Roles of function, reminding, and variability in categorization by 3-month-old infants. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 16, 617-633.
- Gunn, P., Berry, P., & Andrews, R. (1979). Vocalization and looking behaviour of Down syndrome infants. *British Journal of Psychology*, 70, 259-263.
- Hanson, M. J., & Hanline, M. F. (1985). An analysis of response-contingent learning experiences for young children. *Journal of the Association for Persons with Severe Handicaps*, 10, 31-40.
- Hill, W. L., Borovsky, D., & Rovee-Collier, C. (1988). Continuities in infant memory development. *Developmental Psychobiology*, 21, 43-62.
- Hitchcock, D. F. A., & Rovee-Collier, C. (1996). The effect of repeated reactivations on memory specificity in infancy. *Journal of Experimental Child Psychology*, 62, 378-400.
- Hutto, M. D. (2003). Latency to learn in contingency studies of young children with disabilities or developmental delays. *Bridges*, 1(2), 1-16. Available at http://www.evidencebasedpractices.org/bridges/bridges_vol1_no2.pdf.
- Lancioni, G. E. (1980). Infant operant conditioning and its implications for early intervention. *Psychological Bulletin*, 88, 516-534.
- Lewis, M., Sullivan, M. W., & Brooks-Gunn, J. (1985). Emotional behaviour during the learning of a contingency in early infancy. *British Journal of Developmental Psychology*, 3, 307-316.
- Lindsley, O. R. (1963). Experimental analysis of social reinforcement: Terms and methods. *American Jour-*

- nal of Orthopsychiatry*, 33, 624-633.
- Lippman, L. G. (2000). Contingent incentive value in human operant performance. *Psychological Record*, 50, 513-528.
- Lipsitt, L. P., Pederson, L. J., & Delucia, C. A. (1966). Conjugate reinforcement of operant responding in infants. *Psychonomic Science*, 4, 67-68.
- Lipsitt, L. P., & Werner, J. S. (1981). The infancy of human learning processes. In E. S. Gollin (Ed.), *Developmental plasticity: Behavioral and biological aspects of variations in development* (pp. 101-133). New York: Academic Press.
- Mast, V. K., Fagen, J. W., Rovee-Collier, C. K., & Sullivan, M. W. (1980). Immediate and long-term memory for reinforcement context: The development of learned expectancies in early infancy. *Child Development*, 51, 700-707.
- McKirby, L. S., & Rovee, C. K. (1978). The efficacy of auditory and visual conjugate reinforcers in infant conditioning. *Journal of Experimental Child Psychology*, 25, 80-89.
- O'Brien, Y., Glenn, S., & Cunningham, C. (1994). Contingency awareness in infants and children with severe and profound learning disabilities. *International Journal of Disability, Development and Education*, 41, 231-243.
- Ohr, P. S., & Fagen, J. W. (1991). Conditioning and long-term memory in three-month-old infants with Down syndrome. *American Journal of Mental Retardation*, 96, 151-162.
- Ohr, P. S., & Fagen, J. W. (1994). Contingency learning in 9-month-old infants with Down syndrome. *American Journal on Mental Retardation*, 99, 74-84.
- Ramey, C. T., Hieger, L., & Klisz, D. (1972). Synchronous reinforcement of vocal responses in failure-to-thrive infants. *Child Development*, 43, 1449-1455.
- Ramey, C. T., & Ourth, L. L. (1971). Delayed reinforcement and vocalization rates of infants. *Child Development*, 42, 291-297.
- Ramey, C. T., & Watson, J. S. (1972). Nonsocial reinforcement of infants' vocalizations. *Developmental Psychology*, 6, 538.
- Rovee-Collier, C., Griesler, P. C., & Earley, L. A. (1985). Contextual determinants of retrieval in three-month-old infants. *Learning and Motivation*, 16, 139-157.
- Rovee-Collier, C. K., & Capatides, J. B. (1979). Positive behavioral contrast in 3-month-old infants on multiple conjugate reinforcement schedules. *Journal of the Experimental Analysis of Behavior*, 32, 15-27.
- Rovee-Collier, C. K., & Gekoski, M. J. (1979). The economics of infancy: A review of conjugate reinforcement. *Advances in Child Development and Behavior*, 13, 195-255.
- Rovee-Collier, C. K., Morrongiello, B. A., Aron, M., & Kupersmidt, J. (1978). Topographical response differentiation and reversal in 3-month-old infants. *Infant Behavior and Development*, 1, 323-333.
- Rovee, C. K., & Rovee, D. T. (1969). Conjugate reinforcement of infant exploratory behavior. *Journal of Experimental Child Psychology*, 8, 33-39.
- Singer, J. M., & Fagen, J. W. (1992). Negative affect, emotional expression, and forgetting in young infants. *Developmental Psychology*, 28, 48-57.
- Siqueland, E. R., & De Lucia, C. A. (1987). Visual reinforcement of non-nutritive sucking in human infants. In J. Oates & S. Sheldon (Eds.), *Cognitive development in infancy: A reader* (pp. 71-76). Hillsdale, NJ: Erlbaum.
- Standley, J. M. (2000). The effect of contingent music to increase non-nutritive sucking of premature infants. *Pediatric Nursing*, 26, 493-495, 498-499.
- Sullivan, M. W., & Lewis, M. (1990). Contingency intervention: A program portrait. *Journal of Early Intervention*, 14, 367-375.
- Sullivan, M. W., Rovee-Collier, C. K., & Tynes, D. M. (1979). A conditioning analysis of infant long-term memory. *Child Development*, 50, 152-162.
- Tarabulsky, G. M., Tessier, R., & Kappas, A. (1996). Contingency detection and the contingent organization of behavior in interactions: Implications for socio-emotional development in infancy. *Psychological Bulletin*, 120, 25-41.
- Ulrich, B. D., & Ulrich, D. A. (1995). Spontaneous leg movements of infants with Down syndrome and nondisabled infants. *Child Development*, 66, 1844-1855.
- Watson, J. S. (1966). The development and generalization of "contingency awareness" in early infancy: Some hypotheses. *Merrill-Palmer Quarterly*, 12, 123-135.
- Watson, J. S. (1969). Operant conditioning of visual fixation in infants under visual and auditory reinforcement. *Developmental Psychology*, 1, 508-516.
- Watson, J. S. (1972). Smiling, cooing, and "the game". *Merrill-Palmer Quarterly*, 18, 323-339.
- Watson, J. S. (2001). Contingency perception and misperception in infancy: Some potential implications for attachment. *Bulletin of the Menninger Clinic*, 65, 296-320.
- Watson, J. S., Hayes, L. A., & Vietze, P. (1982). Response-contingent stimulation as a treatment for developmental failure in infancy. *Journal of Applied Developmental Psychology*, 3, 191-203.
- Watson, J. S., & Ramey, C. T. (1972). Reactions to response-contingent stimulation in early infancy. *Merrill-Palmer Quarterly*, 18, 219-227.
- Wilk, A. E., Klein, L., & Rovee-Collier, C. (2001). Visual preference and operant measures of infant memory. *Developmental Psychobiology*, 39, 301-312.

Williams, B. A. (2001). The critical dimensions of the response-reinforcer contingency. *Behavioural Processes*, 54, 111-126.

Wishart, J. G. (1990). Learning to learn: The difficulties faced by infants and young children with Down syndrome. In W. I. Fraser (Ed.), *Key issues in mental retardation research: Proceedings of the Eighth Congress of the International Association for the Scientific Study of Mental Deficiency (IASSMD)* (pp. 249-261). New York: Routledge.

Wishart, J. G. (1991). Taking the initiative in learning: A developmental investigation of infants with Down syndrome. *International Journal of Disability, Development and Education*, 38, 27-44.

Young, J. M., Krantz, P. J., McClannahan, L. E., &

Poulson, C. L. (1994). Generalized imitation and response-class formation in children with autism. *Journal of Applied Behavior Analysis*, 27, 685-697.

Authors

Carl J. Dunst, Ph.D., is Co-Director and Research Scientist at the Orelena Hawks Puckett Institute, Asheville, North Carolina (dunst@puckett.org). Andrea J. Storck, B.S., is a Research Associate at the Puckett Institute (astorck@puckett.org). Melanie D. Hutto, Ph.D., is a former Associate Research Scientist at the Research and Training Center on Early Childhood Development, Puckett Institute. Donna Snyder, B.A., is a Research Assistant at the Puckett Institute (dsnyder@puckett.org).

Table 1
Characteristics of the Study Participants

Study	Sample Size	Child Age (months)	Child Gender		Child Diagnosis
			Male	Female	
Alessandri et al. (1990)	48	2-8	24	24	Typical
Alessandri et al. (1993) (Group 1)	36	4-8	18	18	Typical
Alessandri et al. (1993) (Group 2)	36	4-8	18	18	Cocaine exposed
Angulo-Kinzler (2001)	13	3-4	7	6	Typical
Bloom & Esposito (1975) (Study 1)	8	3	7	9	Typical
Brinker & Lewis (1981) (Participant 1)	1	6	-	1	Down syndrome
Brinker & Lewis (1981) (Participant 2)	1	7	1	-	Down syndrome
Brinker & Lewis (1982) (Participant 1)	1	4	-	1	Down syndrome
Brinker & Lewis (1982) (Participant 2)	1	6	1	-	Down syndrome
Caron (1967)	22	4	13	9	Typical
Dunst & Lingerfelt (1985)	17	2-3	10	8	Typical
Dunst et al. (1985) (Participant 1)	1	24	1	-	Multiple disabilities, severe delays
Dunst et al. (1985) (Participant 2)	1	20	1	-	Multiple disabilities, severe delays
Dunst et al. (1985) (Participant 3)	1	17	1	-	Multiple disabilities, severe delays
Dunst et al. (1985) (Participant 4)	1	24	1	-	Multiple disabilities, severe delays
Enright et al. (1983) (Group 1)	5	3	NR	NR	Typical
Enright et al. (1983) (Group 2)	5	3	NR	NR	Typical
Enright et al. (1983) (Group 3)	5	3	NR	NR	Typical
Enright et al. (1983) (Group 4)	5	3	NR	NR	Typical
Fagen & Rovee (1976) (Study 1) (Group 1)	10	3	5	5	Typical
Fagen & Rovee (1976) (Study 1) (Group 2)	10	3	5	5	Typical
Fagen & Rovee (1976) (Study 1) (Group 3)	10	3	5	5	Typical
Gekoski et al. (1984) (Group 1)	10	3	7	3	Typical
Gekoski et al. (1984) (Group 2)	10	5	7	3	Prematurity
Glenn et al. (2005) (Group 1)	20	4	10	10	Typical
Glenn et al. (2005) (Group 2)	20	4	10	10	Typical
Greco et al. (1990) (Study 1)	20	3	20	10	Typical
Hill et al. (1988) (Study 1)	40	6-7	27	18	Typical
Lewis et al. (1985) (Group 1)	10	3	5	5	Typical
Lewis et al. (1985) (Group 2)	10	4	5	5	Typical
Lewis et al. (1985) (Group 3)	10	6	5	5	Typical
Mast et al. (1980)	12	3-4	6	6	Typical
McKirdy & Rovee (1978) (Group 1)	6	3-4	3	3	Typical
McKirdy & Rovee (1978) (Group 2)	6	3-4	3	3	Typical
McKirdy & Rovee (1978) (Group 3)	6	3-4	3	3	Typical
O'Brien et al. (1994) (Participant 1)	1	12	-	1	Cerebral palsy; visual and motor impairment
O'Brien et al. (1994) (Participant 2)	1	3	1	-	Down syndrome

Table 1, continued

Studies	Sample Size	Child Age (months)	Child Gender		Child Diagnosis
			Male	Female	
O'Brien et al. (1994) (Participant 3)	1	44	1	-	Cornelia de Lange syndrome, motor impairment
O'Brien et al. (1994) (Participant 4)	1	19	-	1	CHARGE syndrome; motor, visual, and auditory impairment
O'Brien et al. (1994) (Participant 5)	1	40	1	-	Encephalopathy, motor impairment
Ohr & Fagen (1991) (Group 1)	20	3-4	14	6	Typical
Ohr & Fagen (1991) (Group 2)	20	3-4	9	11	Down syndrome
Ohr & Fagen (1994) (Group 1)	10	9	5	5	Typical
Ramey & Ourth (1971)	15	3-9	NR	NR	Typical
Ramey et al. (1972) (Participant 1)	1	7	-	1	Congenital heart disease
Ramey et al. (1972) (Participant 2)	1	14	1	-	Congenital heart disease
Ramey et al. (1972) (Participant 3)	1	8	-	1	Failure-to-thrive
Ramey et al. (1972) (Participant 4)	1	10	-	1	Failure-to-thrive
Rovee & Rovee (1969)	6	2-3	4	2	Typical
Rovee-Collier & Capatides (1979) (Study 1)	10	3	6	4	Typical
Rovee-Collier et al. (1978)	10	2-4	NR	NR	Typical
Rovee-Collier et al. (1985)	24	3	11	13	Typical
Singer & Fagen (1992) (Group 1)	24	4	11	13	Typical
Singer & Fagen (1992) (Group 2)	24	4	11	13	Typical
Siqueland & DeLucia (1987) (Study 1)	10	4	NR	NR	Typical
Standley (2000)	12	9	6	6	Prematurity
Sullivan & Lewis (1990)	1	3-16	NR	NR	Down syndrome, developmentally delayed
Sullivan et al. (1979) (Study 1)	32	3	18	14	Typical
Sullivan et al. (1979) (Study 2)	24	3	12	12	Typical
Watson et al. (1982) (Study 2)	1	8	-	1	Seizure disorder, severely retarded
Wishart (1990)	1	9	NR	NR	Down syndrome
Wishart (1991)	1	18	NR	NR	Down syndrome

NR = Not reported

Table 2
Research Designs and Characteristics of the Response-Contingent Learning Opportunities

Studies	Child Diagnosis	Type of Study ^a	Research Design	Study Setting	Response-Contingent Learning Opportunities			
					Operant Behavior	Reinforcement	Type ^b	Class ^c
Alessandri et al. (1990)	T	G	ABAB	Lab	Arm pulls	Smiling-face slide and music	E	S/N
Alessandri et al. (1993) (Group 1)	T	G	ABAB	Lab	Arm pulls	Smiling-face slide and music	E	S/N
Alessandri et al. (1993) (Group 2)	D	G	ABAB	Lab	Arm pulls	Smiling-face slide and music	E	S/N
Angulo-Kinzler (2001)	T	G	ABA	Lab	Leg kicks	Mobile with wind chimes	E	N
Bloom & Esposito (1975) (Study 1)	T	G	ABAB	Home	Vocalizations	Vocalization, touch, visual	E	S
Brinker & Lewis (1981) (Participant 1)	D	S	AB	Home	Arm pulls Leg kicks	Tape recording of music or mother's voice; mechanical train with tune, colored lights, or photograph	E	S/N N
Brinker & Lewis (1981) (Participant 2)	D	S	AB	Home	Leg kicks Arm pulls	Tape recording of music or mother's voice; mechanical train with tune, colored lights, or photograph	E	S/N N
Brinker & Lewis (1982) (Participant 1)	D	S	AB	Home	Arm pulls	Tape recording of music, battery-powered train, or presentation of a B&W drawing of a child's face	E	N
Brinker & Lewis (1982) (Participant 2)	D	S	AB	Home	Arm pulls	Tape recording of music, battery-powered train, or presentation of a B&W drawing of a child's face	E	N
Caron (1967)	T	G	ABB ² A	Lab	Head turns	Visual display of various shapes	E	S/N
Dunst & Lingerfelt (1985)	T	G	AA'BAA'	Lab	Leg kicks	Mobile with windchimes	C	N
Dunst et al. (1985) (Participant 1)	D	S	ABA	Lab	Head turns	Visual display of multicolored lights that illuminated repeatedly, suspended over crib	E	N
Dunst et al. (1985) (Participant 2)	D	S	ABA	Lab	Head turns	Visual display of multicolored lights that illuminated repeatedly, suspended over crib	E	N
Dunst et al. (1985) (Participant 3)	D	S	ABA	Lab	Head turns	Visual display of multicolored lights that illuminated repeatedly, suspended over crib	E	N
Dunst et al. (1985) (Participant 4)	D	S	AB ¹ B ² B ³ AB ⁴ A	Lab	Head turns	Visual display of multicolored lights that illuminated repeatedly, suspended over crib	E	N
Enright et al. (1983) (Group 1)	T	G	ABA	Home	Leg kicks	Mobile	C	N
Enright et al. (1983) (Group 2)	T	G	ABA	Home	Leg kicks	Mobile	C	N
Enright et al. (1983) (Group 3)	T	G	ABBA	Home	Leg kicks	Mobile	C	N
Enright et al. (1983) (Group 4)	T	G	ABBA	Home	Leg kicks	Mobile	C	N
Fagen & Rovee (1976) (Study 1) (Group 1)	T	G	ABA	Home	Leg kicks	Mobile (2-6)	C	N
Fagen & Rovee (1976) (Study 1) (Group 2)	T	G	ABA	Home	Leg kicks	Mobile (6-6)	C	N

Table 2, continued

Studies	Child Diagnosis	Type of Study ^a	Research Design	Study Setting	Response-Contingent Learning Opportunities			
					Operant Behavior	Reinforcement	Type ^b	Class ^c
Fagen & Rovee (1976) (Study 1) (Group 3)	T	G	ABA	Home	Leg kicks	Mobile (10-6)	C	N
Gekoski et al. (1984) (Group 1)	T	G	ABA	Home	Leg kicks	Mobile	C	N
Gekoski et al. (1984) (Group 2)	D	G	ABA	Home	Leg kicks	Mobile	C	N
Glenn et al. (2005) (Group 1)	T	G	AB	Lab	Leg kicks	Smiling-face mobile and nursery rhyme chorus song	E	N
Glenn et al. (2005) (Group 2)	T	G	AB	Lab	Leg kicks	Smiling-face mobile and nursery rhyme chorus song	E	N
Greco et al. (1990) (Study 1)	T	G	ABA	Home	Leg kicks	Mobile	C	N
Hill et al. (1988) (Study 1)	T	G	ABA	Home	Leg kicks	Mobile	C	N
Lewis et al. (1985) (Group 1)	T	G	AB	Lab	Arm pulls	Smiling-face slide and music	E	S/N
Lewis et al. (1985) (Group 2)	T	G	AB	Lab	Arm pulls	Smiling-face slide and music	E	S/N
Lewis et al. (1985) (Group 3)	T	G	AB	Lab	Arm pulls	Smiling-face slide and music	E	S/N
Mast et al. (1980)	T	G	ABBA	Home	Leg kicks	Mobile	C	N
McKirdy & Rovee (1978) (Group 1)	T	G	ABA	Home	Leg kicks	Set of 6 bells	C	N
McKirdy & Rovee (1978) (Group 2)	T	G	ABA	Home	Leg kicks	Mobile and set of 6 bells	C	N
McKirdy & Rovee (1978) (Group 3)	T	G	ABA	Home	Leg kicks	Mobile	C	N
O'Brien et al. (1994) (Participant 1)	D	S	ABBB	Lab	Leg movements	Activation of a smiling face and figure with rotating arms and nursery rhymes	E	S/N
O'Brien et al. (1994) (Participant 2)	D	S	ABBA	Lab	Leg movements	Activation of a smiling face and figure with rotating arms and nursery rhymes	E	S/N
O'Brien et al. (1994) (Participant 3)	D	S	ABBAB	Lab	Leg movements	Activation of a smiling face and figure with rotating arms and nursery rhymes	E	S/N
O'Brien et al. (1994) (Participant 4)	D	S	ABBAB	Lab	Leg movements	Activation of a smiling face and figure with rotating arms and nursery rhymes	E	S/N
O'Brien et al. (1994) (Participant 5)	D	S	ABAB	Lab	Leg movements	Activation of a smiling face and figure with rotating arms and nursery rhymes	E	S/N
Ohr & Fagen (1991) (Group 1)	T	G	ABA	Home	Leg kicks	Mobile	C	N
Ohr & Fagen (1991) (Group 2)	D	G	ABA	Home	Leg kicks	Mobile	C	N
Ohr & Fagen (1994) (Group 1)	T	G	ABA	Home	Arm pulls	Lights and carousel rotation	E	N
Ramey & Ourth (1971)	T	G	ABA	Lab	Vocalizations	Smile, touch, vocalizations	E	S
Ramey et al. (1972) (Participant 1)	D	S	ABAB	Lab	Vocalizations	Brightly colored geometric figure	E	N
Ramey et al. (1972) (Participant 2)	D	S	ABAB	Lab	Vocalizations	Brightly colored geometric figure	E	N

Table 2, continued

Studies	Child Diagnosis	Type of Study ^a	Research Design	Study Setting	Response-Contingent Learning Opportunities			
					Operant Behavior	Reinforcement	Type ^b	Class ^c
Ramey et al. (1972) (Participant3)	D	S	ABA	Lab	Vocalizations	Brightly colored geometric figure	E	N
Ramey et al. (1972) (Participant 4)	D	S	ABA	Lab	Vocalizations	Brightly colored geometric figure	E	N
Rovee & Rovee (1969)	T	G	ABA	Home	Leg kicks	Mobile	C	N
Rovee-Collier & Capati- des (1979) (Study 1)	T	G	AB	Home	Leg kicks	Mobile	C	N
Rovee-Collier et al. (1978)	T	G	ABAB ¹ A	Lab	Leg kicks	Mobile	C	N
Rovee-Collier et al. (1985)	T	G	ABA	Home	Leg kicks	Mobile	C	N
Singer & Fagen (1992) (Group 1)	T	G	ABBB	Home	Leg kicks	Mobile	C	N
Singer & Fagen (1992) (Group 2)	T	G	ABBB	Home	Leg kicks	Mobile	C	N
Siqueland & DeLucia (1987) (Study 1)	T	G	ABABA	Lab	Sucking	Visual display	C	N
Standley (2000)	D	G	ABAB	Lab	Non-nutritive sucking	Music	E	S/N
Sullivan & Lewis (1990)	D	S	ABB	Home	Leg kicks	Access to various toys of choice and unspecified consequences	E	N
Sullivan et al. (1979) (Study 1)	T	G	ABA	Home	Leg kicks	Mobile	C	N
Sullivan et al (1979) (Study 2)	T	G	ABA	Home	Leg kicks	Mobile	C	N
Watson et al. (1982) (Study 2)	D	S	AB	Home	Leg-pillow presses	Mobile, buzzer, light	E	N
Wishart (1990)	D	S	ABBA	Lab	Leg movements	Mobile movement	E	N
Wishart (1991)	D	S	ABAB	Lab	Leg movements	Mobile movement	E	N

^aG = Group design study, S = Single participant design study

^bE = Episodic reinforcement, C = Conjugate reinforcement

^cS = Social reinforcement, N = Nonsocial reinforcement, and S/N = Combination of social and nonsocial reinforcement

Table 3
Minutes to Double Operant Responding for the Contrasting Reinforcement Paradigms

Studies	Sample Size	Child Diagnosis	Operant Behavior	Type of Study ^a	Type of Reinforcement	Results	
						Minutes to Criterion ^b	Learning Measure ^c
Alessandri et al. (1990)	48	Typical	Arm pulls	G	Episodic	1	M
Alessandri et al. (1993) (Group 1)	36	Typical	Arm pulls	G	Episodic	3	E
Alessandri et al. (1993) (Group 2)	36	At risk (cocaine exposed)	Arm pulls	G	Episodic	3	E
Angulo-Kinzler (2001)	13	Typical	Leg kicks	G	Episodic	7	E
Bloom & Esposito (1975) (Study 1)	8	Typical	Vocalizations	G	Episodic	12	E
Brinker & Lewis (1981) (Participant 1)	1	Down syndrome	Arm pulls Leg kicks	S	Episodic	5 3	M M
Brinker & Lewis (1981) (Participant 2)	1	Down syndrome	Arm pulls Leg kicks	S	Episodic	1 8	M M
Brinker & Lewis (1982) (Participant 1)	1	Down syndrome	Arm pulls	S	Episodic	7	M
Brinker & Lewis (1982) (Participant 2)	1	Down syndrome	Arm pulls	S	Episodic	4	M
Caron (1967)	22	Typical	Head turns	G	Episodic	1	M
Dunst & Lingerfelt (1985)	17	Typical	Leg kicks	G	Conjugate	4	E
Dunst et al. (1985) (Participant 1)	1	Profound retardation, multiple disabilities	Head turns	S	Episodic	15	E
Dunst et al. (1985) (Participant 2)	1	Profound retardation, multiple disabilities	Head turns	S	Episodic	6	E
Dunst et al. (1985) (Participant 3)	1	Profound retardation, multiple disabilities	Head turns	S	Episodic	24	M
Dunst et al. (1985) (Participant 4)	1	Profound retardation, multiple disabilities	Head turns	S	Episodic	5	M
Enright et al. (1983) (Group 1)	5	Typical	Leg kicks	G	Conjugate	6	E
Enright et al. (1983) (Group 2)	5	Typical	Leg kicks	G	Conjugate	9	E
Enright et al. (1983) (Group 3)	5	Typical	Leg kicks	G	Conjugate	5	E
Enright et al. (1983) (Group 4)	5	Typical	Leg kicks	G	Conjugate	8	E
Fagen & Rovee (1976) (Study 1) (Group 1)	10	Typical	Leg kicks	G	Conjugate	7	E
Fagen & Rovee (1976) (Study 1) (Group 2)	10	Typical	Leg kicks	G	Conjugate	9	E
Fagen & Rovee (1976) (Study 1) (Group 3)	10	Typical	Leg kicks	G	Conjugate	30	E
Gekoski et al. (1984) (Group 1)	10	Typical	Leg kicks	G	Conjugate	7	E
Gekoski et al. (1984) (Group 2)	10	At risk (prematurity)	Leg kicks	G	Conjugate	22	E
Glenn et al. (2005) (Group 1)	20	Typical	Leg kicks	G	Episodic	6	E
Glenn et al. (2005) (Group 2)	20	Typical	Leg kicks	G	Episodic	6	E
Greco et al. (1990) (Study 1)	20	Typical	Leg kicks	G	Conjugate	9	E
Hill et al. (1988) (Study 1)	40	Typical	Leg kicks	G	Conjugate	1	M
Lewis et al. (1985) (Group 1)	10	Typical	Arm pulls	G	Episodic	1	M
Lewis et al. (1985) (Group 2)	10	Typical	Arm pulls	G	Episodic	2	M
Lewis et al. (1985) (Group 3)	10	Typical	Arm pulls	G	Episodic	1.5	M
Mast et al. (1980)	12	Typical	Leg kicks	G	Conjugate	14	E

Table 3, continued

Studies	Sample Size	Child Diagnosis	Operant Behavior	Type of Study ^a	Type of Reinforcement	Results	
						Minutes to Criterion ^b	Learning Measure ^c
McKirby & Rovee (1978) (Group 1)	6	Typical	Leg kicks	G	Conjugate	2	E
McKirby & Rovee (1978) (Group 2)	6	Typical	Leg kicks	G	Conjugate	4	E
McKirby & Rovee (1978) (Group 3)	6	Typical	Leg kicks	G	Conjugate	6	E
O'Brien et al. (1994) (Participant 1)	1	Cerebral palsy; visual and motor impairment	Leg movements	S	Episodic	3	E
O'Brien et al. (1994) (Participant 2)	1	Down syndrome	Leg movements	S	Episodic	6	E
O'Brien et al. (1994) (Participant 3)	1	Cornelia de Lange syndrome, motor impairment	Leg movements	S	Episodic	3	E
O'Brien et al. (1994) (Participant 4)	1	CHARGE syndrome; motor, visual, and auditory impairment	Leg movements	S	Episodic	3	E
O'Brien et al. (1994) (Participant 5)	1	Encephalopathy, motor impairment	Leg movements	S	Episodic	6	E
Ohr & Fagen (1991) (Group 1)	20	Typical	Leg kicks	G	Conjugate	5	E
Ohr & Fagen (1991) (Group 2)	20	Down syndrome	Leg kicks	G	Conjugate	8	E
Ohr & Fagen (1994) (Group 1)	10	Typical	Arm pulls	G	Episodic	4	M
Ramey & Ourth (1971)	15	Typical	Vocalizations	G	Episodic	2	M
Ramey et al. (1972) (Participant 1)	1	Congenital heart disease	Vocalizations	S	Episodic	3.5	M
Ramey et al. (1972) (Participant 2)	1	Congenital heart disease	Vocalizations	S	Episodic	4	M
Ramey et al. (1972) (Participant 3)	1	Failure-to-thrive	Vocalizations	S	Episodic	2	M
Ramey et al. (1972) (Participant 4)	1	Failure-to-thrive	Vocalizations	S	Episodic	1	M
Rovee & Rovee (1969)	6	Typical	Leg kicks	G	Conjugate	3.5	M
Rovee-Collier & Capatides (1979) (Study 1)	10	Typical	Leg kicks	G	Conjugate	3	E
Rovee-Collier et al. (1978)	10	Typical	Leg kicks	G	Conjugate	5.5	M
Rovee-Collier et al. (1985)	24	Typical	Leg kicks	G	Conjugate	2	E
Singer & Fagen (1992) (Group 1)	24	Typical	Leg kicks	G	Conjugate	2	E
Singer & Fagen (1992) (Group 2)	24	Typical	Leg kicks	G	Conjugate	4	E
Siqueland & DeLucia (1987) (Study 1)	10	Typical	Sucking	G	Conjugate	3.5	M
Standley (2000)	12	Premature	Sucking	G	Episodic	1	M
Sullivan & Lewis (1990)	1	Down syndrome	Leg kicks	S	Episodic	2.5	M
Sullivan et al. (1979) (Study 1)	32	Typical	Leg kicks	G	Conjugate	9	E
Sullivan et al. (1979) (Study 2)	24	Typical	Leg kicks	G	Conjugate	7	E
Watson et al. (1982) (Study 2)	1	Seizures	Leg kicks	S	Episodic	95	E
Wishart (1990)	1	Down syndrome	Leg kicks	S	Episodic	2	E
Wishart (1991)	1	Down syndrome	Leg kicks	S	Episodic	2.5	M

^aG = Group design study, S = Single participant design study

^bMinutes to double operant responding (In every study, operant responding at least doubled the average rate of responding during the baseline phase of the study.)

^cM = Minute by minute, E = Estimated or aggregated