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Latency to Learn in Contingency Studies of Young Children With Disabilities or Developmental Delays

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This research synthesis examines the relationship between the severity of developmental delay and latency to learn in contingency studies of young children with disabilities. Whereas children without disabilities learn a contingency almost immediately, studies included in this synthesis indicate that among children with or at risk for delays there is a latency to learn the contingency between a behavior and its consequences. Results indicate the need to consider this latency when using response-contingent learning opportunities to promote behavior capabilities of young children with disabilities.

Purpose

The primary purpose of this research synthesis is to determine if there is a latency to learn in contingency studies among children with disabilities or developmental delays or children at risk for delays for medical or other reasons. This purpose was accomplished by systematically identifying relevant studies, calculating latency-to-learn indexes, and establishing the extent to which severity of delay and other factors were related to latency to learn. A secondary purpose of the synthesis is to determine if the response-contingent learning opportunities produced social-emotional consequences in infants who learned the contingency between a behavior and its consequences.

The conduct of the synthesis is guided by a practice-based research framework (Dunst, Trivette, & Cutspec, 2002) that focuses on the degree to which variations in response-contingent learning opportunities are associated with variations in child-initiated operant behaviors that produce interesting consequences for infants and young children. A practice-based research synthesis differs from more traditional meta-analyses by systematically examining and parsing the characteristics of practices related to differences in outcomes or consequences. The result of this type of analysis is a focus on understanding the conditions under which a practice exerts an observable effect, rather than solely on a statistical relationship among variables.

Background

Research spanning more than 40 years demonstrates that infant behavior that produces interesting or reinforcing consequences has the effect of increasing the child's production of the operant behavior among children with and without disabilities (e.g., Angulo-Kinzler & Horn, 2001; Brackbill, 1958; Cavanagh & Davidson, 1973; Dunst, 1984; Finkelstein & Ramey, 1977; Leuba & Friedlander, 1968; Millar, 1972; Poulson, Kymissis, Reeve, Andreatos, & Reeve, 1991; Poulson, Kyparissos, Andreatos, Kymissis, & Parnes, 2002; Ramey & Ourth, 1971; Rheingold, Gewirtz, & Ross, 1959; Rovee & Rovee, 1969; Watson, 1966, 1972; Watson & Ramey, 1972; Weisberg, 1963; Young, Krantz, McClannahan, & Poulson, 1994). Studies of young children without delays or apparent disabilities indicate that infants almost immediately learn the contingency between their behavior and its consequences when a reinforcement is made available upon an operant response. For example, Cavanagh and Davidson (1973; 1977) found that infants quickly learned to control a stimulus when an audio-visual reinforcement was made available upon an operant response (panel press). Many other studies also report increases in targeted infant behaviors with almost no latency to learn among children who do not have a disability (e.g., Cavanagh & Davidson, 1977; Lipsitt,

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Pederson, & Delucia, 1966; Rheingold et al., 1959; Rovee & Rovee, 1969). Most studies show the latency to learn among typically developing children is four minutes or less in studies where a reinforcer is immediately made available in response to the production of an operant behavior.

A cursory examination of published and unpublished studies of young children with or at risk for developmental delays suggests that these children show a latency to learn (e.g., Dunst, 1984; Dunst, Cushing, & Vance, 1985; Ramey, Hieger, & Klisz, 1972; Ramey, Starr, Pallas, Whitten, & Reed, 1975; Watson & Ramey, 1972). Additionally, it appears that the more severe a child's developmental delay, the longer is the latency to learn (Haskett & Hollar, 1978; Sullivan & Lewis, 1993). In order to investigate the relationship between severity of delay and latency to learn, this research synthesis includes studies that report latency-to-learn measures for young children with disabilities or studies that report data for which latency measures could be calculated.

Description of the Practice

A variety of terms has been used to describe infant operant learning, including response-contingent learning (Dunst et al., 1985; Millar, Weir, & Supramaniam, 1992), conjugate reinforcement (Hulsebus, 1973; Lindsley, 1963; Lipsitt et al., 1966; Sameroff & Cavanagh, 1979), competency striving (White, 1959), contingency learning (Ayoun, 1998; Sullivan & Lewis, 1993; Wijnroks, 1997), contingency awareness (Asendorpf, Warkentin, & Baudonnière, 1996; Purkis & Lipp, 2001; Watson, 1966, 1972), contingent reinforcement (Thompson & Iwata, 2000), response contingency (Williams, 2001), and contiguous reinforcement (Ramey & Ourth, 1971). Despite variations in the terms used to describe infant operant learning, all studies share a common feature; namely, behavior that produces reinforcing consequences increases production of that behavior.

Contingency studies typically involve environmental arrangements where an *a priori* identified behavior is paired with a specific reinforcement, where the reinforcement either is delivered immediately by an adult (e.g., adult vocalizing to an infant each time she smiles) or is made available through some type of mechanical or environmental arrangement (e.g., leg kicks producing movement of a mobile by means of a Velcro strap attached to the child's leg and mobile). Reinforcements used to condition operant behaviors in infants without a disability also function as reinforcements of behavior in children with a disability (Dunst & Lesko, 1988; Young et al., 1994). Lipsitt (1971) noted that the initial contingency is discovered almost accidentally by the infant. When a behavior produces an interesting consequence, infants realize their ability to control an aspect of their environment and tend to repeat the operant behavior (Hanson & Hanline, 1985; Sullivan & Lewis, 1993). In the process, they develop a sense of contingency awareness (Watson, 1972), contingency detection (Tarabulsy, Tessier, & Kappas, 1996), or contingency recognition (Haskett & Hollar, 1978).

Operant behaviors, such as kicking, arm waving, sucking, head turning, smiling, and vocalizing comprise the behaviors that have been shown to be conditionable. When any of these behaviors is reinforced immediately (within 3 seconds) (Cavanagh & Davidson, 1973; Millar, 1972; Ramey & Ourth, 1971), increases in both production of the behavior and rate of behavior production have been reported (e.g., Dunst, 1984; Leuba & Friedlander, 1968; Rheingold et al., 1959; Rovee & Rovee, 1969; Weisberg, 1963).

Search Strategy

Search Terms

Keywords used to search for articles included latency to learn, contingency awareness, contingency learning, contingent learning, response-contingent learning, response contingency, contiguous reinforcement, contingent reinforcement, conjugate learning, concomitant learning, and adjunctive learning. Searches by key author names were done in the Social Sciences Citation Index. Key phrases followed Boolean logic construction and included latency or learning and infants with disabilities, latency and learning and young children with disabilities, contingency learning and infants with disabilities, latency to learn and children with disabilities, learning and young children with disabilities, response contingency and infants with disabilities, and response contingent learning and young children with disabilities.

Sources

Relevant studies were located using the following computer information databases and search engines: Psychological Abstracts (PsycINFO, 1959-2002), Educational Resources Information Center (ERIC, 1966-2002), Ingenta, Dissertation Abstracts (Digital Dissertations, 1960-2002), Social Sciences Citation Index (SSCI, 1994-2002), Health Source: Nursing/Academic Edition, Academic Search Elite (1985-2002), InfoTrac Expanded Academic ASAP (1982-2002), Social SciSearch and SciSearch, ProQuest newspapers, and Ohio Library and Information Network (OhioLINK) Electronic Journal Center (EJC). Archival and hand-searches of relevant 2001-2002 professional journals augmented the computer-assisted search for relevant research on latency to learn in children with disabilities.

Selection Criteria

Studies included in this synthesis were ones that reported individual participant data in which latency-to-learn measures were reported (e.g., Dunst et al., 1985) or could be calculated. Latency to learn was measured in terms of the number of minutes of delay in demonstrating learning following the availability of a reinforcement. In instances where two or more operant behaviors were examined for an individual participant, the behavior with the shortest latency to learn was used for calculating the latency measure.

The studies selected for inclusion were limited to ones that investigated operant learning among children with identified disabilities, developmental delays, and children at risk for delay for various reasons and to ones in which the reinforcements were available immediately upon the child's production of an operant behavior. Studies that intentionally delivered a reinforcement with any length of delay were excluded. This inclusion/exclusion criterion was used to ensure that the studies analyzed had nearly identical experimental conditions. Even though a latency to learn was clearly present in some contingency studies of young children with or at risk for developmental delays (e.g., Ramey et al., 1975), they were excluded if no individual participant data were provided or if latency-to-learn measures could not be calculated for individual study participants.

Search Results

Sixteen (16) studies were located that included 73 participants. Latency-to-learn measures could be calculated or estimated for 49 of the 73 participants (67%). Tables 1 and 2 show selected characteristics of these 49 participants, the research designs used in the studies, and the characteristics of the response-contingent learning opportunities afforded the children.

Participants

The participants ranged in age from 3 months to 209 months old (17.4 years) with several investigators describing participants as "very young" rather than reporting exact ages. In studies where developmental ages were not reported, they were estimated using the chronological ages of typically developing children in studies investigating the same type of response-contingent learning opportunity. The reported or estimated developmental ages for the participants ranged from 1 month to 18 months. The participants' developmental quotients varied from 2 to 90, and were calculated using the formula: Developmental Quotient (DQ) = (Developmental Age divided by Chronological Age) X 100.

Most of the participants had multiple disabilities, with the majority having cerebral palsy (17), followed by Down's syndrome (14). Other disabilities or conditions reported (some co-occurring) were visual impairments (11), seizures (11), specified motor dysfunction (7), unspecified motoric and cognitive delays (7), encephalopathy or microcephaly (5), mental retardation (5), brain damage (4), auditory impairments (4), and congenital heart disease (2).

Research Designs

The 16 studies included in the synthesis used experimental or quasi-experimental designs. Twenty-nine participants were involved in some variation of an ABA research design, in which A represents the baseline or extinction phase of a study and B represents the conditioning phase or phases. Multiple baseline designs were used with 20 study participants.

Practices

In each study included in the review, the environment was arranged such that the production of the operant behavior by the participants was followed immediately by a social or nonsocial reinforcement. The operant behaviors that the participants were targeted to use included leg or foot movements (N = 11, 22%); lever, switch, knob, or panel presses (N = 10, 20%); vocalizations (N = 8, 16%); arm movements (N = 8, 16%); head turns (N = 5, 10%); gazing or visual fixation (N = 4, 8%); and reaching or grasping (N = 3, 6%). These behaviors were reinforced by nonsocial (N = 41, 84%) or social (N = 8, 16%) consequences, including visual access to different kinds of geometric figures, characters, and colored lights (N = 17, 34%); reactive toys (N = 12, 24%); auditory feedback (e.g., music, chimes) (N = 12, 24%); adult vocalizations (N = 7, 14%); mobiles (N = 5, 10%); and vibration (N = 3, 6%).

Synthesis Findings

Table 3 shows the findings from the studies in terms of operant learning and the social-emotional consequences associated with operant learning. The number of minutes (latency to learn) each study participant took to demonstrate learning is shown in the last column of the table. This was determined from inspection of graphs or from information provided in the research reports.

Operant Learning

The fact that the learning demonstrated or reported was due to the relationship between the child's behavior and its reinforcing consequences is supported by findings from other studies where noncontingent experimental conditions were included and were found to be associated with lower levels of operant responding compared to response-contingent experimental conditions .

Learning was demonstrated or reported for 47 (96%) of the 49 participants for whom individual data were available. In 46 cases, the study participants demonstrated increases in their levels of responding that exceeded the baseline response rate by 1.5 times or greater, regardless of the operant behavior or contingent response under investigation. In the case of one additional child, the rate of responding increased 1.4 times over baseline. In several studies, participants also demonstrated their ability to detect a shift in the contingency (e.g., arm to leg movement shift) and increased the level of response using the new operant behavior.

Social-Emotional Concomitants

Investigators reported the social-emotional concomitants associated with learning the contingency between a behavior and its consequence in eight studies (50%). The positive social-emotional outcomes included smiling or laughing, alertness, eagerness, excitement or less apathy, vocalizations, reaching or gesturing, and positive facial expressions. Three investigators reported positive reactions by parents upon witnessing their child's ability to learn the contingency (Dunst et al., 1985; Hanson & Hanline, 1985; Sullivan & Lewis, 1990). Three investigators reported that negative affect (crying, fussing, lack of smiling, self-stimulatory behaviors) occurred during extinction or when the participants realized their loss of control over the contingent reinforcement (Haskett & Hollar, 1978; O'Brien, Glenn, & Cunningham, 1994; Ramey et al., 1972).

Among the studies that reported social-emotional outcomes associated with learning the contingency between a behavior and its consequences, the rate of positive affect increased when the participants learned the contingency and decreased during extinction, often accompanied by indications of frustration when the child's behavior no longer produced a reinforcement. These results suggest that children exhibit more positive social-emotional behaviors when they become aware of their control over an aspect of the environment (contingency awareness).

Latency to Learn

The mean latency to learn was 35.43 minutes (SD = 65.64, Range = 0 to 300). Figure 1 shows the distribution of the children's latency to learn according to different time interval measures. Latencies were calculated from the individual data for the 47 participants. The latencies to learn for two participants in the O'Brien et al. (1994) study were estimated from the graphs and other information in the original reports. Nearly three-quarters (71%) of the participants showed a latency to learn of five (5) or more minutes, and 19 (39%) of the participants showed a latency to learn of 20 or more minutes. Just four (8%) participants showed no latency to learn, and 14 (29%) participants' latency to learn was nearly the same as found in studies of children without delays or identified disabilities (0-4 minutes).

Correlates of latency to learn. The extent to which latency to learn was related to either child characteristics or the characteristics of the response-contingent learning opportunities was determined through bivariate and correlational analyses and a between group ANOVA. The child characteristics examined were chronological age, mental age, severity of delay (i.e., DQ), and child diagnosis (physically disabled/multiply disabled vs. Down's syndrome/at risk). The learning-opportunities characteristics examined were type of operant behavior (arm/hand movement vs. other), operant arrangement (free operant vs. prompted response), and type of reinforcement (social vs. nonsocial). The particular learning-opportunities characteristics examined were identified through preliminary analyses suggesting the environmental conditions that may have been related to the latency measure.

Figure 1. Percentage of study participants showing different latencies to learn.

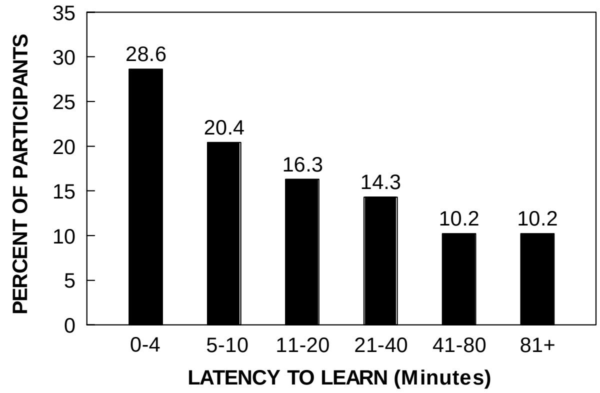


Table 4 shows the zero-order correlations between the latency-to-learn measure and both the child and the response-contingent learning characteristics measures. Three child measures and two response-contingent learning opportunity measures were correlated with a latency to learn. Participants with lower DQs, physical or multiple disabilities, and those who were older, were more likely to show a latency to learn. A latency to learn was more likely to be found when a hand/arm movement was used as the operant behavior and a social response was used as a reinforcement.

Further examination of the data was made by plotting latency to learn against child DQ. The graph is shown in Figure 2, and as can be seen, there is a curvilinear rather than linear relationship between DQ and a latency to learn. Moreover, there is a clearly discernible trend showing a greater latency to learn among children with DQs toward the bottom end of the DQ continuum, specifically children with DQs less than 20.

Further analyses were performed to isolate the nature of the latency to learn among the study participants by constituting groups using DQ as a blocking variable, and ascertaining variations in latency to learn. These results, shown in Figure 3, make more clear the curvilinear relationship between DQ and a latency to learn. A 5-Between Group (Child DQ) ANOVA with latency to learn as the dependent measure and a test for a quadratic trend produced a significant curvilinear finding, $F(1, 47) = 3.77$, $p < .05$.

Figure 2. Scatterplot of the relationship between child developmental quotient and latency to learn.

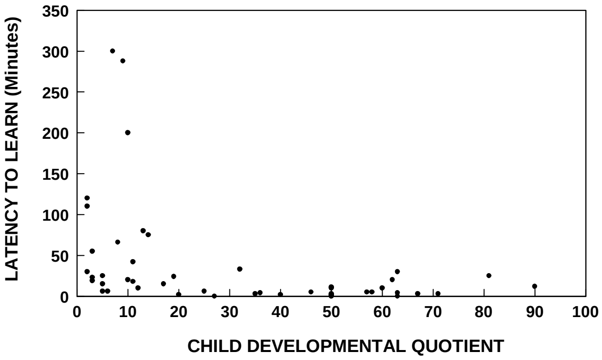
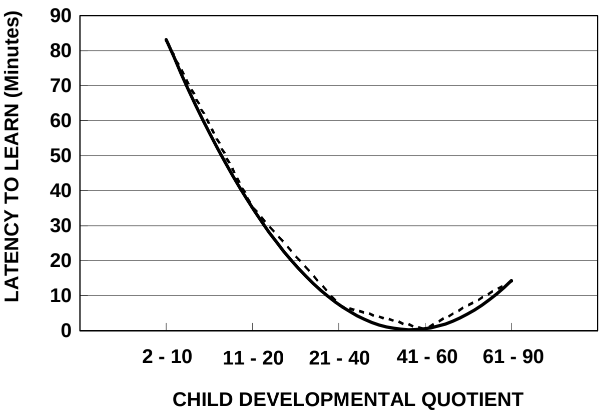


Figure 3. Curvilinear relationship between severity of child delay and a latency to learn. (Dotted line is for mean latency to learn scores and the solid line is the trend line.)



Rival Explanations

Threats to internal validity and rival explanations were minimal because of the relatively short duration of the majority of the response-contingent learning situations and because investigators provided explanations for experimental conditions that could have influenced the outcomes. Other concerns that could have affected the results are discussed in the following section.

Learning outcomes. Maturation or history are unlikely threats because most participants had long histories of not producing operant behaviors and only began to produce the behaviors when they had some control in the learning situation. The concern that learning a contingency between an operant behavior and its consequences might be short-lived was mitigated by those studies in which the participants demonstrated learning a shift in contingencies (e.g., Brinker & Lewis, 1982; Sullivan & Lewis, 1990, 1993). Several of the studies used observation reports; however, instrumentation threats were diminished by the use of more than one trained observer and multiple data sources in those studies. Although parents, experimenters, and observers were often employed to conduct the experiments, outcomes were usually recorded on videotape or on event recorders for later analysis and for observation reliability checks (range = 78%-100% agreement reported across studies). Physical capabilities of some participants resulted in variations in the treatment in several cases; therefore, factors associated with severity of delay, such as extent or pattern of participation in the learning situations, may account for some of the variation. Finally, the difficulties inherent in using control groups and random assignment with a small sample of developmentally young participants may have impacted the learning outcomes for some participants.

Social-emotional outcomes. Although not explicitly measured in most of the included studies, state changes are not unusual for children at younger developmental ages and might have influenced the social-emotional outcomes. However, investigators attempted to plan experimental sessions during times the participants were alert and comfortable. For this reason, it is less likely that general state changes, the attention spans of the participants, or reduction in the value of the reinforcement due to habituation were threats to the validity of the reported social-emotional outcomes. The contention that positive social-emotional behavior accompanies the learning of a contingency between a behavior and its consequences was reinforced in several studies (Haskett & Hollar, 1978; O'Brien et al., 1994; Ramey et al., 1972) by the appearance of negative affect or the reduction of positive affect when the expectancy of control was violated.

Latencies. Latency to learn may have been affected by the experimental conditions. Some studies were conducted in laboratory environments with experimenters or teachers present, while others were conducted without assistance or were conducted in homes by the parents. Habituation to the reinforcer, boredom, or state changes seem unlikely threats, given the investigators' attempts to proceed only when participants were comfortable and to change the reinforcer during the investigation if necessary. Other considerations include individual child characteristics (e.g., physical capabilities), a long history of noncontingent stimulation, and particular characteristics of the experimental arrangement (e.g., hand responses = greater degree of latency). Although these considerations might explain the latency, they also tell something about which kinds of experimental conditions work best to produce rapid learning.

Conclusion

The findings from this research synthesis indicate that children with disabilities and developmental delays do learn the contingency between their behavior and its environmental consequences in a manner identical to children who are typically developing, but that the largest majority of the children take considerably longer to learn a contingency compared to that found for typically developing children. Moreover, the latency to learn is related to a number of person and environmental factors, most notably a child's severity of delay. Results also indicate that the relationship between operant learning and social-emotional responding is very much like that found in studies of infants without disabilities or delays (see Dunst, 2003). In studies measuring or reporting the social-emotional concomitants of operant learning, positive social-emotional outcomes are frequently exhibited by the children as they realize they have an impact on things or events in their environments.

Findings from this synthesis, together with supplemental data analysis performed, indicate that the latency to learn is related to both child characteristics (chronological age, disability type, severity of delay) and characteristics of the learning opportunity (type of operant behavior, type of reinforcement). Secondary analyses of data from primary studies show that children with disabilities are likely to exhibit a latency to learn, with a greater degree of latency reported if they are chronologically older, have a physical disability or multiple disabilities, have a DQ toward the lower end of the DQ continuum, and are required to use a hand or arm movement as the operant behavior or a social reinforcement.

Implications for Practice

Findings reported in this synthesis have a number of implications for practice. First, response-contingent learning opportunities are a form of early intervention that can increase a child's production of either social or nonsocial behavior, or both. The use of contingency games and learning opportunities is especially warranted for children functioning developmentally between 2 and 8-10 months of age. Contingency experiences are ones where a child's behavior is reinforced or elicits an interesting environmental consequence (e.g., talking to a child or tickling a child's tummy in response to his or her looking at the adult's face).

Second, children with disabilities, and especially children with physical or multiple disabilities, need to be provided ample time and opportunity to learn a contingency between their behavior and its consequences. A latency to learn of up to 20 minutes can be expected for some children, and longer latencies can be expected for children with profound and severe developmental delays. The implication for this likely occurrence is not to give up too quickly when a particular contingency experience is first introduced or used to promote child behavior.

Third, it is important to take into consideration both the operant behavior and the types of reinforcement when selecting contingency-learning opportunities for particular children. Children first learning response-contingent relationships are more likely to do so if an operant behavior other than hand or arm movement is paired with a nonsocial reinforcement to condition behavior. If arm or hand movements are used, a longer latency to learn may occur. If social reinforcers are used, it is important that they be delivered as quickly as possible following each operant behavior in order for the child to make the connection between his or her behavior and its consequences (e.g., smiling to and "kissing" the child's hand for reaching toward an adult's face).

A few rules-of-thumb can be followed in deciding whether a child will likely show a latency to learn and, therefore, how much time needs to be allocated to promoting a child's acquisition and use of operant behavior. Does the child have a physical disability or multiple disabilities? Is the child's DQ 40 or less? Is the child chronologically two years of age or older? Is the child functioning developmentally at a 1-2 month age level? If the answer to all of these questions is *Yes*, then there is a higher likelihood that the child will show a latency to learn. If the answer to all or most questions is *No*, then more rapid learning can be expected with the proper contingency arrangements. A combination of *Yes* and *No* answers means that a shorter latency to learn might be expected.

There is one last thing that can be taken into consideration in deciding when a child has "mastered" a contingency. Children often display social-emotional responding as part of learning a contingency. It is generally agreed that this type of response is an indication that the child has come to "understand" the relationship between his or her behavior and its consequences ("I did it!" "I made it happen!" etc.). This type of response can help determine when new contingency experiences might be introduced or existing opportunities might be modified to "make them more interesting." Decisions about introducing new learning opportunities, changing existing ones, child mastery, etc., can be enhanced when the full range of information about the child's disability or delays, the characteristics of the response-contingent learning opportunities, and child operant and social-emotional responding are used to determine the types and amount of learning experiences that he or she needs to be afforded to promote competence.

Practice-based research syntheses of the sort described in *Bridges* shed light on how to use research to inform practice. A companion to the *Bridges* is a *Bottomlines* (Vol. 1, No. 5) report that describes the major findings of the research in nontechnical, user-friendly language. The *Bottomlines* summarizes for parents and practitioners what we know about latency to learn in response-contingent learning situations and provides a realistic vignette illustrating the practice with young children and parents.

In addition, *Bridges* and *Bottomlines* are being used to produce practice guides that provide guidelines for determining the effort that is necessary before learning is likely to occur, based on the child's diagnosis and severity of delay. Further elaborations on how this is done are included in the different versions of the practice guides based on this topic, available to readers in electronic versions at our website (*www.researchtopractice.info*) and in written versions that can be obtained by writing to our Research and Training Center address. Practice guides are developed by our staff when research evidence supports the use of a particular practice.

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Table 1
Characteristics of the Study Participants

Study	P[a]	Chronological Age (Months)	Developmental Age (Months)	DQ[d]	Diagnosis
		Participant Characteristics			
Bailey & Meyerson (1969)	1	84	6[b]	7	Blind, partially deaf, non-vocal, non-ambulatory, care dependent
Brinker & Lewis (1981)	1	6	4	67	Down's syndrome
	2	3.5	2	57	Down's syndrome
	4	6.5	3	46	Down's syndrome
	5	4	2.5	63	Down's syndrome
Brinker & Lewis (1982)	1	5	2	40	Low birth weight, premature
	3	6	3.5[c]	58	Down's syndrome
Correa et al. (1984)	1	28	3.6	13	Cortical blindness, cerebral palsy, seizures
	2	51	4.5	9	Cerebral cortical atrophy, congenital/cortical blindness, optic atrophy, seizures, motor delay, failure to thrive
	3	27	2.8	10	Congenital blindness, hydrocephaly, motor delay, seizures
Dunst et al. (1985)	1	36	4	11	Hypotonia, seizure disorder
	2	33	2	6	Quadriplegia, seizure disorder, hypoglycemia
	5	31	1	3	Encephalopathy, seizure disorder, quadriplegia, microcephaly
	6	36	1	3	Severe brain damage, seizure disorder, quadriplegia
Gazdag & Warren (2000)	1	29	18	62	Mild cerebral palsy, mental retardation
	2	28	17.5	63	Mental retardation
	3	26	15.5	60	Down's syndrome, mental retardation
Hanson & Hanline (1985)	1	19	1	5	Severe neuromuscular spastic quadriplegia, seizures, tube fed
	2	8	6.5	81	Down's syndrome, developmental delay, visual/ auditory impairment
	3	25	3.5	14	Cerebral palsy, seizure disorder, severely delayed in all developmental areas, visual disability
Haskett & Hollar (1978)	1	208	4.5	2	Postnatal cerebral infection, unspecified
	2	196	4.25	2	Chromosomal abnormality, G group
	3	114	5.5	5	Unknown prenatal influence, unspecified
	4	209	6.5	3	Gross brain disease postnatal, unspecified
Horn & Warren (1987)	1	24	6	25	Methylmalonic academia, severe visual impairment
	2	17	6	35	Cerebral hypotonia
Laub & Dunst (1974)	1	12	6	50	Severe cerebral palsy

Table 1, continued

Study	P[a]	Participant Characteristics			
		Chronological Age (Months)	Developmental Age (Months)	DQ	Diagnosis
O'Brien et al. (1994)	1	12	2.3	19	Cerebral palsy, visual and motor impairments
	2	48	4	8	Killian-Pallister syndrome, visual and motor impairments
	3	3	2.7	90	Down's syndrome
	4	19	6	32	CHARGE syndrome, motor, visual, auditory impairments
	5	44	12	27	Cornelia de Lange syndrome, motor impairment
	6	40	2	5	Neonatal encephalopathy, motor impairment
	7	28	3	11	Unknown, auditory impairment
Ramey et al. (1972)	1	7	5	71	Failure to thrive
	2	14	5	36	Failure to thrive
	3	8	5	63	Congenital heart disease; otherwise, apparently normally developing
	4	10	5	50	Congenital heart disease; otherwise, apparently normally developing
Sullivan & Lewis (1990)	1	NR	NR		Down's syndrome
Sullivan & Lewis (1993)	1	NR	6		Cerebral palsy
	2	NR	3		Down's syndrome
	3	NR	6		Down's syndrome
	4	NR	6		Down's syndrome
	5				Down's syndrome
Utley et al. (1983)	1	22	3	14	Athetoid cerebral palsy and cortical blindness due to neonatal asphyxia
	2	26	3	12	Spastic quadriplegia and convulsive disorder
	3	18	3	17	Febrile seizure disorder, static encephalopathy, spastic quadriplegia
	4	31	3	10	Seizure disorder and athetosis due to meningitis
Watson (1972)	1	8	NR	2	Severe retardation

[a] Study participants

[b] These are estimated developmental ages based on the average ages that typically developing children learned the same contingency under similar reinforcement conditions

[c] Mid-point of the reported 2-5 months MA range

[d] Developmental quotient

Table 2

Research Designs and Characteristics of the Response-Contingent Learning Opportunities

Study	P[a]	Research Design[b]	Response-Contingent Learning Opportunities		
			Operant Behavior	Reinforcement	Type[c]
Bailey & Meyerson (1969)	1	ABA	Lever presses (available 24 hours a day)	6-second vibration (available 24 hours a day)	NS
Brinker & Lewis (1981)	1	AB	Arm pull	Individually selected tape recording of music or mom's voice; mechanical train with tune, colored lights, or photographic slide	NS
	2	AB	Arm pull	Individually selected tape recording of music or mom's voice; mechanical train with tune, colored lights, or photographic slide	NS
	4	AB	Leg kicks	Individually selected tape recording of music or mom's voice; mechanical train with tune, colored lights, or photographic slide	NS
	5	AB	Leg kicks	Individually selected tape recording of music or mom's voice; mechanical train with tune, colored lights, or photographic slide	NS
Brinker & Lewis (1982)	1	AB	Arm pull	Battery-powered train	NS
	3	AB	Arm pull switched to leg kicks	Recorded music	NS
Correa et al. (1984)	1	Multiple baseline	Reach-grasp response with graduated prompting	Social praise and access to novel noisemaking toys	S
	2	Multiple baseline	Reach-grasp response with graduated prompting	Social praise and access to novel noisemaking toys	S
	3	Multiple baseline	Reach-grasp response with graduated prompting	Social praise and access to novel noisemaking toys, vibration added in phase 2	S
Dunst et al. (1985)	1	ABA	Fixated head turns	Visual display of multicolored lights that illuminate repeatedly, suspended over crib	NS
	2	ABA	Fixated head turns	Visual display of multicolored lights that illuminate repeatedly, suspended over crib	NS
	5	ABA	Fixated head turns	Visual display of multicolored lights that illuminate repeatedly, suspended over crib	NS
	6	$AB_1B_2B_3B_4A$	Fixated head turns	Visual display of multicolored lights that illuminate repeatedly, suspended over crib	NS
Gazdag & Warren (2000)	1	Multiple baseline	Vocalization	Adult contingent vocal imitation	S
	2	Multiple baseline	Vocalization	Adult contingent vocal imitation	S
	3	Multiple baseline	Vocalization	Adult contingent vocal imitation	S
Hanson & Hanline (1985)	1	ABA	Leg kicking	Vibratory stimulation	NS
	2	ABABA	Panel presses	Beep that calls parents for social reinforcement	S
	3	ABA	Head turns to midline	Combined chimes and light in row of cubes	NS
Haskett & Hollar (1978)	1	ABAB	Lever presses	Illumination	NS
	2	ABAB	Lever presses	Illumination	NS
	3	ABAB	Lever presses	Audio (music) feedback	NS
	4	ABAB	Lever presses	Audio (music) feedback	NS

Table 2, continued

Study	P[a]	Research Design[b]	Response-Contingent Learning Opportunities: Operant Behavior	Reinforcement	Type[c]
Horn & Warren (1987)	1	Multiple baseline	Switch presses	Access to preferred toy of individual child	NS
	2	Multiple baseline	Switch presses	Access to preferred toy of individual child	NS
Laub & Dunst (1974)	1	ABAB	Child vocalizations	Imitative vocalization	S
O'Brien et al. (1994)	1	ABA	Leg movement	When an infrared beam to a smiling face display is disrupted by arm or leg movement, four rotating arms and nursery rhymes are activated.	NS
	2	ABA	Arm movement	When an infrared beam to a smiling face display is disrupted by arm or leg movement, four rotating arms and nursery rhymes are activated.	NS
	3	$AB_1B_1B_2A$	Leg movement	When an infrared beam to a smiling face display is disrupted by arm or leg movement, four rotating arms and nursery rhymes are activated.	NS
	4	$AB_1B_1B_2B_1A$	Leg movement	When an infrared beam to a smiling face display is disrupted by arm or leg movement, four rotating arms and nursery rhymes are activated.	NS
	5	$AB_1B_1B_2B_1A$	Leg movement	When an infrared beam to a smiling face display is disrupted by arm or leg movement, four rotating arms and nursery rhymes are activated.	NS
	6	$AB_1B_2B_1A$	Leg movement	When an infrared beam to a smiling face display is disrupted by arm or leg movement, four rotating arms and nursery rhymes are activated.	NS
	7	$AB_1B_1B_2B_1A$	Leg movement	When an infrared beam to a smiling face display is disrupted by arm or leg movement, four rotating arms and nursery rhymes are activated.	NS
Ramey et al. (1972)	1	$AB_1B_2B_3B_1A$	Vocalization	Brightly colored geometric figure	NS
	2	$AB_1B_2B_3A$	Vocalization	Brightly colored geometric figure	NS
	3	AB	Vocalization	Brightly colored geometric figure	NS
	4	AB	Vocalization	Brightly colored geometric figure	NS
Sullivan & Lewis (1990)	1	ABB	Arm pull lever (contingent) and kick panel (non-contingent)	Access to various toys of choice and unspecified consequences	NS
Sullivan & Lewis (1993)	1	ABB	Left arm pull	Drummer toy	NS
	2	ABB	Leg kicks	Barking puppy toy, with switch to jack-in-the-box	NS
	3	ABB	Leg kicks	Toy	NS
	4	ABB	Arm pulls	Drummer bear with switch to TV music box	NS
	5	ABB	Switch plate tapping, which changed to barrel switch tapping	Musical jack-in-the-box, with switch to mambo bear	NS
Utley et al. (1983)	1	AB_1B_2A	Visual fixation	Multicolored lights circled around a central night light	NS
	2	AB_1B_2A	Visual fixation	Multicolored lights circled around a central night light	NS
	3	AB_1B_2A	Visual fixation	Multicolored lights circled around a central night light	NS
	4	AB_1B_2A	Visual fixation	Multicolored lights circled around a central night light	NS

Table 2, continued

Study	P[a]	Research Design[b]	Response-Contingent Learning Opportunities		
			Operant Behavior	Reinforcement	Type[c]
Watson (1972)	1	ABA	Leg movement	Turning mobile	NS

[a] Study participants

[b] A = Baseline or extinction phase of a study, B = Conditioning phase of a study, and the subscripted A or B phases of a study indicate different baseline/extinction or experimental conditions respectively

[c] Type of reinforcement: S = Social, NS = Nonsocial

Table 3
Results and Latency-to-Learn Measures

Study	Results: Operant Learning	Results: Social-Emotional Behavior	P[a]	Latency to Learn (Minutes)
Bailey & Meyerson (1969)	Participant more than doubled lever presses over the baseline frequency and decreased them during extinction to baseline level during conditioning.	Remained motionless or giggled occasionally (observer statement)	1	1440[b]
Brinker & Lewis (1981)	Four of the five participants increased arm pulls and leg kicks during conditioning. P3 did not demonstrate learning the contingency; not included in data report.		1 2 4 5	3 5 5 4
Brinker & Lewis (1982)	Both participants increased arm pulls, leg kicks, and arm-leg switches during conditioning. Data for P2 & P4 included in previous data and not repeated in this reporting.		1 3	2 5
Correa et al. (1984)	Graduated prompting procedure was effective in training reach-grasp responding in all three participants. For one participant, the procedure was effective in reaching toward all three positions on a high chair tray and generalized to toys presented without sounds; verbal instruction was provided only during conditioning.		1 2 3	80 288 200
Dunst et al. (1985)	Four of the six infants demonstrated increases in head turns during conditioning. P3 & P4 did not demonstrate learning during a single experimental session attempted; data not included.	Parents and caregivers responded positively to evidence that child could learn.	1 2 5 6	18 6 23 4
Gazdag & Warren (2002)	All three participants exhibited increases in vocal imitation during conditioning. None of the children, however, showed an increase in elicited vocal imitation in response to adult contingent imitation or elicited imitation prompts in the generalization and posttest sessions.		1 2 3	20 30 10
Hanson & Hanline (1985)	Three participants with severe disabilities increased the production of leg kicks, panel presses, and head turns with contingency feedback during conditioning.	Smiling and vocalization measures were elevated for only 1 child; state changes were not evident. Mothers reported that fathers and siblings became more actively involved in the "teaching" procedures when using technology. Data were equivocal about contingency awareness and attention as measured by affective behavior production.	1 2 3	15 25 75
Haskett & Hollar (1978)	Three of the four participants were able to select and maintain operant responding for illumination or for music and to discriminate contingent from noncontingent stimulation. Examination of the collateral behavior of P4 yielded indirect support for discriminating the contingent stimulation.	Frequencies of vocalizing (3 participants) and smiling (1 participant) were measured by observers. Authors noted that enhanced vocalization suggested frustration over lack of control and that smiling for another participant in contingent conditions suggested a positive reaction to rediscovery of control.	1 2 3 4	30 120 25 55
Horn & Warren (1987)	Both participants showed substantial increases in levels of sensorimotor performance using a neuromotor/behavioral intervention. When contrasted to baseline, verbal and physical prompts also decreased over time, further indicating that learning occurred. Both demonstrated a high level of generalization and maintenance of each skill.		1 (Skill 1) 2 (Skill 1)	6 3
Laub & Dunst (1974)	Imitation of vocalization as reinforcement resulted in an increase in infant vocalizations during conditioning.		1	10

Table 3, continued

Study	Results: Operant Learning	Results: Social-Emotional Behavior	P[a]	Latency to Learn (Minutes)
O'Brien et al. (1994)	Five of the seven participants demonstrated increases in leg or arm movements during conditioning. (Examination of data yielded estimates for the extended latencies for P2 and P7).	Video recorded affective responses showed negative emotional reactions (fussing, crying) in one child; three others did not smile, which authors attributed to their detecting a change in causal relationships. Increased rates of self-stimulatory behavior were recorded for two children, possibly as a result of loss of control over the environment.	1 2 3 4 5 6 7	24 66[c] 12 33 0 6 42[c]
Ramey et al. (1972)	All four participants produced increases in overall mean vocalizations per minute during conditioning and increases in overall length of vocalizations following synchronous reinforcement.	P1: Increased rate and volume of previous soft guttural vocal response, but began crying during extinction. P2: Increased rate and quality of vocalizations, but began crying during extinction. Authors considered the frequent crying responses indicated frustration over loss of control of their environment. Anecdotal notations included: dramatic change in quality of each infant's vocal behavior; babbling for P1, more variety for P2. General positive changes for P1: less apathy and listlessness; Cattell = 93, which authors consider higher than it would have been pre-experiment. General positive changes for P2: Cattell at onset was 43, at end of conditioning, Cattell = 64. Elimination of gaze aversion and face-covering behaviors occurred.[d]	1 2 3 4	3 4 0 2
Sullivan & Lewis (1990)	Individual data reported on one infant with Down's syndrome who detected a contingency shift, switching from arm to leg responses. In the study, 19 of the 20 babies mastered control of more than one toy using a single response and almost all of the babies added a second response during conditioning.	Incidental statements and surveys by parents stated their children seemed more alert and interested, that the children began to seek out and pull any string-like object to see the results and to get parent's attention.	1	3
Sullivan & Lewis (1993)	P1 increased left arm pulling response; P2 recovered leg response after habituation to first reinforcer; P3 mastered a second contingency (leg) when a novel toy was introduced; P4 mastered both arm and leg, as well as a left-right discrimination with recovery of a left arm response for both toys; and P5 learned the contingency and shifted from one means of control to another.		1 2 3 4 5	2 0 11 0 1
Utley et al. (1983)	All four children increased mean duration of visual fixation under alternate treatments during conditioning. Ps discriminated between contingent and noncontingent conditions.		1 2 3 4	5 10 15 20
Watson (1972)	Leg activity increased four-fold, from 3 to 12 kicks per minute, during conditioning.	Vigorous and prolonged smiling and cooing	1	110

[a] Study participants

[b] For calculation of latencies and comparisons, 300 minutes was used in place of 1440 minutes to counteract the potential effects of the extreme measure

[c] Estimated latency to learn

[d] Catell = Cattell Infant Intelligence Scale (Cattell, 1960)

Table 4

Correlations Between Child Characteristics, Learning-Opportunities Characteristics and Latency to Learn

	Child Characteristics				Response-Contingent Learning Characteristics		
Measures	CA	MA	DQ	CD	OB	OA	TR
Latency to Learn	.28*	-.02	-.40**	-.29*	-.30*	.15	-.32*
Child Characteristics							
Chronological age (CA)	—	.07	-.48***	-.29*	-.42**	-.10	.11
Mental age (MA)		—	.36**	.26	.05	.39**	-.53***
Developmental quotient (DQ)			—	.73***	.03	.25*	-.21
Child diagnosis (CD)[a]				—	-.11	.33*	.01
Learning Opportunity Characteristics							
Operant behavior (OB)[b]					—	-.46***	-.06
Operant arrangement (OA)[c]						—	-.46***
Type of reinforcement (TR)[d]							—

* $p < .05$, ** $p < .01$, *** $p < .001$

[a] 0 = Physical or multiple disability vs. 1 = No physical or multiple disability

[b] 0 = Manual vs. 1 = Nonmanual response

[c] -1 = Free, 0 = Combination, 1 = Prompted

[d] 0 = Social vs. 1 = Nonsocial