In Search of Contingency Learning: Something Old, Something New, Something Borrowed

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Adaptive switches can bring desired environmental events, such as cool air from a fan or music from a favorite radio station under the control of people with profound motor and communication deficits. A number of investigators have reported difficulties, however, in assessing whether people supported with switch-device configurations show cause-and-effect or contingency learning. Without expensive computer interfaces, analysis of switch-use is limited severely by inadequacies in commercially available adaptive equipment. Automated augmentations of typical switch-device configurations are described herein that provide data essential to accurate conclusions regarding the volitional nature of switch use. Case study examples of the importance of duration measures of responding and real-time data collection are provided. Relevance of this technology for identification of reinforcer preference hierarchies, field-based infant research, and treatment of challenging behavior are addressed.

Key words: adaptive switches, profound multiple disabilities, cause-and-effect learning, contingency learning, response variability, bin analyses, cumulative records

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Adaptive switches often are employed in educational and activity programs serving children and adults with profound multiple disabilities (Reid, Phillips, & Green, 1991). Adaptive switch programs often are directed at establishing communication skills such as signaling for attention, requesting, and choice making (Kennedy & Haring, 1993; Wacker, Wiggins, Fowler, & Berg, 1988). For others, the programs focus on establishing personal control of leisure-oriented materials or appliances, such as audio tape players, fans, vibrators, mechanical toys, and computer-delivered entertainment (Crawford & Schuster, 1993; Realon, Favell, & Dayvault, 1988; Saunders et al., 2001).

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Adaptive switches most commonly employed in such programs are constructed by housing a small electro-mechanical switch, or microswitch, in a user interface designed to make closure of the switch relatively effortless. Commercially manufactured microswitches, including pressure-sensitive disks, joysticks, mercury filled tubes and motion detectors, are available from a number of vendors. Switches can be used to toggle power on and off from both alternating current (AC) and direct current (DC) sources.

Adaptive switch programs usually are adopted and employed when efforts to establish more typical communication and environmental-control repertoires have failed. The individuals enrolled in switch programs often have severe motor skill deficits, with limitations in range of motion, grasp and release, coordination, and strength. Indeed, a common challenge to establishing a switch program is to identify a single physical movement that appears to be volitional and that also occurs with sufficient force and distance to displace a switch interface. Motor movement assessment also must address positioning and postural issues in the nonambulatory. Deafness, low vision, uncontrolled seizures, postural discomfort, multiple medications, frequent illnesses and other medical conditions characterize many individuals who might benefit from switch programs. Thus, individuals considered for microswitch supports frequently present with characteristics that interact to make interpretation of their switch responding difficult. These individuals are at risk of having switch supports discontinued or provided inconsistently because their switch use is perceived to be involuntary and therefore not functional.

Most data-based programs that employ adaptive switches usually employ a method of assessing whether switch use implies learning. In the present context, learning refers to establishment of differential responding across different response-event contingencies in adaptive switch configurations. Across disciplines other than behavior analysis, the descriptive phrase for differential responding is usually cause-and-effect learning, contingency learning (Gewirtz, 1997), or contingency awareness (Watson, 1966). In a typical test for contingency learning, an individual is exposed first to conditions in which responses to the switch do not produce an arranged outcome (no-activation condition). No-activation conditions are alternated with activation conditions in which responses produce an arranged outcome, such as music. Comparison of activation and no-activation conditions have been made across short consecutive periods (e.g., 5 min) within a session (Schweigert, 1989; Schweigert & Rowland, 1992), across single days with several short sessions per day (Dunst, Cushing, & Vance, 1985) and across several evaluation periods (e.g., 5-10 days) (e.g., Realon, Favell, & Lowerre, 1990; Schweigert, 1989; Saunders et al., 2001; Wacker et al., 1988).

In a review of studies of switch use in persons with disabilities, Lancioni, O'Reilly, and Basili (2001) reported that some participants did not show differential responding across no-activation and activation conditions. Participants either failed to show condition-related changes in responding (Dewson & Whiteley, 1987; Realon, Favell, & Dayvault, 1988; Ivancic & Bailey, 1996; Leatherby, Gast, Wolery, & Collins, 1992) or showed such highly variable responding across conditions that conclusions about contingency learning were equivocal (Leatherby et al., 1992; Ivancic et al., 1996). Discovering why contingency learning is not shown is complicated. Some switches provide sensory feedback (e.g., clicks, sudden displacement) that could compete with scheduled consequences (e.g., music). Response effort and fatigue, satiation, insufficient exposure to the contingencies and other factors also must be considered in data interpretation. This paper summarizes and presents illustrative data from our ongoing research on adaptive switch use by individuals with profound disabilities. The purpose of the paper is to introduce the reader to the data collection and analysis methods that have emerged to support this research. The methods have potential applications to clinical and field-based research in areas such as the treatment of aberrant behavior, infant learning, and self-monitoring of medication effects and side effects.

Method and Results

Participants

The individuals currently supported and studied in our work consist of about 120 individuals with severe to profound multiple disabilities, receiving services either in a skilled nursing facility or in community program offering vocational training, life enrichment and other supports in residential and day locations. Generally, these individuals present with an absence of language and other forms of communication, few coordinated movements, and suspected but difficult-to-measure sensory impairments. Profound mental retardation is inferred in nearly all but most are untestable with standardized instruments. Nearly all are nonambulatory. All require pervasive and extensive supports. A review of clinical records revealed that, prior to the institution of their switch programs, evidence of operant learning from formal programming was rare. Table 1 shows characteristics of the 9 participants whose data are discussed below.

Rate versus Duration Measurement

More than half of the individuals tested in our program of switch research initially showed little or no differences between activation and no-activation test phases. Our initial tests, conducted in the regularly scheduled daily recreation and leisure activity periods, relied on commercially available switch interfaces. Consequently, counts of switch closures were the only data we could collect with automated methods. To calculate rates of responding, session duration was measured with clocks or stopwatches and the automated counts were divided by session duration. The results of this limited methodology were disappointing. In most cases very low rates or highly variable rates of responding were recorded. Further, tests for contingency learning did not often provide conclusive data.

Table 1. Description of Participants

Participant	Age	Sensory impairment	Motor impairment	Other medical issues
Diane	58		severe bilateral spastic quadriplegia	scoliosis hydrocephaly seizure disorder
Robert	61	vision impairment	spastic quadriplegia	kyposcoliosis seizure disorder
Karen	29	blind: optic atrophy	spastic quadriplegia	kyposcoliosis microcephaly seizure disorder
Charles	37	blind: optic atrophy chorioretinitis	spastic quadriplegia	thorocolumbar rotoscoliosis
William	61	visual impairment	spastic quadriplegia	seizure disorder dysphagia
Mary	50	blind: retrolental fibroplasia	spastic quadriplegia choreoathetosis	encephalopathy hyperkeratosis of hands tardive dyskinesia
Ann	40	mild vision impairment	spastic quadriplegia	developmental aphasia
Tom	49	visual impairment	spastic paraplegia	seizure disorder
Alice	24		unsteady gait due to lymphedema	

When we changed to a homemade interface that permitted measurement of response duration, conclusions about contingency learning by our participants quickly changed (Saunders et al., 2001). The interface or data recorder was a 17.5 x 12 x 5 cm metal box housing a counter, timer, and other electronic components, shown in Figure 1, (Questad & Cullinen, 1987). All components were purchased through an electronics supply catalog. The box was connected in line between a participant's switch and a leisure device or appliance selected as a potential reinforcer. When the switch was depressed, concurrently the counter advanced one digit, the timer was activated, and the leisure device was activated. Device activation continued and the timer advanced digitally in increments of one-tenth of a minute until the switch was released. The total number and total duration of switch closures were recorded from the display panels located on the side of the box.

For the tests of contingency learning, the switch, leisure device, and data recorder were positioned physically in reference to the individual in the same way each activity period. When individuals were seated for activity periods, hand-depressed switches and the data recorder were located either on the individual's wheelchair tray or on a table in front of the individual's wheelchair. The switch was taped or affixed with Velcro® to the surface of the table or wheelchair tray top, as were all wires. Switches that operated with a head movement were attached to the back of the wheelchair using either a Velcro® strap or a special switch mount. Most leisure devices and the data recorder were located in front of the individual either on the table or wheelchair tray. When vibrators were the leisure devices, they were located in contact with the individual's body (e.g., vibrating pads are placed on upper legs; tube vibrators, around the neck). When an individual was positioned in bed for the activity period, the switch was clipped to the pillow or bed covers and wires were covered with a strip of cloth. Recorders and leisure devices other than vibrators were usually placed on a bedside table or shelf.

Table 2. Description of Switch Configuration

Participant	Type of switch	Position of switch	Leisure item activated	Position of participant
Diane	Big Red®	on wheel-chair tray	radio	sitting in wheelchair
Robert	Bass (Don Johnston, Inc.[4])	on wheel-chair tray	radio	sitting in wheelchair
Karen	Spec® (Ablenet, Inc.[2])	on pillow next to head	radio	prone in bed
Charles	Jelly Bean® (Ablenet, Inc.[2])	on wheel-chair head-rest	audio tape player	sitting in wheelchair
William	Pal Pad (Adaptivations Inc.[1])	on wheel-chair tray	audio tape player	sitting in wheelchair
Mary	Ellipse switch (Don Johnston[3])	on wheel-chair tray	tube vibrator	sitting in wheelchair
Ann	Pal Pad	on wheel-chair tray	vibrating pillow in lap	sitting in wheelchair
Tom	Multi-Sensory Center (Enabling Devices[4])	on table	vibration	sitting in chair
Alice	Pal Pad	on table	music	sitting in chair

Note.

[1]Adaptivations, Inc,. 2225 West 50th Street, Suite 100, Sioux Falls, SD 57105

[2]Ablenet, Inc., 1081 Tenth Avenue S.E., Minneapolis, MN 55414-1312

[3]Don Johnston, Inc., 26799 West Commerce Drive, Volo, IL 60073

[4]Enabling Devices, 385 Warburton Avenue, Hastings-on Hudson, NY 10706

At the start of each leisure activity period, the individual was prompted verbally and physically assisted to close the switch one time to activate the device. No further prompts were provided for the remainder of the activity period. At the end of the activity period, the time was recorded and the cumulative number of switch closures *and cumulative* duration of switch closures were transcribed from the readouts on the data recorder. The switch-closure count was transformed to rate. Total duration was transformed to "percent of activity period." Data were collected 3-4 times per week in activity periods of 45 min each. Recently, the data recorder shown in Figure 1 was replaced with a recorder with additional features, shown in Figure 2. The new recorder, manufactured specifically for this research by the University of Washington's Scientific Instruments Department, automatically records the length of the test period in addition to the total duration of responding and the number of responses. The new recorder also permits switch closures to either turn on a device or turn off a device that is already active or on.

Figure 3 shows results from Diane's tests for contingency learning in the top panels, with rate data plotted on the left and duration data (percent of activity period) plotted on the right. Table 2 provides information on Diane's switch, switch position, her position, and the leisure device she controlled (and similar information for the other participants).

Figure 1. Drawing of an early prototype of a data recorder for evaluation of adaptive switch use.

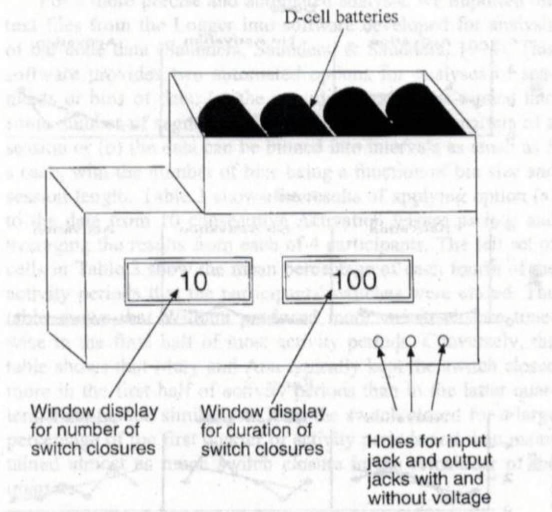


Figure 2. Drawing of the current data recorder. This unit displays switch closures, cumulative duration of switch closures, and cumulative duration of the session in the three LCD display windows labeled as a-c. Input/output jacks allow switches to activate a device, deactivate a device, or activate one device and deactivate a second device concurrently. The unit also has output for updating the HOBO® Logger regarding the state of the adaptive switch.

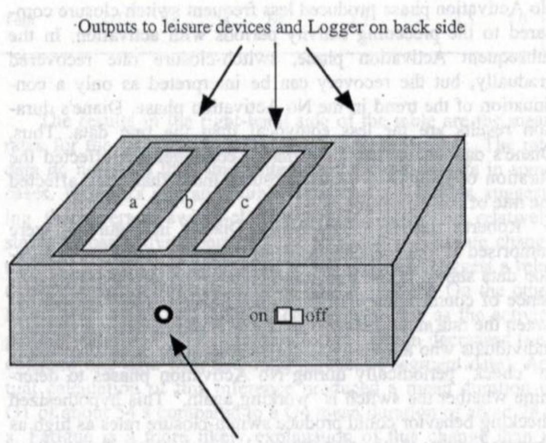
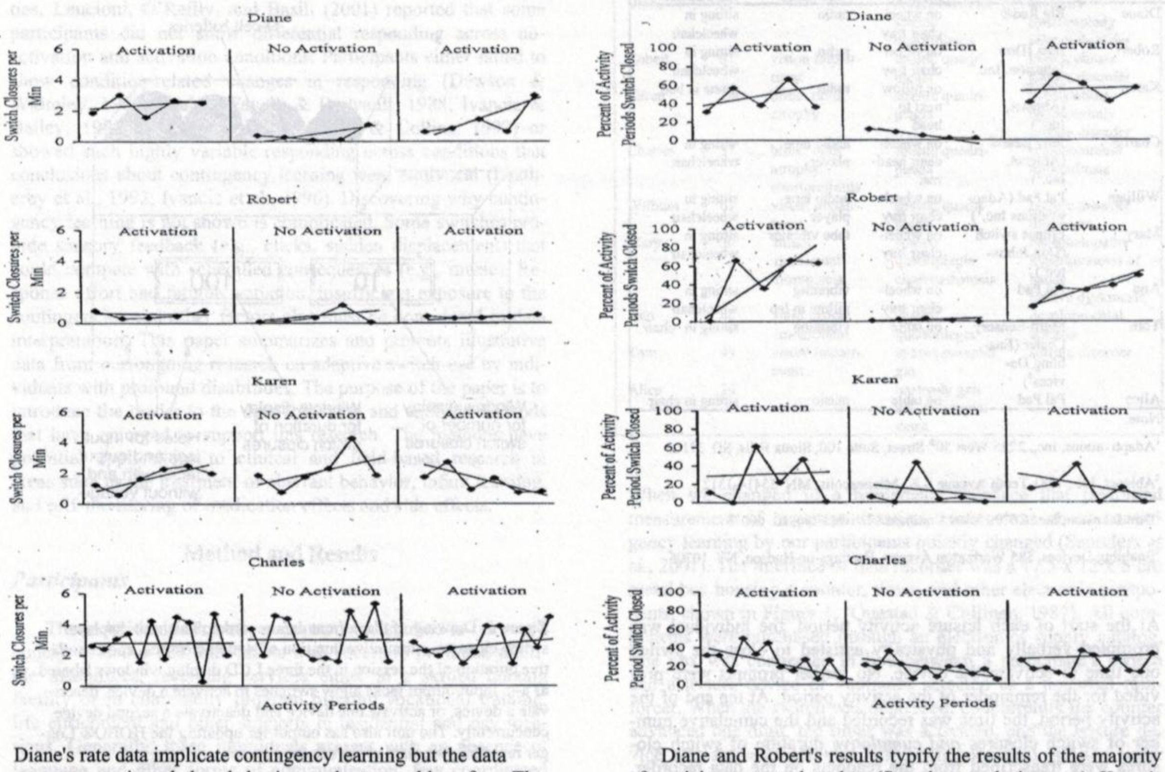


Figure 3. Graphs of rate switch closure and percent of session with switch closed (total duration) for 4 participants across multi-session tests for contingency learning.



Diane's rate data implicate contingency learning but the data are more equivocal than behavior analysts would prefer. The No Activation phase produced less frequent switch closure compared to the preceding activity periods with activation. In the subsequent Activation phase, switch-closure rate recovered gradually, but the recovery can be interpreted as only a continuation of the trend in the No Activation phase. Diane's duration results are far less equivocal than the rate data. Thus, Diane's data show that the different contingencies affected the duration of individual switch closures more than they affected the rate of those closures.

Robert's results, shown below Diane's in Figure 3, were comprised of totally inconclusive rate data. In contrast, the duration data shown in the right-hand panel provide convincing evidence of contingency learning as did Diane's. This contrast between the rate and duration results is not necessarily unexpected. Individuals who are motivated to activate their device are likely to "check" periodically during No Activation phases to determine whether the switch is "working again." This hypothesized checking behavior could produce switch-closure rates as high as observed during Activation Phases, but with much shorter durations. Alternatively, short duration responses might be maintained in the No Activation phase by sensory feedback from switch closures, as mentioned above.

Diane and Robert's results typify the results of the majority of participants tested to date (Saunders et al., in press). Karen's and Charles' results, shown below Robert's, are equivocal both when interpreted with the rate data or duration data. Their patterns typify the remaining smaller percentage of participants tested. Karen and Charles' results may mean (a) that the particular leisure device tested was not a reinforcer; (b) seizure activity, other medical conditions, or medication side effects mitigated potentially larger differences between test phases; or (c) the test periods were too short or too long. This latter case refers to the possibility that participants tired or satiated during long periods, washing out potentially clear effects. Were only the data from the first 5 min of each period analyzed, for example, contingency learning might have been shown. Alternatively, each may have had to learn the contingency anew each day. Thus, only the latter portion of each test period should be compared

Bin Analyses

To conduct analyses of specific portions of test periods the experimenter must either stop the tests at predetermined points, record the results, reset the counters, and restart the test or collect data throughout with real-time methods. In previous research requiring real time data, we employed bar code data collection technology (e.g., R. Saunders, Saunders, Brewer, &

Roach, 1996; M. Saunders, Saunders, & Marquis, 1998). Bar code systems require continuous observation by a human observer, however. In search of a methodology that did not require continuous observation, we found that the Onset Computer Corporation manufactures a variety of devices for continuous automated real time data collection. Some of their devices are used in climate and weather research. For our work, we borrowed from their technology by acquiring HOBO® State Loggers, HOBO® Shuttles and BoxCar ® Pro software.

HOBO® State Logger. The Logger is a plastic unit measuring approximately 4 x 6 x 1 cm. A CR-2032 lithium battery that provides enough power to operate for approximately 1 year of continuous use powers the unit. The Logger records switch closures in real time via input through a miniplug into its side. Thus, switch closures that activated participants' leisure devices could also be recorded with the Logger. The output from the Logger is a date and time stamped text file showing each change in the state of the switch--open versus closed. The Logger can store 2000 changes in state before its contents must be uploaded to a computer and its memory emptied.

HOBO® Shuttle. The Shuttle is a unit approximately 9 x 6 x 2 cm designed for uploading the contents of Loggers in the field. The Shuttle can store the contents of 200 Loggers before its contents must be uploaded to a computer. When the Shuttle empties the memory of a Logger, it re-initializes the Logger with the correct time and date and insures that its program is operational. The program operating in the Logger and the Shuttle is provided via BoxCar ® Pro software.

Figure 4. Schematic of the set up of a data recorder, Logger, adaptive switch, and leisure device.

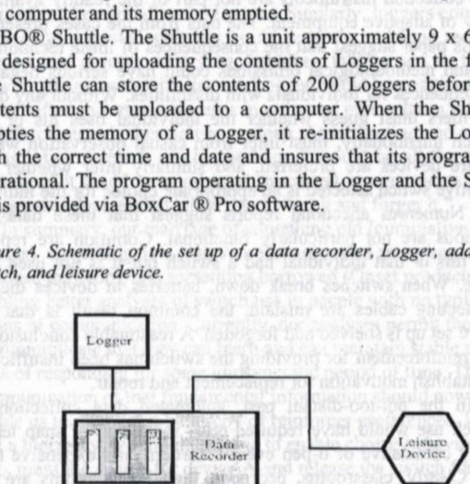


Figure 4 shows a schematic of the new recorder, a switch, a Logger, and a leisure device in the typical configuration. With this configuration, data have been collected and analyses begun to test our hypothesis that some participants do not respond consistently across their rather lengthy leisure activity periods. Following an activity period in which data are collected with this configuration, the BoxCar® Pro software produces summary statist*ics* (e.g., total number of closures) and can produce an on-screen depiction of the responding that occurred. The data are presented in the same form produced by event recorders, often common to animal laboratories. A continuous horizontal line depicts a switch in the open state and switch closures as vertical deviations from that line. The deviations are maintained as long as the switch is closed. Variations in response rate and response duration within the entire activity period can be detected with careful visual inspection of the event record.

For a more precise and automated analysis, we imported the text files from the Logger into software developed for analysis of bar code data (Saunders, Saunders, & Saunders, 1994). This software provides two automated options for analyses of segments or bins of data: (a) the recorded data can be binned into some number of segments of equal length, such as quarters of a session or (b) the data can be binned into intervals as small as 5 s each, with the number of bins being a function of bin size and session length. Table 3 shows the results of applying option (a) to the data from 10 consecutive Activation leisure periods and averaging the results from each of 4 participants. The left set of cells in Table 3 show the mean percentage of each fourth of the activity periods that the participants' switches were closed. The table shows that William produced more switch closure time-wise in the final half of most activity periods. Conversely, the table shows that Mary and Ann typically kept the switch closed more in the first half of activity periods than in the latter quarters. Tom tended similarly to keep the switch closed for a large percentage of the first quarter of activity periods and then maintained almost as much switch closure in the remainder of the quarters.

Table 3. Percent of Time Closing the Switch and Rate of Switch Closures in Each Quarter of a Session

Participant	Percent				Rate per min			
	Q 1	Q 2	Q 3	Q 4	Q1	Q2	Q3	Q4
William	9	8	23	16	0.4	0.3	0.8	0.6
Mary	72	60	40	33	0.8	0.5	0.7	0.7
Ann	21	26	14	11	3.0	2.1	1.3	1.3
Tom	71	53	54	64	1.2	1.2	1.5	1.0

The results in the right-hand side of the table are the mean rates for the quarters of the same 10 activity periods. The rate data do not yield the same pattern as the duration data in some cases. William's rate and duration patterns are similar, suggesting that average switch-closure duration remained relatively stable across activity periods (i.e., percentages and rate change together in the same directions). Ann's data also suggest a relatively consistent average duration across quarters. On the other hand, Mary's rate and duration data suggest that as the activity periods progressed, her average closure duration decreased (i.e., constant rate data with declining percent-of-segment data). Actual calculation of this inference produced a mean duration in Q1 of about 54 s compared to a Q4 mean duration of about 28.5 s. Fatigue is a more likely explanation of this change than is satiation because Mary's rate in Q4 was nearly as high as in Q1. Tom's rate and duration data reveal no particular interaction. Thus, for individuals whose whole-session data are ambiguous, bin analyses can lead the experimenter to closer examination of particular periods of responding.

Cumulative Records

One method for closer examination of responding is the production of cumulative records (e.g., Ferster & Skinner, 1957), a technique rarely seen in reports of applied research today. We produced cumulative records from the HOBO® text files by binning a session or session segment into small intervals of time and calculating the percent of each interval that the switch was closed and the number of closures per interval (option b, above). These data were exported to an Excel® spreadsheet wherein an embedded formula was used to transform the data into a series of cumulative sums.

Figure 5. Cumulative records of within-session tests of contingency learning with Alice from consecutive 20-s bins of data. In the upper graph, the arrow labeled "a" points to a burst of responses in the first 20-s interval, arrow labeled "b" points to a single response lasting several intervals, and the arrow labeled "c" points to s series of intervals with several responses in each.

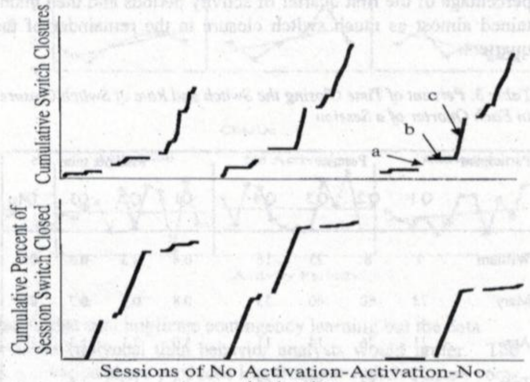


Figure 5 shows cumulative graphs for three contingency learning test sessions for Alice. Each 15-min test session was comprised of three 5-min phases. In these test sessions, Alice's tape player for listening to music was present on the table in front of her throughout each session. The tape player was not connected to the switch, however, in the first and third 5 min of each session.

The experimenter demonstrated what the switch did or did not do at the beginning of each 5-min phase by assisting Alice to make one switch closure. No prompts occurred thereafter. The cumulative records in the figure highlight the strengths of this form of analysis. First, the data show that learning occurred across test sessions. In particular, by the third session, the duration data (lower graph) show the pattern expected if learning occurred: The switch was closed nearly throughout the Activation phase, but was closed only briefly in the No Activation phases. The upper graph of cumulative responses shows a consistent pattern of low rate responding in the first No Activation phase followed by an increase during the Activation phase and even higher rate responding in the second No Activation phase. The data from the two graphs together can be interpreted as follows: Responding was not reinforced in the first phase; thus, response rates were low and long-duration responses extinguished across sessions. Responding was reinforced in the second phase, but high rates of responding are counter-productive if one desires continuous music; thus, rates remained modest and individual switch closures were relatively lengthy. In the third phase, high rate responding with very brief switch closures probably represents a schedule-history effect: Brief-duration, high-rate responding was an efficient method of "checking" to see if the music connection has been restored.

Discussion

Many clinicians, teachers, and care staff provide adaptive switches to individuals with profound multiple disabilities so they may control leisure devices. There is scant guidance from published research, however, on how to measure switch performances and evaluate the results. Most likely this is because data collection instruments are not part of the readily available array of adaptive equipment. The data from the cases presented in this paper suggest that the consequences of these technological and methodological omissions could have serious negative consequences for individuals with disabilities. Without any data, providers must guess whether the individual uses his or her switch intentionally, must infer from casual observation which leisure devices are preferred, and similarly infer whether the adaptive switch selected is an appropriate choice for the individual. Numerous anecdotal reports suggest that these data-less methods are not particularly functional. Common are reports that this or that individual had a switch but it is not used any more. When switches break down, batteries in devices die, or connecting cables are mislaid, the common result is that the entire set up is shelved and forgotten. A reasonable conclusion is that reinforcement for providing the switch has been insufficient to establish motivation for replacement and repair.

In the not-too-distant past, automated data collection of switch use would have required relay racks full of snap leads, bulky cumulative or 6-pen event recorders, and expensive timers. Clearly, classrooms, bedrooms, and living rooms are not places for these instruments. Microcircuitry and microprocessors are rapidly changing the possibilities, with emerging opportunities for behavior analysts. In the context of adaptive switches, for example, numerous areas need attention from professionals skilled in data analysis. In the current program climate, assessment of reinforcer preferences and provision of choice opportunities are hot topics. Field-based empirical evaluation of reinforcer preference is possible with equipment such as we described. Perhaps no better measure of preference can be found than comparison of the slopes of cumulative rate and duration. Another opportunity is evaluation of functional vision and hearing. Responding shown to be under the control of leisure devices with auditory or visual output can be tested for resistance to extinction as the auditory or visual output of the leisure devices is systematically altered (e.g. volume lowered). Alternatively, switch responding could be brought under the control of conditional auditory or visual stimuli. For example, the switch could be placed on a lighted tray and switch use scheduled to produce an outcome only when the light tray is turned on. Systematic modification of the brightness or color of the light tray could reveal some parameters of the individual's functional vision.

Field-based treatments or research on aberrant behavior, such as self-injury and severe tantrums, also could benefit from this technology. With a toggle switch or pressure switch attached to a belt or belt loop and a Logger in a pocket, parents, teachers, and care staff could obtain real-time records that permit measurement of rate and duration, as well as time-based scatter plots of target behaviors. Onset and duration of symptoms of medication side effects, epileptic seizures, and other health-related events could be measured accurately and easily. Similarly, medical patients could monitor and self-report the onset and duration of medical symptoms or medication side effects with this technology. Possibilities such as these in applied treatment settings appear endless.

Researchers interested in infant development might find this technology useful also. Placing a HOBO® in line between a crib-mounted kick panel and a mobile, for example, would permit real-time recording of play behavior without an experimenter or parent present. Indeed, several days of recording could occur between experimenter visits to upload the data to a Shuttle® and re-initialize the Logger. Similarly, loggers coupled with sound-activated switches could produce real-time records of onset and duration of crying, babbling, talking and so forth. Pressure plates, each with its own Logger, could be positioned to record infant movement patterns in cribs and other places infants are left to entertain themselves or sleep. As interesting and exciting as infant research can be, perhaps it would be all the more exciting if it could be conducted in natural environments with inexpensive devices that allow one to "set it and forget it."

In summary, our marriage of something old (cumulative records), something new (a device for automated recording of response duration), and something borrowed (Onset products) is enabling better analyses of switch use in people with no typical means of communication. Currently, our analyses permit them to communicate that they can learn and can maintain stable patterns of responding for some idiosyncratic period of time. The communication of that fundamental information should now enable us to establish a hierarchy of reinforcer preferences. If we find a hierarchy, we should be able to enable choice behavior (e.g., press the switch for device A and release the switch for device B) or even requesting (e.g., press the switch for device A and release the switch for a prolonged period to request device B in place of device A). This methodology may benefit not only our current population, but also, potentially, victims of stroke, traumatic brain injury, and neurological disease.

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