JOURNAL OF APPLIED BEHAVIOR ANALYSIS 2005, **38,** 335–348 NUMBER 3 (FALL 2005)

A PRELIMINARY ANALYSIS OF ADAPTIVE RESPONDING UNDER OPEN AND CLOSED ECONOMIES

HENRY S. ROANE

MARCUS AND KENNEDY KRIEGER INSTITUTES AND
EMORY UNIVERSITY SCHOOL OF MEDICINE

AND

NATHAN A. CALL AND TERRY S. FALCOMATA

MARCUS INSTITUTE

In the current investigation, we evaluated the effects of open and closed economies on the adaptive behavior of 2 individuals with developmental disabilities. Across both types of economy, progressive-ratio (PR) schedules were used in which the number of responses required to obtain reinforcement increased as the session progressed. In closed-economy sessions, participants were able to obtain reinforcement only through interaction with the PR schedule requirements (i.e., more work resulted in more reinforcer access). In open-economy sessions, participants obtained reinforcers by responding on the PR schedule and were given supplemental (free) access to the reinforcers after completion of the session. In general, more responding was associated with the closed economy.

DESCRIPTORS: behavioral economics, positive reinforcement, reinforcer assessment

Positive-reinforcement-based procedures are commonly used in response acquisition and reduction programs for individuals with developmental disabilities. In some respects, a positive reinforcement contingency is similar to the economic relation between the performance of a task and the delivery of a commodity (i.e., payment; Kagel & Winkler, 1972; Skinner, 1953). Based on this perspective, behavioral economics has emerged as a subfield of behavior analysis in which responding is viewed as an interaction between price (e.g., reinforcement schedule requirements, changing delays to reinforcement, varying response effort) and consumption (e.g., reinforcers obtained; Allison, 1983). Behavioral economic research has yielded several important findings that may have implications for applied investigators. Examples of such research include studies on reinforcer substitutability and complementarity (e.g., Green & Freed, 1993), the use of reinforcer-demand and work-rate curves (e.g., Tustin, 1995), and the effects of delayed reinforcement on response allocation (e.g., Richards, Mitchell, de Wit, & Seiden, 1997).

As the application of economic principles to operant behavior has developed in the laboratory, applied investigations have utilized these procedures with humans. Recent applied economic research has addressed issues of consumer choice (e.g., Oliveira-Castro, 2003; Smith & Hantula, 2003), addiction (e.g., Audrain-McGovern et al., 2004; Johnson, Bickel, & Kirshenbaum, 2004), and obesity (Epstein, Paluch, Kilanowski, & Raynor, 2004; Epstein, Smith, Vara, & Rodefer, 1991). Despite these advancements in behavioral economics with

This investigation was supported in part by Grant 1 RO1 MH069739-01 from the National Institute of Child Health and Human Development. We thank Gina Sgro and Michael Kelley for their comments on an earlier version of this manuscript and Alyson Hovanetz, Jason Neely, Tracy Kettering, and Stacy Nether for their assistance with various aspects of this investigation. Nathan Call is now at Louisiana State University and Terry Falcomata is at the University of Iowa.

Requests for reprints should be addressed to Henry Roane, Marcus Institute, 1920 Briarcliff Rd., Atlanta, Georgia 30329 (e-mail: Roane@marcus.org).

doi: 10.1901/jaba.2005.85-04

humans, relatively few investigators have conducted economic analyses when developing therapeutic programs for individuals with disabilities (for notable exceptions, see DeLeon, Neidert, Anders, & Rodriguez-Catter, 2001; Kerwin, Ahearn, Eicher, & Burd, 1995; Perry & Fisher, 2001; Shore, Iwata, DeLeon, Kahng, & Smith, 1997).

One area of behavioral economic research that may have clinical implications is the effect of postsession variables (i.e., access to reinforcers delivered for responding in a preceding session) on responding during an experimental session. Hursh (1980, 1984) conceptualized such availability (or lack) of extraexperimental access to reinforcement as two types of economic systems. In general, an *open economy* is a system in which consumption of a reinforcer is not completely dependent on within-session performance. That is, reinforcement can be obtained through interaction with the experimental environment, but reinforcement also is available outside the experimental context. For example, a rat's daily food consumption may be artificially fixed at 80% of its free-operant intake. During an experimental session, the rat may be able to obtain and consume food contingent on the emission of a target response (e.g., a lever press). Following the completion of the session, however, the rat may be given access to a supplemental amount of food (up to the 80% daily feeding allotment). Thus, the rat can obtain reinforcement through (a) interaction with the experiment, (b) response-independent food delivery outside the experimental setting, or (c) a combination of the above.

In a *closed economy*, consumption of a reinforcer is restricted to that which is obtained through interaction with the experimental environment. Using the above example, the food-deprived rat could obtain a daily feeding allotment only through the emission of the target response during an experimental session. Thereafter, the rat would receive no supplemental food. Thus, in a closed economy, daily consumption of the reinforcer depends exclusively on responding in the experimental setting.

In summary, the most common distinction between open and closed economies is the availability of supplemental reinforcement (Timberlake & Peden, 1987). Hursh (1980) provided data from multiple investigations in which the experimental arrangements were characterized as either open or closed economies. In all cases, more responding occurred under the closed economies than in the open economies, suggesting that supplemental access to reinforcement affected within-session responding. This general pattern has been observed in the majority of studies. More recently, research has been conducted on variables that affect relative response rates under open and closed economies, such as the reinforcement schedule and delay to supplemental reinforcement (e.g., Collier, Johnson, & Morgan, 1992; Foster, Blackman, & Temple, 1997; Hall & Lattal, 1990; Ladewig, Sorensen, Nielsen, & Matthews, 2002; LaFiette & Fantino, 1989; Timberlake & Peden).

The effects of differential responding under open and closed economies may have implications for the development of positive-reinforcement-based therapy programs. For example, a child who engages in disruptive behavior in the classroom may receive access to a preferred activity if he or she exhibits appropriate classroom behavior. However, if the same activity is available in other settings (thus approximating an open economy), appropriate behavior may not occur in the classroom. By contrast, if the activity is unavailable in other settings (approximating a closed economy) and the child can only receive access to the activity contingent on appropriate classroom behavior, the results of basic literature suggest that appropriate behavior should increase.

Despite the robust data suggesting that open and closed economies may result in differential response rates, to date there have been no

examinations of the relative effects of open and closed economic systems on responding during therapeutic programs for individuals with developmental disabilities. Nonetheless, basic findings on open and closed economies may not be applicable to applied situations. For example, in the studies mentioned above, the subjects had limited access to reinforcers that were vital to their survival (e.g., food), an arrangement that would be unethical in applied settings. In contrast, tangible stimuli (e.g., toys) or specific foods (e.g., chocolate cookies) are commonly used in clinical programs because they can be restricted outside the therapy session without raising ethical concerns. It is unclear if basic findings would be relevant when using these types of reinforcers, especially because effective substitutes may be readily available in applied settings. That is, nonhuman participants did not have access to alternative sources of the restricted commodities (e.g., alternative sources of food). Athough it might be possible to restrict a child's access to a specific positive reinforcer (e.g., a preferred videotape, chocolate cookies), it is possible that other items with similar properties (e.g., other videotapes, muffins) might serve as effective substitutes for the restricted item. Thus, the use of tangible reinforcers and the availability of substitutable sources of reinforcement may make it difficult to approximate a closed economy in an applied setting.

Some laboratory procedures also may be difficult to replicate with clinical populations for practical reasons. In the basic studies described above, subjects received extensive training under different reinforcement schedules that were gradually thinned to very high values. For example, Foster et al. (1997) exposed hens to progressive-ratio (PR) schedules (fixed-ratio [FR] 10, 20, 40, 20, 10, 5, and 10) after each bird had displayed steady-state responding at each schedule requirement (i.e., completed an average of 44 experimental sessions at each schedule value). Likewise, it is common for experimental sessions to be in effect for extended periods of time (e.g., 24-hr sessions in the Foster et al. investigation). The use of such preexperimental training and high schedule requirements would be time consuming and impractical in most applied research settings.

In summary, basic research findings suggest that the provision of extraexperimental access to a reinforcer might decrease responding for that reinforcer in the experimental setting. Such results would be noteworthy when teaching vocational or educational skills to individuals with developmental disabilities in that these skills are considered to be an essential component of supported habilitation programs (Rusch & Hughes, 1989). However, the procedural and practical issues described above may limit the generality of basic research findings to applied settings. To extend this line of research to educational and vocational programs, it is necessary to deviate from laboratory procedures for practical reasons (e.g., the use of high schedule values may require significant time expenditures and preclude other educational activities) and to more closely approximate conditions that are common in applied situations (e.g., the use of tangible reinforcers) Thus, in the current investigation, we attempted to evaluate the effects of open and closed economies using procedures that deviated from but approximated those used in basic studies. The use of modified experimental procedures permitted an evaluation of the generality of basic findings on open and closed economies within an educational-vocational training program for individuals with developmental disabilities.

METHOD

Participants and Settings

Two individuals participated. Floyd was an 18-year-old man who had been diagnosed with autism and mild mental retardation. Melvin was a 14-year-old boy who had been diagnosed with Smith-Magenis syndrome and who func-

tioned in the moderate range of mental retardation. Floyd and Melvin could follow multistep instructions, and each spoke in brief (e.g., three-word) sentences. Both participants attended a 6-hr day treatment/school program for the assessment and treatment of destructive behavior (e.g., physical aggression, self-injury, property destruction). In addition, both participants had been referred for the acquisition of academic and vocational skills. As part of his enrollment, Floyd participated in a variety of work activities including washing dishes and clothes, preparing lunch, shredding paper, delivering mail, and household cleaning. Melvin's program focused on traditional academic tasks such as writing and basic math skills.

All sessions for Floyd were conducted in an unused classroom (9 m by 9 m) located in the school facility. The room contained a table, two chairs, a combination television and videocassette recorder, and the necessary task materials. All sessions for Melvin were conducted in a fully padded therapy room (4 m by 4 m) that contained a table, chairs, task materials, a television, and a videogame console. One to four sessions were conducted daily, and all sessions were conducted during the first 2 hr of the participants' day.

Response Measurement and Reliability

The target responses were selected by examining the goals listed in each participant's individual education plan. The target response for Floyd was the completion of an envelope-sorting task, which was defined as taking an envelope from an "in box" and placing it into an "out box" that was located approximately 7 m away. Multiple envelopes were available in the in box, but Floyd was allowed to carry only one envelope at a time (i.e., attempts to pick up multiple envelopes were blocked) to keep the response requirements consistent throughout the analysis. The target response for Melvin was the correct completion of math worksheets (i.e., forming the digit that represented the correct answer in the space under each problem). The worksheets contained single-digit addition problems, and each sheet contained 25 problems.

Observers seated in unobtrusive positions in the classroom used laptop computers to collect data on the frequency of the target tasks and on reinforcer delivery (i.e., presentation of the preferred stimulus). A second observer collected data on 60% of sessions for Floyd and 63% of sessions for Melvin. To calculate interobserver agreement, each session was partitioned into 10-s intervals. The number of intervals with agreement on the occurrence and nonoccurrence of a response was divided by the number of intervals with agreements plus the number of intervals with disagreements. The resulting quotient was then multiplied by 100%. Total agreement averaged 95% and 92% for the target responses and 97% and 99% for reinforcer delivery for Floyd and Melvin, respectively.

Preference Assessment

Prior to the analysis of open and closed economies, a stimulus preference assessment similar to that described by Fisher et al. (1992) was conducted with both participants to identify a high-preference item to evaluate as a reinforcer for the target responses. A cartoon video was identified as the preferred item for Floyd, and a videogame was identified as the preferred item for Melvin.

Preexperimental Observation

In most basic studies on open and closed economies, reinforcer consumption is limited to a percentage of the baseline (free-feeding) level of consumption or weight (e.g., Catania & Reynolds, 1968; Foster et al., 1997; Hall & Lattal, 1990; Zeiler, 1999). To develop an analogous methodology, we first identified the amount of reinforcer consumption that would occur if the participant had continuous free access to the item identified in the preference assessment. We then restricted the participants' daily access to their respective reinforcers to a percentage of this level of consumption.

To obtain this measure, the participants were each given one 5-hr period to interact with their preferred items (i.e., there were no other requirements of them on that day). During this time, an observer used a stopwatch to record the cumulative amount of time that the participants interacted with the preferred item (defined as Floyd's eyes oriented toward the television screen or Melvin holding the videogame controller while his eyes were oriented toward the television screen). Data were collected continuously throughout these observations, and the observation was terminated when 10 consecutive minutes elapsed without item interaction. A 10-min termination criterion was implemented based on the request of school personnel who did not want the participants to engage in an inordinate amount of time in research-related activities if they were not actively involved in an activity (i.e., the participants were expected to return to their daily routines as soon as possible).

During the preexperimental observation, Floyd watched the video for approximately 17 min and Melvin interacted with the videogame for approximately 48 min. Once these data were obtained, the preferred item was restricted across all other contexts (i.e., the item was unavailable at home and at school). Restriction at school was accomplished by placing the reinforcers in an unavailable area during the course of the investigation. In addition, primary caregivers were asked to restrict access to the items at the participants' homes (both sets of caregivers agreed to do so). Throughout the remainder of the investigation, the participants' access to their preferred item was restricted to a daily maximum that was approximately 75% of the free-operant level of consumption. This maximum level approximated the percentage of daily allowance that is typically used in basic studies. This resulted in a maximum daily allowance of 12 min of the video for Floyd and 36 min of the videogame for Melvin.

Analysis of Open and Closed Economies

Across the analysis, a number of discriminative stimuli were paired with each condition. For both participants, the discriminative stimuli included spoken instructions (described below) delivered prior to the onset of each session and a colored posterboard (0.6 m by 1.0 m), with a different color associated with each condition.

Response requirements. During both open and closed economies, PR schedules were used to evaluate the potency of the reinforcers under response requirements that increased in a relatively rapid manner (Hodos, 1961). Under PR schedules, ratio requirements typically increase in an additive fashion during the course of a session until no responding occurs for a prespecified period. The efficacy of reinforcers is then determined by comparing the number of responses or completed schedule values (i.e., breaking points) associated with each reinforcer. PR schedules allow the examination of multiple schedule values in a relatively brief time and are often used in basic research to evaluate reinforcer potency (Baron, Mikorski, & Schlund, 1992; Findley, 1958; Hodos, 1961). Participants were exposed to a number of different schedule values so that any differences in responding across the open and closed economies would emerge. For example, responding might persist under an FR 2 schedule and be extinguished under a higher schedule value (e.g., FR 20), regardless of economy type. Yet, it would be very time consuming to evaluate responding under a variety of schedule values in separate phases of the study.

PR schedules were implemented in a manner similar to that described by Roane, Lerman, and Vorndran (2001) with one exception. Throughout each schedule progression, the amount of access to the reinforcer was yoked to match the increase in the response requirements. That is, the ratio of responses to reinforcement obtained was constant across all ratio requirements (e.g., 2 responses produced 20 s of reinforcement, 4 responses produced

40 s of reinforcement, etc.). For Floyd, the unit of reinforcement was 20 s and for Melvin, the unit of reinforcement was 60 s. Some research has shown that responding persists at more effortful response requirements when larger magnitude reinforcers are delivered (e.g., Neef, Shade, & Miller, 1994). In addition, it has been recommended that practitioners make the amount of reinforcement to be delivered proportional to differences in response effort (Cooper, Heron, & Heward, 1987). Thus, reinforcement magnitude was yoked to match increases in the response requirements so that responding would likely persist at higher schedule values. From a procedural perspective, yoking reinforcement magnitude to changes in response requirements permitted the participants to reach their 75% daily allowance in less time, which kept session length reasonable.

To illustrate responding under the PR schedules, 60 s of reinforcement might have been delivered after one response at the beginning of the session. After the 60-s reinforcement interval, the participant would then have to complete two responses to obtain the next reinforcer (e.g., 120 s). This additive pattern continued throughout the remainder of the session until the session terminated (termination criteria described below). All sessions began at the lowest schedule value (PR 1).

The response requirements and corresponding reinforcer durations were as follows: PR 2/20 s, PR 4/40 s, PR 6/60 s, PR 8/80 s, PR 10/100 s, PR 12/120 s, PR 14/140 s, and PR 16/160 s (Floyd) and PR 1/60 s, PR 2/120 s, PR 3/180 s, PR 4/240 s, PR 6/300 s, PR 6/360 s, PR 7/420 s, and PR 8/480 s (Melvin). During the open and closed economies, Floyd could emit a maximum of 72 responses for a maximum of 720 s (12 min) of access to the video, and Melvin could emit a maximum of 36 responses for a maximum of 2,160 s (36 min) of reinforcement. It is important to note that we established an upper limit on the number of responses that could occur in a session. This manipulation allowed us to control for the participants' daily access to the reinforcer under the increasing schedule requirements. As noted above, we wanted to restrict the participants' daily access to the reinforcers to a maximum allowance (75% of the free-operant consumption). The use of an upper response limit also permitted comparisons to be drawn about responding in the two conditions relative to the number of responses that could have occurred during the two conditions (i.e., constant response opportunities across conditions).

Baseline. At the beginning of the analysis, a baseline condition was conducted to establish rates of the target response in the absence of any programmed reinforcement contingency. Thus, during all baseline sessions the target responses resulted in no differential consequences. Prior to each baseline session, a therapist presented the instruction "You can do as much work as you want. I am not going to make you do it." All baseline sessions were 10 min in length.

Open economy. In the open economy, access to the preferred items was provided contingent on the emission of a progressively increasing number of responses. Prior to each open economy session, the therapist presented the instruction, "If you want to watch [or play with] —, you have to do the work. You can do as much work as you want. I am not going to make you do it. No matter how much work you do now, you'll get to watch [or play with] — later." Each session lasted until the available amount of reinforcement (720 s and 2,160 s for Floyd and Melvin, respectively) had been consumed or until 5 min elapsed without a response.

Once the session terminated, the participant received supplemental access to the reinforcer if he did not earn all available reinforcement during the session. For Floyd, supplemental access to the video (up to the 720-s maximum) was provided immediately after the session in an unused portion of the room. For example, if he completed 10 responses during a session, he

received a total of 300 s of access to the video during the session and would have an additional 420 s of access available following the session. However, he could have failed to respond during the session and then receive supplemental access to the reinforcer just 5 min later (i.e., after the 5-min termination criterion elapsed), an arrangement that could have reinforced nonresponding. To address this concern, Melvin's access to supplemental reinforcement was withheld until the end of the school day (approximately 4 hr after the session) and was provided in a separate padded therapy room (4 m by 4 m).

Closed economy. During the closed economy, the participants received access to the reinforcers by engaging in the target response. However, at the completion of each session, they did not receive supplemental access to the reinforcers. For example, if Floyd completed 10 responses, he received a total of 300 s of access to the video with no additional access at the completion of the session. Thus, during the closed economy, consumption of the reinforcer was dependent on interaction with the PR schedules that were in effect during the session. Prior to all closed economy sessions, the participants were given the instruction, "If you want to watch [or play with] —, you have to do the work. You can do as much work as you want. I am not going to make you do it."

The baseline, open-economy, and closed-economy conditions were compared in a reversal design for Floyd (ABCACB) and for Melvin (ABCACAB). Open- or closed-economy sessions were conducted once per day, whereas three to four baseline sessions were conducted daily. Session duration varied as a function of economy type and response persistence (i.e., more responding produced a longer session length; Foster et al., 1997).

Data analysis. Data were analyzed using three methods. First, the frequency of the target response in the open and closed economies was examined. Frequency data were used to compare the number of responses emitted under each economy to the total number of responses that could be emitted (i.e., there was a cap in place for the maximum number of responses that could have occurred in a session: 72 for Floyd and 36 for Melvin). Frequency data are appropriate when the opportunity to respond is held constant across conditions (Cooper et al., 1987). It should be noted that similar findings were obtained when the data were converted to a response rate.

In the second data-analysis method, work-rate functions were used to assess changes in responding across increasing response requirements. Typically, work-rate functions show that responding persists at higher response requirements for highly preferred ("valuable") stimuli relative to less preferred stimuli (e.g., Roane et al., 2001; Tustin, 1994, 1995). Work-rate functions were calculated by adding the total number of responses emitted for each ratio requirement (across all sessions for both conditions) to yield the total number of responses that occurred at each schedule requirement. The totals were then divided by the number of sessions to yield the average number of responses emitted at each schedule requirement.

Reinforcer demand curves, which show reinforcer consumption across increasing response requirements, were constructed for the final data-analysis method (Tustin, 1994, 1995). Typically, more valuable reinforcers are obtained at higher prices relative to less valuable reinforcers. Demand curves were constructed by adding the number of reinforcers earned at each ratio requirement (across sessions) to yield the total number of reinforcers earned under each schedule. These numbers were then averaged by dividing the total number of reinforcers obtained by the number of sessions conducted for each condition. Finally, separate consumption lines were plotted for each condition. Thus, the demand curve displayed the average amount of reinforcement earned across each increase in schedule requirement under the open and

closed economies. It was hypothesized that the slope of the line depicting consumption at each schedule value would be steeper for less potent reinforcers (i.e., reinforcer consumption should be less stable) than that for more potent reinforcers.

RESULTS

Results for Floyd are shown in Figure 1. Near-zero levels of responding were observed in baseline. When reinforcement was provided contingent on sorting in the open economy, responding increased (M = 56 responses). Responding further increased when the closed economy was implemented (M = 71 responses). Following a reversal to baseline, responding returned to the maximum level in the closed economy (M = 68 responses). Finally, response levels decreased when the open economy was reintroduced (M = 51 responses).

The middle panel of Figure 1 shows the work-rate function for Floyd. For the first five response requirements, similar amounts of responding were observed in the open and closed economies. As the response requirements increased beyond PR 10, however, less responding occurred in the open economy than in the closed economy. These summative results reveal that Floyd worked under higher response requirements in the closed economy than in the open economy.

The lower panel of Figure 1 shows the demand curves for the two conditions. As the response requirements increased in the open economy, the average number of reinforcers obtained decreased at the midrange schedule requirements (PR 10) and continued to decrease as the response requirements increased. By contrast, reinforcer consumption during the closed economy was near one per response requirement until the schedule reached its highest value (PR 16). That is, Floyd usually earned the maximum amount of reinforcement during the closed economy, regardless of the increase in the response requirement.

Melvin's results are shown in Figure 2. During baseline, responding gradually decreased to zero (M = 5 responses). Responding increased slightly during the first phase of the open economy (M = 20 responses) and occurred at the highest possible level under the closed economy (M = 36 responses). Following a reversal to baseline (M = 7 responses), responding again occurred at high levels during the closed economy (M = 31 responses). After another reversal to baseline (M = 8 responses), responding decreased during the final open economy (M = 9 responses).

Results of the work-rate functions for Melvin are shown in the middle panel of Figure 2. Responding was similar across both conditions until the fourth increase in the response requirement (PR 4). Thereafter, responding steadily decreased in the open economy and persisted in the closed economy, suggesting that Melvin's responding persisted under increasing response requirements in the closed economy relative to the open economy.

The lower panel of Figure 2 shows the demand curves for the open and closed economies. Reinforcer consumption under the open economy was steady until the schedule reached PR 4, after which consumption decreased as response requirements increased. By contrast, reinforcer consumption under the closed economy persisted at a high level across all response requirements. That is, Melvin typically earned the maximum amount of reinforcement that was available under the closed economy.

DISCUSSION

Results showed that reinforcement increased adaptive responding relative to baseline for both participants. However, increases in the cost of the reinforcer (i.e., within-session increases in the ratio schedule) affected responding more in the open economy than in the closed economy. Both participants were less likely to complete their target tasks at the higher PR requirements

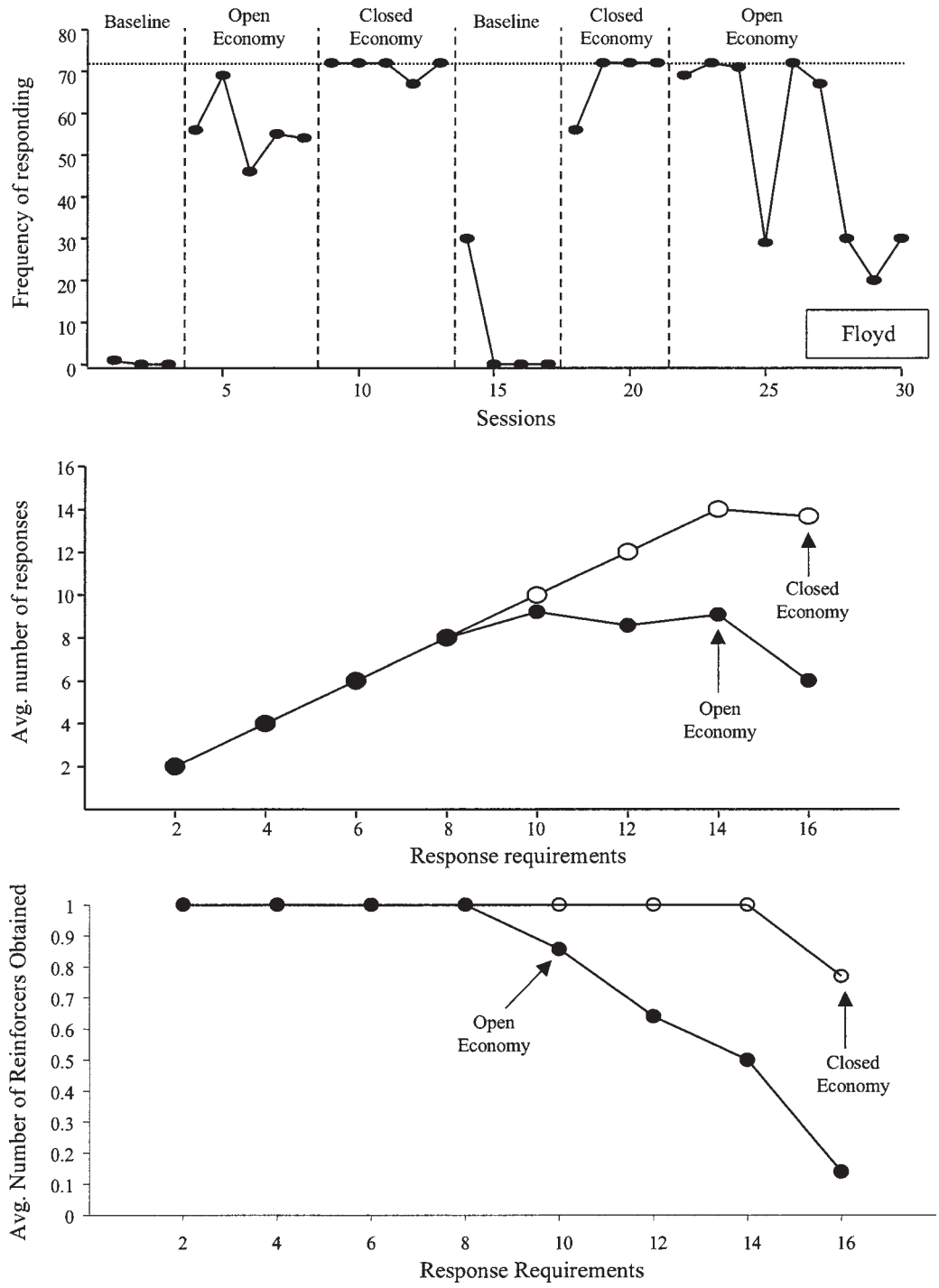

Figure 1. Frequency of responses across sessions during baseline, open economy, and closed economy (top) for Floyd. The dashed line near the top shows the maximum number of responses that could be emitted (i.e., 72 responses in each session). Average number of responses emitted across response requirements during the open and closed economies (middle). Average amount of reinforcer consumption across response requirements during the open and closed economies (bottom).

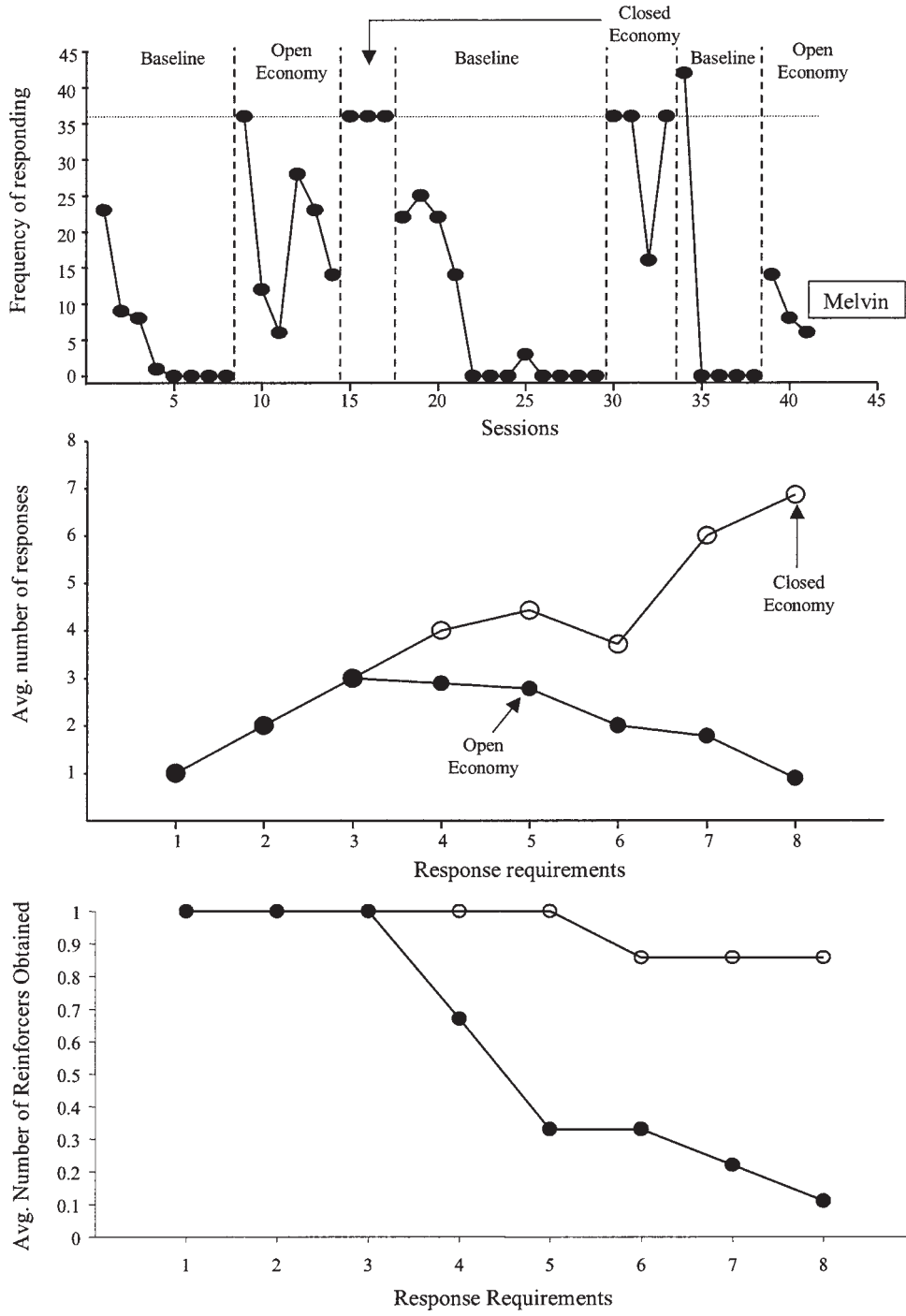

Figure 2. Frequency of responses across sessions during baseline, open economy, and closed economy (top) for Melvin. The line near the top represents the maximum number of responses that could be emitted under the constraints of the open and closed economies (i.e., 36 responses in each session). Average number of responses emitted across response requirements during open and closed economies (middle). Average amount of reinforcer consumption across response requirements during open and closed economies (bottom).

when access to the reinforcer was available in other contexts (i.e., outside the training session). This outcome is similar to that found in basic research on responding under open and closed economies (Hursh, 1980). Furthermore, results were replicated across participants even though Floyd obtained the supplemental reinforcers immediately after the session, whereas Melvin had to wait for several hours.

From a clinical perspective, these results suggest that access to postsession reinforcement may affect responding during acquisition programs and that the reinforcer should be unavailable outside the training situation to maximize program effectiveness. Nevertheless, given that responding increased under both conditions, the outcome reveals an important practical consideration: Although restriction of a reinforcer may be helpful in increasing responding, it may be unnecessary or contraindicated in some situations (e.g., if the reinforcer is also used as a component of another therapeutic program). It also should be noted that ethical issues might arise if access to a highly potent reinforcer must be restricted to training settings.

The term *translational research* has been used to describe the application of basic laboratory findings to applied research and practice (Lerman, 2003). One benefit of conducting translational research is the development of new technologies and the evaluation of existing research paradigms (Mace & Wacker, 1994). The current investigation examined the generality of basic research findings on responding under open and closed economies. The results were similar to those of laboratory research even though a number of procedural modifications were made to accommodate the applied nature of the current study.

Some commonly used basic procedures (e.g., food deprivation, lengthy sessions, preexperimental exposure to multiple reinforcement schedules) were deemed impractical for applied research settings. Thus, the current methods only approximated those of basic studies. One procedural difference was the use of PR schedules, which allowed the examination of responding under increasing schedule requirements in a relatively brief period of time without lengthy preexperimental exposure to various schedule values (cf. DeLeon, Iwata, Goh, & Worsdell, 1997). Several other changes were made to more closely approximate the use of reinforcement-based programs in applied settings. For example, participants received tangible reinforcers, and the reinforcement interval was yoked to increases in the response requirements throughout the open and closed economies. These and other procedural modifications may limit the interpretations of the results relative to basic findings on open and closed economies.

From a technical perspective, the current results may be limited in that the closed economy may not have fully approximated the type of closed economies used in basic research. As discussed by Hursh (1980), economic systems may vary along a continuum from completely open (e.g., free feedings) to completely closed. In a closed economy, consumption of a reinforcer is dependent on a certain amount of responding per a given amount of reinforcement, which is referred to as equilibrium. An equilibrium point is reached by allowing an indefinite amount of responding and consumption to occur (see Allison, 1983, for a discussion of equilibrium points and the development of closed economic systems). Due to practical considerations, it was not possible to establish an equilibrium point because participants were unable to be involved in experimental sessions for unlimited periods throughout their day. Thus, an artificial ceiling on the amount of responding that could occur within a given session was established such that the participants' daily reinforcement consumption could be controlled, permitting a constant state of deprivation across all conditions.

The amount of reinforcement was increased proportional to increases in response require-

ments to address a variety of procedural and practical concerns. Procedurally, it was important to ensure that responding would persist at appreciably high requirements so that differences in the two conditions could be seen. Reinforcement magnitude could have been held constant (e.g., 60 s) across all response requirements to better approximate basic procedures. However, unyoked reinforcement intervals would have required more responses and a corresponding increase in session duration for the participants to achieve their daily allotment of reinforcement. One possible area of future research would be a comparison of response persistence under economic systems with both yoked and unyoked increases in reinforcer magnitude.

The current results also should be interpreted with caution because the use of PR schedules may limit the generality of the findings to applied situations. PR schedules are commonly used in basic research to evaluate relative reinforcer potency (Baron et al., 1992; Findley, 1958; Hodos, 1961). Baron et al. concluded that PR schedules provide an efficient way to study response patterns under static ratio schedules, ''particularly when concern is with interactions between an experimental variable and variations in the size of the ratio'' (p. 388). In an applied investigation, Roane et al. (2001) showed that different levels of responding occurred for two high-preference items under PR schedules. Furthermore, responding under the PR schedules predicted the relative efficacy of the stimuli when used as components of reinforcement-based treatments for destructive behavior. Nonetheless, PR schedules are not commonly employed in clinical settings, and they have been used infrequently in previous basic research on open versus close economies. Thus, further research is needed to determine if these relations would be obtained under schedules that are more typical to application. For example, responding could be evaluated under different economy types while response requirements are held constant.

The presentation of spoken instructions prior to each session also may complicate the interpretation of the findings. Responding of both participants immediately increased to high levels in the closed economy without contacting changes in the contingencies (i.e., the unavailability of supplemental reinforcement). This pattern suggests that the responses may have been under the control of the instructions (i.e., rule-governed behavior) as opposed to the contingency (i.e., contingency-shaped behavior). However, both participants contacted the contingency in the closed economy at least once. It should be noted also that the open and closed economies did not differ appreciably from one another during the course of a session. That is, the participant did not contact the differential availability of supplemental reinforcement until a session ended. Nevertheless, differences in responding were observed, presumably because of the presentation of instructions and other discriminative stimuli.

There is another practical difficulty that must be addressed when arranging open and closed economies. Although appealing in terms of the influence of economic systems on adaptive responding, additional research is needed to evaluate the extent to which other factors (e.g., reinforcer substitutability; Green & Freed, 1993) could affect responding in applied settings. For example, in the current investigation, we were able to restrict access to the target reinforcer (e.g., a cartoon video or a videogame); however, we were unable to restrict access to other items that shared stimulus properties with the reinforcers (e.g., other videos, music). Thus, the participants could have received extraexperimental access to similar forms of stimulation that may have functioned as substitutes for the reinforcers used in the open and closed economies. Future research should examine the extent to which the availability of substitute reinforcers influences the effects of open and closed economies in applied settings.

Finally, multiple explanations have been offered to account for different response patterns under open and closed economies. For example, Hursh (1980, 1984) suggested that differences between open and closed economies might be due to the anticipated access to supplemental feeding, which affects the elasticity of the demand for the reinforcer (i.e., an animal learns that supplemental food is available in an open economy and is less likely to respond in the session but will continue to respond when supplemental food is not available). Others (e.g., Timberlake & Peden, 1987) have suggested that any differences in responding under open and closed economies are a function of reward density (reinforcement obtained relative to its cost), not a function of specific economic arrangements. Further studies designed to examine potential mechanisms responsible for these results may be important to research and practice in applied behavior analysis.

REFERENCES

Allison, J. W. (1983). *Behavioral economics*. New York: Praeger.

Audrain-McGovern, J., Rodriguez, D., Tercyak, K. P., Epstein, L. H., Goldman, P., & Wileyto, E. P. (2004). Applying a behavioral economic framework to understanding adolescent smoking. *Psychology of Addictive Behaviors*, *18*, 64–73.

Baron, A., Mikorski, J., & Schlund, M. (1992). Reinforcement magnitude and pausing on progressive-ratio schedules. *Journal of the Experimental Analysis of Behavior*, *58*, 377–388.

Catania, A. C., & Reynolds, G. S. (1968). A quantitative analysis of the responding maintained by interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, *11*, 327–383.

Collier, G., Johnson, D. F., & Morgan, C. (1992). The magnitude-of-reinforcement function in closed and open economies. *Journal of the Experimental Analysis of Behavior*, *57*, 81–89.

Cooper, J. O., Heron, T. W., & Heward, W. L. (1987). *Applied behavior analysis*. New York: Macmillan.

DeLeon, I. G., Iwata, B. A., Goh, H., & Worsdell, A. S. (1997). Emergence of reinforcer preference as a function of schedule requirements and stimulus similarity. *Journal of Applied Behavior Analysis*, *30*, 439–449.

DeLeon, I. G., Neidert, P. L., Anders, B. M., & Rodriguez-Catter, V. (2001). Choices between positive and negative reinforcement during treatment for escape-maintained behavior. *Journal of Applied Behavior Analysis*, *34*, 521–525.

Epstein, L. H., Paluch, R. A., Kilanowski, C. K., & Raynor, H. A. (2004). The effect of reinforcement or stimulus control to reduce sedentary behavior in the treatment of pediatric obesity. *Health Psychology*, *23*, 371–380.

Epstein, L. H., Smith, J. A., Vara, L. S., & Rodefer, J. S. (1991). Behavioral economic analysis of activity choice in obese children. *Health Psychology*, *10*, 311–316.

Findley, J. D. (1958). Preference and switching under concurrent scheduling. *Journal of the Experimental Analysis of Behavior*, *1*, 123–144.

Fisher, W. W., Piazza, C. C., Bowman, L. G., Hagopian, L. P., Owens, J. C., & Slevin, I. (1992). A comparison of two approaches for identifying reinforcers for persons with severe and profound disabilities. *Journal of Applied Behavior Analysis*, *25*, 491–498.

Foster, T. M., Blackman, K. A., & Temple, W. (1997). Open versus closed economies: Performance of domestic hens under fixed-ratio schedules. *Journal of the Experimental Analysis of Behavior*, *67*, 67–89.

Green, L., & Freed, D. E. (1993). The substitutability of reinforcers. *Journal of the Experimental Analysis of Behavior*, *60*, 141–158.

Hall, G. A., & Lattal, K. A. (1990). Variable-interval schedule performance in open and closed economies. *Journal of the Experimental Analysis of Behavior*, *54*, 13–22.

Hodos, W. (1961). Progressive ratio as a measure of reward strength. *Science*, *134*, 943–944.

Hursh, S. R. (1980). Economic concepts of the analysis of behavior. *Journal of the Experimental Analysis of Behavior*, *34*, 219–238.

Hursh, S. R. (1984). Behavioral economics. *Journal of the Experimental Analysis of Behavior*, *42*, 435–452.

Johnson, M. W., Bickel, W. K., & Kirshenbaum, A. P. (2004). Substitutes for tobacco smoking: A behavioral economic analysis of nicotine gum, denicotinized cigarettes, and nicotine-containing cigarettes. *Drug and Alcohol Dependence*, *74*, 253–264.

Kagel, J. H., & Winkler, R. C. (1972). Behavioral economics: Areas of cooperative research between economics and applied behavioral analysis. *Journal of Applied Behavior Analysis*, *5*, 335–342.

Kerwin, M. E., Ahearn, W. H., Eicher, P. S., & Burd, D. M. (1995). The costs of eating: A behavioral economic analysis of food refusal. *Journal of Applied Behavior Analysis*, *28*, 245–260.

Ladewig, J., Sorensen, D. B., Nielsen, P. P., & Matthews, L. R. (2002). The quantitative measurement of motivation: Generation of demand functions under open versus closed economies. *Applied Animal Behaviour Science*, *79*, 325–331.

LaFiette, M. H., & Fantino, E. (1989). Responding on concurrent-chains schedules in open and closed economies. *Journal of the Experimental Analysis of Behavior*, *51*, 329–342.

Lerman, D. C. (2003). From the laboratory to community application: Transitional research in behavior analysis. *Journal of Applied Behavior Analysis*, *36*, 415–419.

Mace, F. C., & Wacker, D. P. (1994). Toward greater integration of basic and applied behavioral research: An introduction. *Journal of Applied Behavior Analysis*, *27*, 569–574.

Neef, N. A., Shade, D., & Miller, M. S. (1994). Assessing influential dimensions of reinforcers on choice in students with serious emotional disturbance. *Journal of Applied Behavior Analysis*, *27*, 575–583.

Oliveira-Castro, J. M. (2003). Effects of base price upon search behavior of consumers in a supermarket: An operant analysis. *Journal of Economic Psychology*, *24*, 637–652.

Perry, A. C., & Fisher, W. W. (2001). Behavioral economic influences on treatments designed to decrease destructive behavior. *Journal of Applied Behavior Analysis*, *34*, 211–215.

Richards, J. B., Mitchell, S. H., de Wit, H., & Seiden, L. S. (1997). Determination of discount functions in rats with an adjusting-amount procedure. *Journal of the Experimental Analysis of Behavior*, *67*, 353–366.

Roane, H. S., Lerman, D. C., & Vorndran, C. M. (2001). Assessing reinforcers under progressive schedule requirements. *Journal of Applied Behavior Analysis*, *34*, 145–167.

Rusch, F. R., & Hughes, C. (1989). Overview of supported employment. *Journal of Applied Behavior Analysis*, *22*, 351–363.

Shore, B. A., Iwata, B. A., DeLeon, I. G., Kahng, S., & Smith, R. G. (1997). An analysis of reinforcer substitutability using object manipulation and self-injury as competing responses. *Journal of Applied Behavior Analysis*, *30*, 21–40.

Skinner, B. F. (1953). *Science and human behavior*. New York: Macmillan.

Smith, C. L., & Hantula, D. A. (2003). Pricing effects on foraging in a simulated internet shopping mall. *Journal of Economic Psychology*, *24*, 653–674.

Timberlake, W., & Peden, B. F. (1987). On the distinction between open and closed economies. *Journal of the Experimental Analysis of Behavior*, *48*, 35–60.

Tustin, R. D. (1994). Preference for reinforcers under varying schedule arrangements: A behavioral economic analysis. *Journal of Applied Behavior Analysis*, *27*, 597–606.

Tustin, R. D. (1995). Assessing preference for reinforcers using demand curves, work-rate functions, and expansion paths. *Journal of the Experimental Analysis of Behavior*, *64*, 313–329.

Zeiler, M. D. (1999). Reversed schedule effects in closed and open economies. *Journal of the Experimental Analysis of Behavior*, *71*, 171–186.

Received July 6, 2004
Final acceptance April 18, 2005
Action Editor, Dorothea Lerman