

The Effects of Changing Values of Concurrent

Fixed Ratio Schedules on Mand

Allocation in Children with Autism

By

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## Abstract

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Teaching situations with children with autism usually involve concurrent schedules of reinforcement. During concurrent schedules, manipulation of the schedule of reinforcement for one response affects the occurrence of alternative responses. This study evaluated the effects of four sets of unequal and one set of equal concurrent fixed-ratio schedules on the allocation of two mands in three children with autism. All three participants emitted a higher rate of mands for a highly preferred item than for a less preferred item determined by an initial preference assessment during a concurrent FR1/FR1 schedule. All participants increased mands for the less preferred item when the schedule value for mands for the highly preferred item was at some value greater than FR1. In terms of behavioral economics, positive cross price demand for the less preferred item as a function of increasing FR values for mands for the highly preferred item showed that all three participants substituted a less preferred item for a highly preferred item. This substitution, along with a negative own price demand for the highly preferred item as a function of increasing FR values for mands for that item, indicated some degree of demand elasticity for the highly preferred item. In addition, an increase in response variability measured

by the number of switches from one mand to the other accompanied the increase in mands for the less preferred item at FR values greater than FR1 for the highly preferred item for two of the three participants. Comparison of measures of demand elasticity to more traditional measures of matching and maximization show that the former provides a more detailed account of response allocation during concurrent schedules. These findings have implications for the use of behavioral economics in the analysis of behavior change interventions during concurrent schedules in applied settings where a single behavior occurs at an inappropriate frequency and in the absence of desirable alternative behaviors.

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## The Effects of Changing Values of Concurrent

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By Haven Bernstein

Teachers often use ratio schedules of reinforcement when teaching new skills or maintaining previously acquired skills in children with autism. Ratio schedules are practical because teachers need only to measure the frequency of a particular behavior. Teachers can increase or decrease the density of reinforcement for a particular behavior by simply counting the number of occurrences of the behavior and adjusting schedule values as needed. During the acquisition of new behaviors, teachers reinforce instances of the behavior using dense schedule values such as continuous reinforcement schedules which result in faster acquisition of responses than leaner schedules (Skinner, 1953). Teachers may subsequently reinforce already acquired behaviors on leaner reinforcement schedules that result in greater resistance to extinction than dense schedules (Theios, 1962).

One can analyze teaching situations as concurrent ratio schedules because a child can emit more than one behavior during a single teaching situation and teachers can reinforce each behavior on an independent ratio schedule of reinforcement. The Matching Law states that during concurrent schedules the relative rate of responding will equal the relative rate of obtained reinforcement for each response (Herrnstein, 1961, 1970). Empirical deviations from matching are prominent in the literature and occur when responding is either less sensitive to changes in concurrent schedule values than matching would predict, more sensitive to changes in concurrent

schedule values than matching would predict, or when organisms show some preference for one response over another despite schedule values. These deviations are termed undermatching, overmatching, and bias respectively and researchers often use the generalized matching equation to incorporate these deviations into the Matching Law (Baum, 1974; Baum & Rachlin, 1969). Examinations of matching theory typically utilize concurrent interval schedules of reinforcement. During concurrent ratio schedules, the Matching Law predicts exclusive responding to the denser of the two ratio schedules (Herrnstein, 1970). Such a manner of responding would result in relative response rates being precisely equal to relative rates of obtained reinforcement, or perfect matching. In addition, responding solely to the denser of two ratio schedules yields reinforcement at a greater rate than does switching between two unequal ratio schedules, thus resulting maximization of reinforcement. Maximization occurs when an organism obtains the maximum amount of reinforcement available during a given time. Studies employing concurrent ratio schedules have found that subjects allocated almost all responding to the denser of two concurrent ratio schedules (Herrnstein, 1970; Herrnstein & Loveland, 1975). Subjects did, however, emit some responses to the leaner schedule, thus undermatching and failing to obtain the maximum rate of reinforcement possible. A limitation of matching studies is that qualitatively identical reinforcers are usually available on both concurrent schedules. In the natural environment alternatively available reinforcers are rarely identical. Applied human studies during which qualitatively dissimilar reinforcers were available, however, have also shown preference for the denser of two concurrent ratio schedules (Hoch et al., 2002; Horner & Day, 1991; Richman, Wacker, & Winborn, 2001).

Some researchers have examined response rate during concurrent schedules from an economic viewpoint. Behavioral economic theory applies principles of economics to behavior.

Such principles often predict the rate of responding to obtain a particular reinforcer at particular schedule values. Thus, behavioral economics attempts to account for the number of responses a particular reinforcer can sustain under various conditions (Green & Freed, 1993; Hursh, 1984). The demand functions, a concept in behavioral economics, plots the rate of reinforcement obtained for a particular response across various response requirements (Johnson & Bickel, 2006). Researchers use demand functions to analyze the efficacy of reinforcers at maintaining responding as response requirements for reinforcement increase. By plotting the rate of reinforcement as a function of the response requirement, researchers can measure the strength of the demand for a particular reinforcer at various schedule values. In addition, plotting demand functions in double logarithmic coordinates allows for an examination of changes in demand along increasing schedule values. Log/log demand functions display absolute changes in reinforcement rate along the continuum of schedule values, therefore small changes at low schedule values appear as large effects and large changes at higher schedule values appear as relatively small effects. If the slope of the log/log demand function is greater than 1 then the demand for the particular reinforcer is inelastic, meaning that the demand remains nearly constant despite increases in response requirement, as shown by maintained reinforcement across increasing schedule values. If the slope of the function is less than -1 then the demand for the particular reinforcer is elastic, meaning that demand weakens as response requirements increase as shown by a decrease in reinforcement (Hursh, Raslear, Shurtleff, Bauman, & Simmons, 1988). Degree of demand elasticity may not always be stable over time, and demand slopes may change as a function of more or less extreme changes in response requirements, the altering of reinforcers, or the additional availability of alternative reinforcers (Hursh, 1980). The slope of a demand function during a single reinforcement schedule can predict demand elasticity for that

reinforcer under concurrent schedules of reinforcement. For example, Johnson and Bickel (2006) showed that the point at which demand functions shifted from greater than one to less than negative one during a single schedule predicted the schedule values at which subjects switched to responding for an alternative reinforcer during a concurrent schedule.

Analysis of response rate can also provide information regarding the demand for a particular reinforcer. Work functions plot rate of responding as a function of response requirements for a reinforcer. Inelastic demand would yield a positive slope in the work function; as response requirements increase response rate increases to maintain reinforcement. Elastic demand would yield a negative work slope; as response requirements increase, response rate for the particular reinforcer decreases. As with demand functions, work functions may not remain linear across changing schedule values. Researchers have progressively increased ratio schedules showing that the density of a schedule value that can maintain a steady rate of responding prior to ratio strain varies according to the topography of the response and the particular reinforcer delivered contingent on that response (DeGrandpre, Bickel, Higgins, & Hughes, 1994). In addition, the effects of increasing schedule value on rate of responding depend on whether typical daily consumption occurs during an experimental session (closed economy) or whether the same reinforcers are available outside the experimental session as well (open economy). In a closed economy, response rate is typically non-elastic, unless experimenters provide the concurrent availability of alternative reinforcers (Hursh, 1984).

When two reinforcers are concurrently available, manipulation of the schedule value for one reinforcer across experimental conditions affects not only the rate of responding for that reinforcer but also the rate of responding for the alternatively available reinforcer as well, even

when the schedule value for the alternative reinforcer remains unchanged (Fisher & Mazur, 1997; Roane, Lerman, & Vorndran, 2001; Tustin, 1994). Behavioral Economics calls this phenomenon stimulus substitutability. Two stimuli are substitutable as reinforcers to the extent that an organism switches from obtaining one reinforcer to obtaining another reinforcer as response requirements change. As the response requirement for one reinforcer increases, organisms may switch responses to obtain an alternatively available reinforcer associated with a lesser response requirement. Therefore, response rate for a particular reinforcer may change despite unchanged response requirements if that reinforcer serves as a substitute for an alternative reinforcer. Stimuli that are similar in type and or functionally equivalent tend to be more substitutable than stimuli that are dissimilar (Green & Freed, 1993). The slope of the demand functions for two alternative reinforcers illustrates the extent to which the reinforcers are substitutable, and concepts such as demand elasticity and substitutability may determine the extent to which organisms maximize reinforcement during unequal concurrent ratio schedules.

Tustin (1994), for example, demonstrated stimulus substitutability. Participants responded for an auditory stimulus as a reinforcer at a higher rate than for a visual stimulus during a concurrent auditory stimulus FR1 visual stimulus FR5 schedule. Subsequently, as the schedule value for the auditory stimulus increased, response rate for the auditory stimulus decreased while response rate for the visual stimulus increased. Tustin (1994) also examined the rate of reinforcement obtained for each response as a function of the schedule values in effect and found an inverse relationship, indicating stimulus substitutability. Response rate for one reinforcer increased as the response requirements for the alternative reinforcer increased, thus by substituting reinforcers participants maintained absolute reinforcement rates across the two conditions despite changes in response requirement and response allocation.

Tustin (1994) described own price demand as a demand function plotting the rate of reinforcement as a function of the schedule value for that reinforcer. Cross price demand is a demand function plotting the rate of reinforcement as a function of the schedule value for an alternatively available reinforcer. Typically, the schedule value for the reinforcer plotted as a cross price demand curve remains unchanged in order to examine the effects of the alternative schedule value on that reinforcer. Tustin examined own price demand curves in single schedule situations and found that a participant obtained higher rates of one reinforcer across increasing schedule values compared to a another reinforcer across the same schedule values, indicating that reinforcer type determined own price demand elasticity. During concurrent schedules one can examine both own and cross price demand functions. Tustin found that when an own price demand function showed a negative slope over increasing schedule values, the cross price demand function of an alternative reinforcer showed a positive slope. The negative own price slope across increasing schedule values indicates that demand was elastic for that reinforcer, and the positive cross price slope for the alternative reinforcer indicates that the two available reinforcers were substitutable. In this example, elastic own price demand allowed for substitution. Had own price demand been inelastic the cross price demand function for the alternative reinforcer would not have increased. Whether or not own price demand would have been elastic in the absence of alternative, substitutable reinforcers is an empirical question that could only be determined by examination of responding for that reinforcer under single schedule conditions.

Behavioral economic findings on concurrent schedules have applied significance for teachers. By manipulating the schedule of reinforcement for one behavior, teachers may be able to predict and alter the occurrence of other behaviors. Bernstein, Brown, and Sturmey (2009)

examined the effects of manipulating the ratio schedule value for one response on the rate of an alternative response in a concurrent situation with children with autism. They concurrently reinforced two types of behaviors on FR1 schedules, a play response (manipulating an age appropriate toy) and mands (a vocal request for a preferred item). When the schedule value for mands increased to FR10, the rate of play responses for all three participants increased above baseline levels. Play responses became the more efficient response for acquiring reinforcement when the response requirement for mands increased to FR10. Participants did not maximize reinforcement, however, as mands persisted throughout the experiment often meeting response requirements for reinforcement. Rate of both play responses and mands increased from baseline levels for one participant when the schedule value was changed from FR1 to FR10, indicating a positive work slope for both responses. An analysis of these results in terms of stimulus substitutability is not possible, however, because the experimenters delivered the same reinforcers contingent on both mands and play responses. The experimenters reinforced play with items previously manded for by the participants. Therefore, the two responses were functionally equivalent, and the more efficient response would be likely to replace the less efficient response.

In a related study, Bernstein and Sturmey (2008) found that when teachers reinforced six mands in the repertoire of two participants with autism on concurrent FR1 schedules, both participants emitted a single mand at a higher rate than the other five mands. When the teachers increased the schedule of reinforcement for the high rate mand to FR10, the rate of that mand decreased while the combined rate of the other five alternative mands increased for one participant. For the second participant, the increase in schedule value to FR10 resulted in an increase in the rate of the high rate mand while the rates of the other five alternative mands

remained low. Response allocation only changed when the teachers further increased the schedule value for the high rate mand to FR25. For this participant, under an FR25 schedule, the rate of the high rate mand decreased while the combined rate of all five alternative mands increased. Because the experimenters reinforced mands by delivering reinforcers identified by the various items manded for, alternative mands earned different items and were not functionally equivalent responses. Bernstein and Sturmey (2008) did not report rates of obtained reinforcement to support an analysis of demand elasticity; however, it is likely that stimulus substitutability occurred in that the participants maintained reinforcement by switching from a mand with a high response requirement to more efficient mands. Also, one participant altered response allocation at an FR10 schedule value for the high rate mand while an FR25 schedule value for the high rate mand was necessary to alter response allocation in the second participant, indicating the possibility that degree of demand elasticity for the high rate mand differed across participants. While the data show an increase in the rate of all five alternative mands combined when the schedule value for the high-rate mand increased, increases in the rate of each individual alternative mand were minimal.

In both of the aforementioned studies a single behavior occurred at a higher rate than alternative behaviors despite equal concurrent schedule values; however, studies show that differences in quality, magnitude, and immediacy of reinforcers, as well as response effort across concurrent response-reinforcer contingencies, can also affect response allocation (Neef, Shade, & Miller, 1994). For example, Bernstein et al. (2009) found a higher rate of mands than rate of play responses for all participants despite equal FR1 schedule values for mands and play. While the experimenters attempted to hold constant differences in the quality, magnitude, and immediacy of the reinforcers across the two concurrent responses, the topographically different

responses may have required different amounts of effort. The study did not quantify the effort of the responses in order to examine effects of effort on response allocation. In Bernstein and Sturmey (2008), the concurrent responses were topographically similar in that they were all either vocal or picture exchange mands. Nevertheless, the experimenters delivered different items and activities as reinforcers for mands depending on what item or activity each mand requested. The experimenters attempted to hold constant the magnitude and immediacy of the reinforcers, yet participants manded for a single item or activity at a much higher rate than all other available items or activities. The high rate of this single mand may be due to the difference in quality of that reinforcer relative to alternatives. The experimenters did not conduct preference or reinforcer assessments to conclude that the reinforcer for the high rate mand was actually a more effective reinforcer than those for alternative mands; however, preference may have affected response allocation.

In addition to rate of responding, response variability may also be a relevant measure when examining concurrent schedules. Teachers usually attempt to teach children with autism to exhibit a number of appropriate behaviors, rather than a single behavior repetitively. Duker and Lent (1991) noted that children with developmental disabilities often use only a small portion of their language. By placing a high-rate mand on extinction, they increased variability in communicative gestures from baseline levels in six individuals with mental handicaps. Bernstein and Sturmey (2008) also induced variability through schedule manipulation. They defined variability as the total number of alternative mands emitted during a single session and recorded the first instance only of each item or activity manded for by the participants as a measure of variability. They found an increase in response variability when the high rate mand was on an FR10 schedule for one participant and FR25 for a second participant compared to response

variability when all mands were on concurrent FR1 schedules. The effects of the schedule values on response variability were not always clear, however, due to an increasing trend in variability during the FR1 condition for one of the participants.

Thus far, researchers have only manipulated schedule values for mands across blocks of sessions, not across individual sessions to examine the immediacy of behavior changes as a result of the concurrent schedule values in effect. In addition, researchers have not examined mand allocation in a concurrent schedule within a behavioral economic framework, and analyses of behavioral economic theory in humans (DeGrandpre, Bickel, Higgins, & Hughes, 1994; Johnson & Bickel, 2006; Tustin, 1994) have not employed preference assessments. Therefore, the goal of this study was to identify the concurrent values of ratio schedules that result in shifts in mand allocation, and those that do not. The present experiment examined rate of manding as a dependent measure to extend behavior economic theory to a typical teaching situation with children with autism. The experimenter manipulated concurrent schedule values across both individual sessions and blocks of sessions in different phases of this experiment to assess the effectiveness of each of those methods of schedule value presentation and extend the practicality of each to typical teaching situations. The experimenter conducted preference assessments prior to each session to identify high and low preference items and ensure the effectiveness of the items delivered as reinforcers for manding, and conducted an initial functional analysis to demonstrate that the dependent measures did in fact function as mands. This paper describes own price and cross price demand functions for two reinforcers concurrently available for manding.

## Method

### *Participants*

Participants were three children previously diagnosed with autism by an outside agency. Participants Jake, Tyler, and Vin aged 7, 7, and 5 years respectively. All three children had at least two vocal mands or experience using the Picture Exchange Communication System (PECS) (Bondy & Frost, 1994).

### *Setting and Materials*

The experimenter held sessions in the same rooms in the participant's homes where they typically received special education services. Participants sat in a chair at a table approximately 2 x 3 m. The experimenter sat in a chair at the same table directly across from or perpendicular to and facing the participant. Two items selected during a preference assessment (described in a later section) were available for manding as mand 1 and mand 2. These items were either auditory/visual devices, such as small music playing toys, coloring books, or tactile items, such as a bin filled with beans. The items were on the edge of the table about 15 cm in front of the experimenter.

PECS materials were always on the edge of the table about 2 cm in front of the participant. PECS materials included an 8 cm x 8 cm picture of each of the two available items.

The only individuals present in the room during experimental sessions were the participant and the experimenter. The experimenter used a timer to time the session length. The experimenter videotaped all sessions for purposes of measuring interobserver agreement (IOA) at a later time.

### *Response Definitions*

A vocal mand was a vocalization containing the entire label of an item. A PECS mand was the participant either tapping or picking up a picture card and holding it at least 25 cm away from the original position of the picture in a direction towards the experimenter. For a tap to be recorded as a mand the participant had to remove his finger or hand from the picture no longer than 1 s following the initial tap. The experimenter did not record as a mand sliding the picture along the table, placing a finger or hand on the picture without removing it within 1 s, or the participant holding the picture closer than 25 cm away from his body. For one participant, who manded both vocally and using PECS, the experimenter recorded only vocal mands that occurred more than 3 s prior to or more than 3 s following a PECS mand for that same item, and vice versa. For example, if the participant tapped a picture and then vocalized the label of that picture following 3 s elapsing on the session timer, the experimenter recorded both the picture tap and the vocalization as two individual mands. If the participant tapped a picture and then vocalized the label of that picture prior to 3 s elapsing on the session timer, the experimenter only recorded a single mand. Also, if a vocalization and a PECS mand occurred for two different items at any time, in any order, and with any duration between them within the session the experimenter recorded both as mands.

A switch was each occurrence of a mand for an item that was different from the item previously manded for. For example, if a participant manded for music and the following mand was for a book, the experimenter recorded one switch. If a participant manded for music and the following mand was also for music, the experimenter did not record a switch.

### *Data Collection and Analysis*

The experimenter recorded all vocal and PECS mands occurring throughout the entire session by writing either a number “1” for mand 1 or a number “2” for mand 2 on a data sheet in sequential order of occurrences. The number corresponding to each mand depended on results of the preference assessment, number “1” corresponding to the first item chosen during the preference assessment (highly preferred item) and number “2” corresponding to the second item chosen during the preference assessment (less preferred item). The experimenter recorded all mands that met the response definition whether the participant had either, both, or neither of the available items at the time of the mand. A second observer recorded mands in the same manner during videotape observations at a later time.

The experimenter calculated the rate of responding per minute for each mand by dividing the frequency of each mand by the session length. Session length included reinforcement time, or the time the participant had access to either one or both of the reinforcers within the session, because the experimenter recorded any mands emitted by the participants during access to a reinforcer. Mands occurring during reinforcement time were eligible for reinforcement themselves if they met response requirements. Even if they did not satisfy the reinforcement contingency, the experimenter recorded them as partial fulfillment of the FR requirement. To avoid deletion of mands recorded during reinforcement time from the data, the experimenter included reinforcement time in the calculation of response rate.

The experimenter calculated percentage of switches by counting each instance of switching from one mand to the other and dividing the number of switches by 1 less than the total number of mands occurring in the session and multiplying by 100%. The experimenter

subtracted 1 from the total number of mands because the first mand could not count as a switch as no mands preceded it, and because by subtracting 1 from the total number of mands each remaining mand could potentially be a switch and the percentage of switches could reach 100 %. The experimenter videotaped all sessions for purposes of collecting IOA and procedural integrity data at a later time.

The experimenter calculated rates of obtained reinforcement by dividing the frequency of each reinforcer delivered during a session by the total session length, including reinforcement time. The experimenter calculated the means of the obtained rates of reinforcement for each experimental condition for purposes of displaying demand functions. The experimenter also calculated the standard error of the mean (SEM) for the mean rate of reinforcement for each experimental condition. Mean rates of reinforcement and SEM's of those means derive from the rate of reinforcement obtained during each session of a particular condition. The experimenter calculated the rate of obtained reinforcement, the mean rate of obtained reinforcement, and the SEM for both mand 1 and mand 2 using data obtained from each session of each experimental condition.

The experimenter plotted the demand function for mand 1 on double logarithmic axes to facilitate examination of changes in demand elasticity across each experimental condition. The experimenter determined the elasticity of the demand function by calculating the slope of each line segment. The experimenter used the equation  $\Delta \log y / \Delta \log x$  to calculate the slopes, in which  $y$  is the mand 1 reinforcement rate and  $x$  is the mand 1 schedule value.

### *Preference Assessment*

During every session, within 5 min of preparing the materials the experimenter began a multiple stimulus without replacement preference assessment (Ciccone, Graff & Ahearn, 2005). The experimenter placed five items on the floor at least 50 cm away from the participant. Within 2 s of placing the last of the five items on the floor, the experimenter began handing each item to the participant one at a time for 5 s each. The experimenter turned on and pressed any buttons that were present on the item if the participant did not do so. Within 2 s of taking back the last of the 5 items sampled by the participant the experimenter said to the participant, “What do you want?” If the participant touched or vocally manded for any of the items on the floor the experimenter immediately handed that item to the participant for 10 s. After the 10 s, the experimenter took back the item and placed it behind himself on the floor out of reach and view of the participant. Within 2 s of removing the first chosen item, the experimenter repeated, “What do you want?” with the four items remaining on the floor. If the participant touched or vocally manded for any of the remaining items on the floor, the experimenter immediately delivered that item to the participant for 10 s. After the 10 s, the experimenter took back the item from the participant. The two items chosen were the only items available for the remainder of the session. The experimenter labeled the first item chosen as the highly preferred item and the second item as the less preferred item for the remainder of that session. On a few occasions for each participant, the participant did not choose two items within 5 min and the experimenter terminated that session. The experimenter never needed to terminate two consecutive sessions for any of the participants.

Appendix A shows the two items selected and the order of selection during each preference assessment. It was possible for a participant to select an item as highly preferred during one session and then select that same item as the less preferred item during a subsequent session, and vice versa.

### *Functional Analysis*

Prior to the start of the experiment, the experimenter conducted a functional analysis of the target behaviors to demonstrate that the vocal behaviors and PECS exchanges functioned as mands. The functional analysis consisted of two conditions, a mand test condition during which the experimenter deprived participants of access to the items chosen during the preference assessment for some time to increase the effectiveness of those items at promoting mands, and a control condition during which the experimenter provided the participants with access to the items chosen during the preference assessment to decrease the effectiveness of those items at promoting mands. The experimenter conducted the two conditions in a reversal design, using an ABA design for two participants and a BAB design for the third. The experimenter conducted nine functional analysis sessions for each participant. All functional analysis sessions were 20 min in duration including a 10 min deprivation/satiation manipulation and 10 min of data collection.

*Mand Test.* For 10 min prior to the start of data collection, during the deprivation/satiation manipulation, the experimenter allowed the participant to move freely around the room and to manipulate any toys typically found in that room such as toy cars, puzzles, dolls, etc. The experimenter placed the two items selected during the preference assessment on a shelf out of reach of the participant and did not allow access to the two items

during this time. Immediately following the 10 min deprivation/satiation manipulation, the experimenter sat the participant at the table and placed the two preferred items on the table about 1.5 m from the participant. The experimenter also placed the PECS materials described earlier in the Materials section on the edge of the table in front of the participant. The experimenter sat at the table directly across or perpendicular to the participant and recorded using pen and paper the order of occurrence of each vocal and PECS mand emitted by the participant for 10 min. Within 3 s of each vocalization of the label of one of the items or correct use of PECS by the participant, the experimenter turned on and or handed that item to the participant. Following 15-s access to the item, the experimenter turned off and or took the item away from the participant until another vocalization of a label or use of PECS occurred.

*Control.* For 10 min prior to the start of data collection, during the deprivation/satiation manipulation, the experimenter again allowed the participant to move freely around the room and to manipulate any toys typically found in that room such as toy cars, puzzles, dolls, etc., including the two items selected during the preference assessment. Following the 10 min deprivation/satiation manipulation, the experimenter sat the participant at the table and placed the two items selected during the preference assessment on the table allowing the participants to manipulate them. The experimenter sat in a chair against the wall furthest from the participant for 10 min and recorded using pen and paper any vocalizations or use of PECS by the participant. No programmed consequences followed any vocalizations or use of PECS.

### *General Procedures*

Throughout the experiment, the experimenter attempted to physically redirect any motor stereotypies emitted by the participants by physically placing their hands on the table or on their

lap, their feet flat on the floor, or positioning their body upright in the chair. The experimenter also attempted to redirect vocal stereotypies by holding a finger up to his own mouth and saying “sh” within 3 s of any vocal stereotypies. It was not possible to redirect many stereotypies emitted by participants due to frequent delivery and removal of reinforcers, frequent data recording, and timer management by the experimenter. The experimenter did not provide any other instructions or prompts throughout the experiment.

During all sessions, the experimenter either picked up or moved away any available item the participant reached for without manding. The experimenter placed the item back in its original position if the participant no longer reached for the item for 3 s and did not mand for it. The experimenter redirected inappropriate use of PECS materials such as holding them, bending them, sliding them along the table, or manipulating them in any way other than that defined as a PECS mand following 3 s of the inappropriate behavior by placing the picture back on the table or physically removing the picture from the participant’s hands. Each time the participant handed a PECS picture to the experimenter, the experimenter placed it back in its original position either immediately following delivery of a reinforcer if the mand met schedule requirements or immediately upon receiving the picture if the mand did not meet schedule requirements. Within 1 min of completion of the preference assessment, the experimenter arranged the preferred items on the table as well as PECS materials (with an exception during the Functional Analysis Phase when the deprivation/satiation manipulation followed the preference assessment). Once the materials were in place the experimenter started the timer. The experimenter delivered consequences for available mands according to the experimental conditions in effect. When a particular mand met response requirements for reinforcement the experimenter turned on and or handed the item manded for to the participant within 3 s of that

mand. The participant had access to the item for 15 s before the experimenter turned off and/or removed the item from the participant and placed it in its original position. No programmed consequences followed any mands that did not yet meet response requirements for reinforcement or mands for items other than the two items selected during the preference assessment prior to a particular session. On few occasions mands occurred for one item during reinforcement of the alternative mand, or mands occurred for both items by simultaneous use of a vocal mand for one item and a PECS mand for the other. During these occurrences, if both mands met schedule requirements the experimenter allowed access to both items for 15 s each. Also on a few occasions a mand occurred for an item the participant already had access to. During these instances, if the mand met schedule requirements, the experimenter restarted the 15 s reinforcement timer extending the reinforcement time, and recorded a mand. If the mand did not meet schedule requirements the experimenter only recorded it without delivering any consequences. Once the experimenter delivered a total of 20 reinforcers for any combination of the two mands the session ended.

### *Experimental Conditions and Design*

The study employed both an alternating treatments design and a reversal design to show experimental control of schedule value over mands per minute and variability of manding.

*Alternating Treatments Phase.* The Alternating Treatments Phase consisted of four conditions: FR1/FR1, FR3/FR1, FR9/FR1, and FR27/FR1. For each set of values the first FR value refers to the schedule of reinforcement for mands for the highly preferred item or mand 1, and the second FR value refers to the schedule of reinforcement for mands for the less preferred item or mand 2. The FR schedule value for mand 1 changed across sessions, while the FR

schedule value for mand 2 remained at FR1 during all sessions. Only one set of values, or condition, was in effect for the duration of each session. There were five blocks of sessions. Each block contained four sessions. A different condition was in effect for each of the four sessions within a block, with each condition occurring only once in each block. The experimenter determined the order of conditions within each individual block using a random number generator. The experimenter conducted 20 sessions during the Alternating Treatments Phase for each participant. Appendix B lists the order of presentation of conditions for each participant.

*Reversal Phase.* The Reversal Phase began during the session immediately following the last session of the Alternating Treatments Phase for each participant individually. During the Reversal Phase the experimenter arranged two conditions: FR1/FR1 and FR50/FR1. Again, the first FR value in each set refers to the schedule of reinforcement for mand 1 and the second FR value in each set refers to the schedule of reinforcement for mand 2, and the schedule value for mand 1 changed across blocks of sessions while the schedule value for mand 2 remained unchanged. Rather than changing every session, each condition in this phase remained in effect for a block of consecutive sessions before changing. With Jake and Vin, the experimenter conducted the FR1/FR1 condition, then the FR50/FR1 condition, and then reversed back to the FR1/FR1 condition for three consecutive sessions each for a total of nine Reversal Phase sessions for each of the two participants. With Tyler, the experimenter initially conducted eight consecutive FR50/FR1 sessions, then three consecutive FR1/FR1 sessions, and then reversed back to three consecutive FR50/FR1 sessions. The experimenter conducted five additional FR1/FR1 sessions with Tyler during the initial block of FR1/FR1 sessions to ensure stability in

the data prior to exposing Tyler to the next condition (some of the data recorded for Tyler during the Alternating Treatments Phase were not stable).

### *Interobserver Agreement*

The experimenter obtained IOA by observing videotaped sessions with a second observer some time following the actual sessions and collecting data using pen, paper and clicker in the same manner as the experimenter did during the experimental sessions. The experimenter calculated percentage of IOA for a single session of each of the five blocks of sessions during the Alternating Treatments Phase, each session being of a different condition with one condition observed twice, and one session of each of the three blocks of sessions of the Reversal Phase for all participants. Thus, the experimenter collected IOA data for 25% of sessions for the Alternating Treatments Phase for each participant, 33% of sessions for Jake and Vin for the Reversal Phase, and 21% of sessions for Tyler for the Reversal Phase. The experimenter used a random number generator to determine which session within each block to observe. The experimenter and second observer obtained IOA for mand 1 responses, mand 2 responses, and number of switches during each videotaped observation.

The experimenter defined agreements as any mands or switches recorded by both the experimenter and the second observer and disagreements as any mands or switches recorded by one observer but not the other. The experimenter calculated IOA by dividing total number of agreements by total number of agreements plus disagreements and multiplying by 100% for each session. Table 1 shows the mean percentages and ranges of IOA calculated for each participant and each dependent measure.

Table 1. Mean percentages of IOA and ranges of IOA for mand 1, mand 2, and switches.

Participant	Mand 1		Mand 2		Switches	
	Mean %	Range	Mean %	Range	Mean %	Range
Jake	96.8%	92%-100%	99.1%	97%-100%	99.8%	98%-100%
Tyler	94.6%	87%-100%	99.3%	98%-100	98.6%	95%-100%
Vin	100%	100%	99.9%	99%-100%	99.9%	99%-100%

### *Procedural Integrity*

For the same sessions of which the experimenter obtained IOA data, the experimenter and the same second observer also collected data on procedural integrity. The experimenter defined procedural integrity as the percentage of correct reinforcements delivered by the experimenter according to the reinforcement schedule in effect. The second observer wrote a check mark next to a recorded mand if the experimenter correctly delivered a reinforcer as scheduled. The second observer wrote an "X" next to a recorded mand if the experimenter did not deliver a reinforcer when a mand met schedule requirements, or if the experimenter delivered a reinforcer for a mand that did not meet schedule requirements. If the experimenter delivered a reinforcer for a mand that did not meet schedule requirements, the second observer scored an "X" next to the mand that the experimenter incorrectly reinforced and an "X" next to the nearest prior or subsequent mand that met schedule requirements but that the experimenter did not reinforce. The second observer then began counting the number of mands to meet schedule requirements at number one following the actual reinforcement by the experimenter so that all subsequent reinforcements were not incorrect. The experimenter calculated percentage of procedural integrity by dividing the number of correct reinforcements by the number of correct plus incorrect reinforcements and multiplying by 100 percent. Table 2 shows the mean percentages of procedural integrity for all participants.

Table 2. Mean percentages and ranges of procedural integrity.

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Participant	Mean %	Range
Jake	97.9%	93%-100%
Tyler	96.1%	87%-100%
Vin	99.9%	99.9%-100%

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## Results

This section reports results from all phases of the experiment. Subsections report the results for each individual dependent variable. The rate of vocalizations and PECS during the Functional Analysis Phase demonstrate that those responses functioned as mands. The following subsection reports the rate of mand 2, the primary dependent variable, during the conditions of the Alternating Treatments and Reversal Phases of the experiment. Subsequent subsections report the rate of mand 1 and the percentage of switches during the Alternating Treatments and Reversal Phases. Demand and work functions then display the mean rate of reinforcement and the mean rate of responding for each condition of the Alternating Treatments Phase respectively. An additional demand function shows the mean rate of reinforcement obtained from mand 1 as a function of mand 1 schedule value plotted on double logarithmic coordinates to calculate the demand elasticity of mand 1. Finally, mean session lengths show the extent to which participants maximized reinforcement.

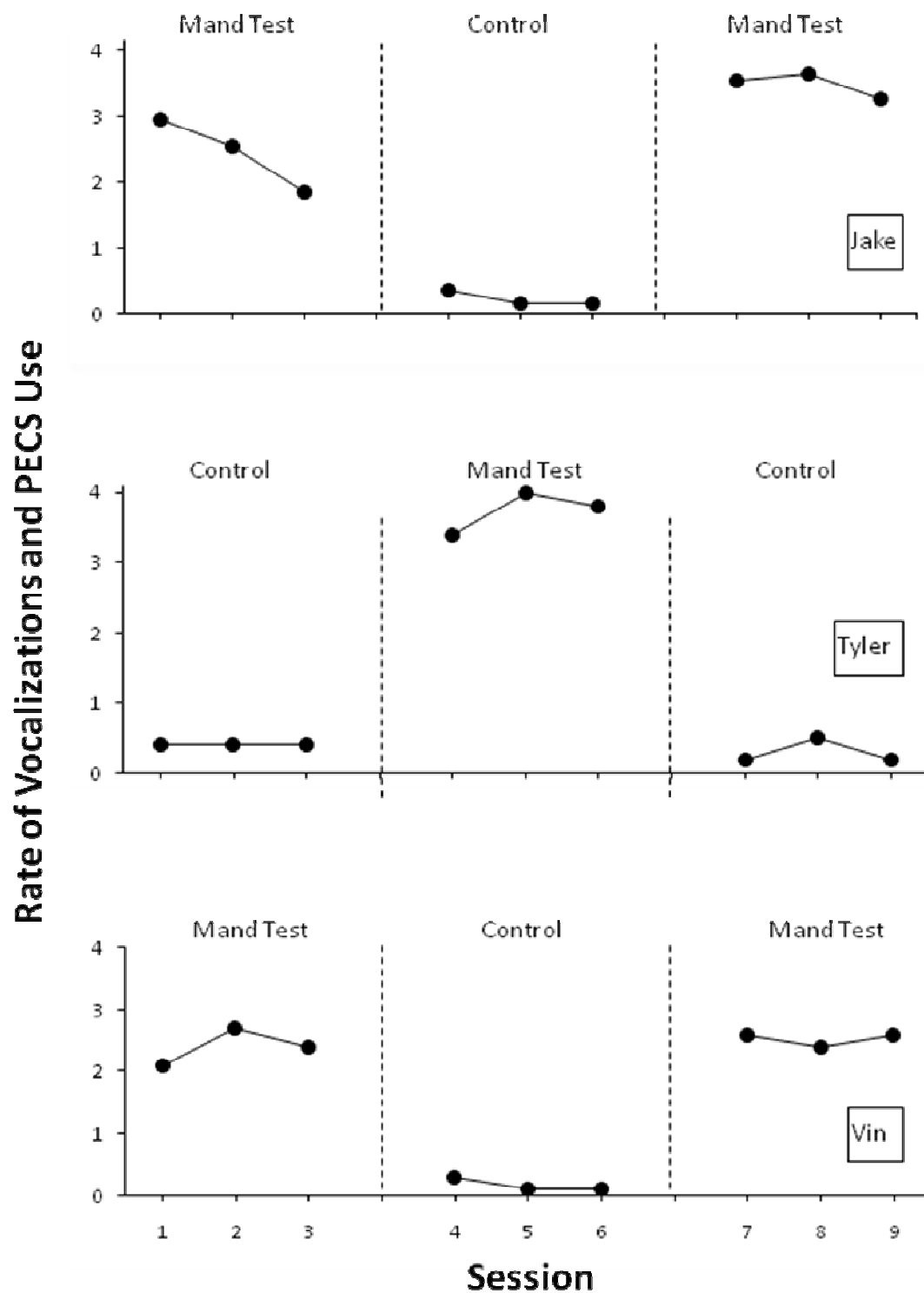
### *Functional Analysis*

Figure 1 shows results for all 3 participants during the Functional Analysis Phase. Plotted on the abscissa are consecutive sessions and plotted on the ordinate is the combined rate of vocalizations and use of PECS, or mands, during each session. The top panel shows that Jake emitted between 1.70 and 2.80 mands per minute during the initial three Mand Test sessions and between 3.10 and 3.50 mands per minute during the final 3 Mand Test sessions. During the three Control sessions, Jake emitted between 0.00 and 0.20 mands per minute.

The middle panel shows that Tyler emitted between 3.30 and 3.90 mands per minute during the three Mand Test sessions. Tyler emitted 0.30 mands per minute during each of the initial three Control sessions and between 0.10 and 0.40 mands per minute during the final three Control sessions.

The bottom panel shows that Vin emitted between 2.20 and 2.80 mands per minute during the initial three Mand Test sessions and between 2.50 and 2.70 mands per minute during the final three Mand Test sessions. Vin emitted between 0.20 and 0.40 mands per minute during the three Control sessions.

Figure 1. The combined rate of vocalizations and use of PECS during the Mand Test and the Control conditions of the Functional Analysis.



*Mand 2*

Figure 2 shows the rate of mand 2 responses for each session of the Alternating Treatments and Reversal Phase for all three participants. Plotted on the abscissa are consecutive sessions and plotted on the ordinate are mand 2 response rates for each session.

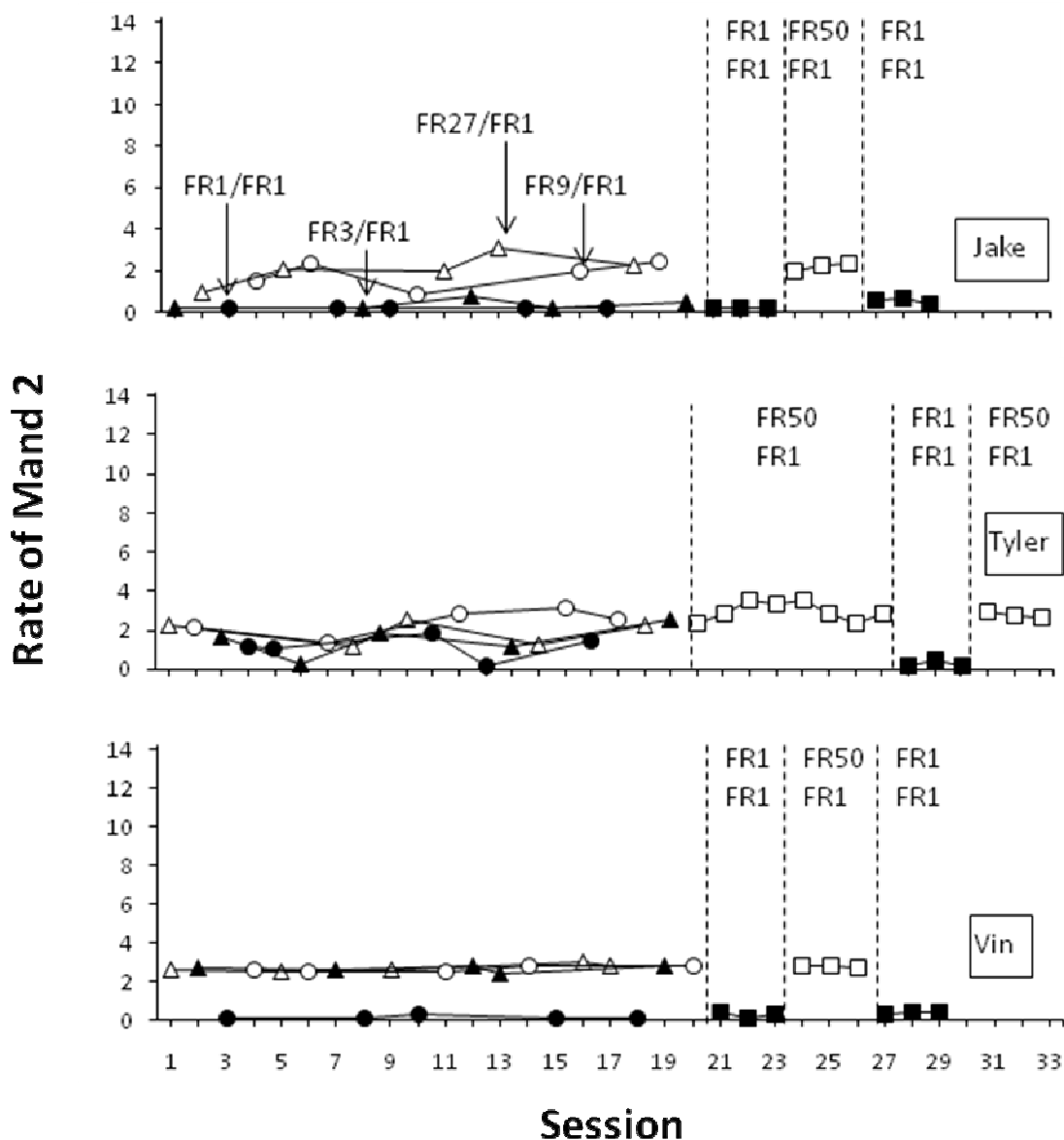
The top panel shows that Jake emitted a higher rate of mand 2 responses during the FR9/FR1 and FR27/FR1 sessions than during the FR1/FR1 and FR3/FR1 sessions of the Alternating Treatments Phase. The rate of mand 2 responses remained at 0.00 during all FR1/FR1 sessions of the Alternating Treatments Phase and ranged between 0.00 and 0.54 during FR3/FR1 sessions. The rate of mand 2 responses ranged between 0.63 and 2.2 during FR9/FR1 sessions and between 0.77 and 2.89 during FR27/FR1 sessions. During the Reversal Phase Jake emitted a higher rate of mand 2 responses during the FR50/FR1 sessions than during the FR1/FR1 sessions. The rate of mand 2 responses was 0.00 during each of the initial three FR1/FR1 sessions, between 1.75 and 2.17 during the three FR50/FR1 sessions, and between 0.15 and 0.49 during the final three FR1/FR1 sessions of the Reversal Phase.

The middle panel of Figure 2 shows the rate of mand 2 responses for Tyler. Mand 2 response rates were highly variable throughout all sessions of the Alternating Treatments Phase. During FR1/FR1 sessions the rate of mand 2 responses ranged from 0.00 to 1.69, during the FR3/FR1 sessions from 0.13 to 2.35, during the FR9/FR1 sessions from 1.17 to 2.97, and during the FR27/FR1 sessions from 0.95 to 2.42. During the Reversal Phase Tyler emitted a higher rate of mand 2 responses during the FR50/FR1 sessions than during the FR1/FR1 sessions. The rate of mand 2 responses ranged between 2.15 and 3.36 during the initial eight FR50/FR1 sessions,

between 0.00 and 0.27 during the three FR1/FR1 sessions, and between 2.47 and 2.82 during the final three FR50/FR1 sessions of the Reversal Phase.

The bottom panel of Figure 2 shows the rate of mand 2 responses for Vin. The figure shows a higher rate of mand 2 responses during the FR3/FR1, FR9/FR1, and FR27/FR1 sessions compared to the FR1/FR1 sessions of the Alternating Treatments Phase. Mand 2 response rates were similar during FR3/FR1, FR9/FR1, and FR27/FR1 sessions and ranged between 2.28 and 2.83. During the FR1/FR1 sessions the rate of mand 2 responses was 0.00 during four out of the five sessions and 0.14 during the remaining session. During the Reversal Phase the rate of mand 2 responses was greater during the FR50/FR1 sessions than during the FR1/FR1 sessions. The rate of mand 2 responses ranged between 0.00 and 0.26 during the initial three FR1/FR1 sessions, between 2.59 and 2.64 during the three FR50/FR1 sessions, and between 0.14 and 0.27 during the final three FR1/FR1 sessions of the Reversal Phase.

Figure 2. The rate of mand 2 during all sessions of the Alternating Treatments and Reversal Phase. For the Alternating Treatments Phase, closed circles represent FR1/FR1 sessions, closed triangles represent FR3/FR1 sessions, open circles represent FR9/FR1 sessions, and open triangles represent FR27/FR1 sessions. For the Reversal Phase closed squares represent FR1/FR1 sessions and open squares represent FR50/FR1 sessions.



### *Mand 1*

Figure 3 shows the rate of mand 1 responses during all sessions of the Alternating Treatments and Reversal Phases for all three participants. Plotted on the abscissa are consecutive sessions and plotted on the ordinate are mand 1 response rates for each session.

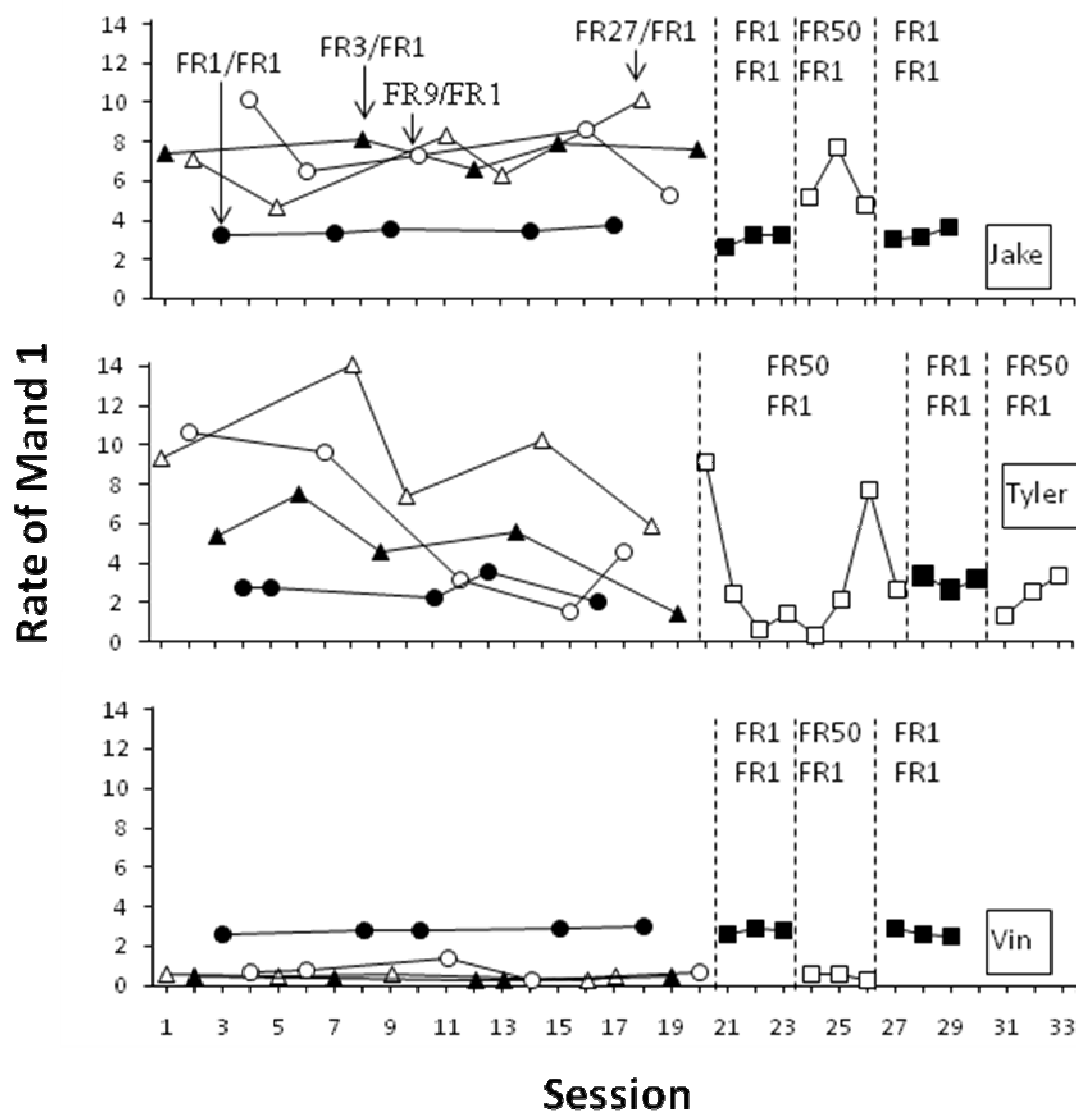
The top panel shows the rate of mand 1 responses for Jake. The figure shows a lesser rate of mand 1 responses during the FR1/FR1 sessions of the Alternating Treatments Phase than all other sessions of that phase. The rate of Mand 1 responses during the FR1/FR1 sessions of the Alternating Treatments Phase ranged between 3.06 and 3.59. The mand 1 response rate ranged between 6.47 and 8.00 during FR3/FR1 sessions, between 5.08 and 10.01 during FR9/FR1 sessions, and between 4.47 and 9.98 during FR27/FR1 sessions. During the Reversal Phase mand 1 response rates were greater during the FR50/FR1 sessions than during the FR1/FR1 sessions. The rate of mand 1 responses ranged between 2.47 and 3.09 during the initial three FR1/FR1 sessions, between 4.57 and 7.57 during the three FR50/FR1 sessions, and between 2.86 and 3.48 during the final three FR1/FR1 sessions of the Reversal Phase.

The middle panel of Figure 3 shows the rate of mand 1 responses for Tyler. Mand 1 response rates were highly variable within each condition of the Alternating Treatments Phase and show a decreasing trend for all conditions except FR1/FR1. The rate of mand 1 ranged between 1.88 and 3.44 during FR1/FR1 sessions, between 1.24 and 7.39 during FR3/FR1 sessions, between 1.41 and 10.49 during FR9/FR1 sessions, and between 5.71 and 13.96 during FR27/FR1 sessions. The Reversal Phase shows no difference in mand 1 response rates across FR1/FR1 sessions and FR50/FR1 sessions. The rate of mand 1 ranged between 0.50 and 8.94 during the initial eight FR50/FR1 sessions, between 2.44 and 3.16 during the three FR1/FR1

sessions, and between 1.13 and 3.21 during the final three FR50/FR1 sessions of the Reversal Phase.

The bottom panel of Figure 3 shows the rate of mand 1 responses for Vin. Vin emitted a higher rate of mand 1 responses during all FR1/FR1 sessions compared to all other sessions of the Alternating Treatments Phase. The mand 1 response rates during the FR1/FR1 sessions of the Alternating Treatments Phase ranged from 2.46 to 2.80. The mand 1 response rates for all FR3/FR1, FR9/FR1, and FR27/FR1 sessions combined ranged from 0.13 to 0.63. During the Reversal Phase the rate of mand 1 was greater during the FR50/FR1 sessions than during the FR1/FR1 sessions. The rate of mand 1 responses ranged between 2.38 and 2.70 during the initial three FR1/FR1 sessions, between 0.13 and 0.39 during the three FR50/FR1 sessions, and between 2.28 and 2.73 during the final three FR1/FR1 sessions of the Reversal Phase.

**Figure 3.** The rate of mand 1 during all sessions of the Alternating Treatments and Reversal Phase. For the Alternating Treatments Phase, closed circles represent FR1/FR1 sessions, closed triangles represent FR3/FR1 sessions, open circles represent FR9/FR1 sessions, and open triangles represent FR27/FR1 sessions. For the Reversal Phase closed squares represent FR1/FR1 sessions and open squares represent FR50/FR1 sessions.



### *Switches*

Figure 4 shows percentages of switches occurring during all sessions of the Alternating Treatments and Reversal Phase for all three participants. Plotted on the abscissa are consecutive sessions and plotted on the ordinate are the percentages of switches during each session.

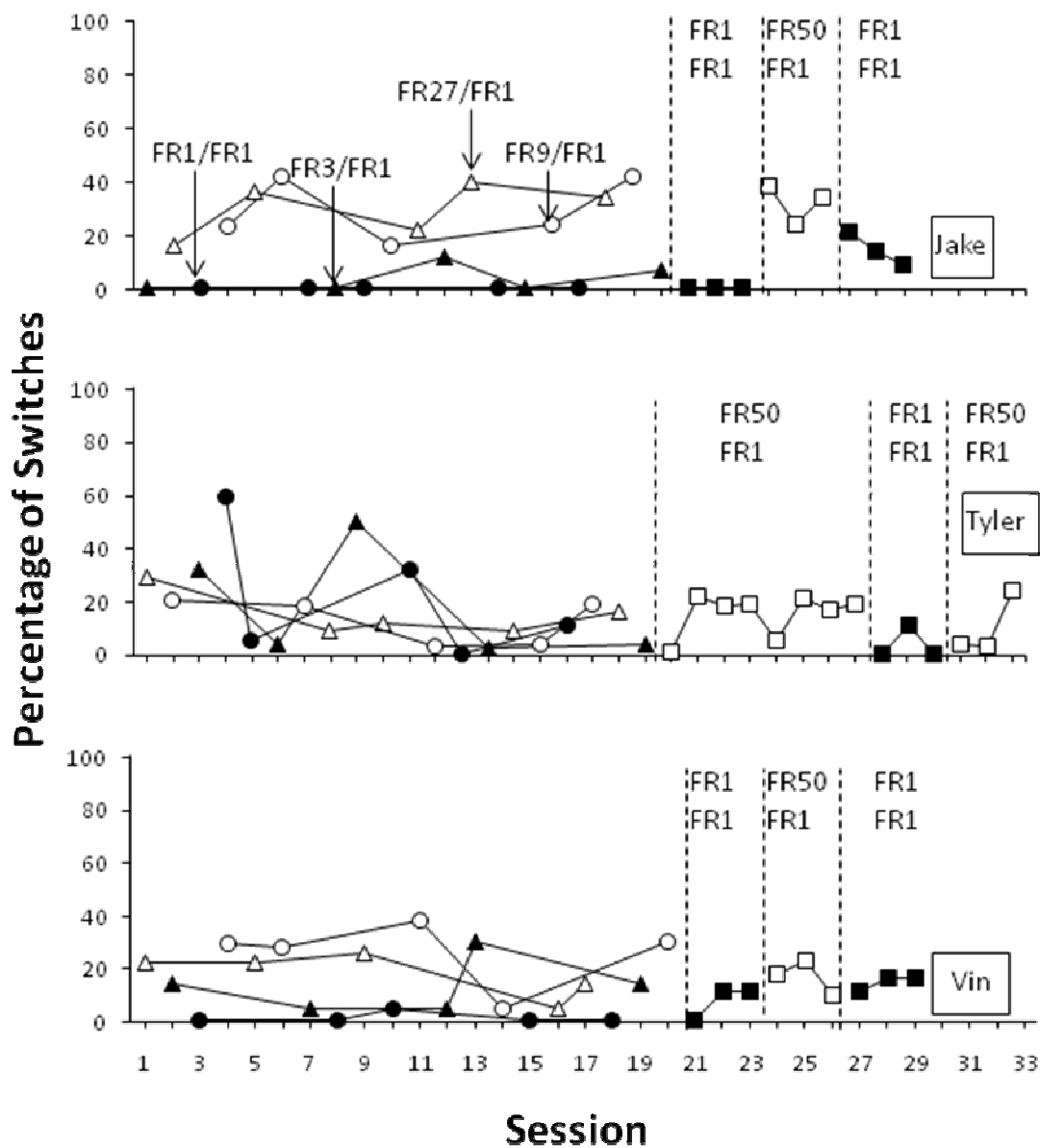
The top panel of Figure 4 shows greater percentages of switches for Jake during the FR9/FR1 and FR27/FR1 sessions of the Alternating Treatments Phase compared to the FR1/FR1 and FR3/FR1 sessions of that phase. The percentages of switches remained at 0% throughout all FR1/FR1 sessions and ranged between 0% and 12% during FR3/FR1 sessions. Percentages of switches ranged between 16% and 42% during FR9/FR1 sessions and between 16% and 40% during FR27/FR1 sessions. During the Reversal Phase percentages of switches were greater during the FR50/FR1 sessions than during the FR1/FR1 sessions. The percentages of switches were 0% during each of the initial three FR1/FR1 sessions, ranged between 24% and 38% during the three FR50/FR1 sessions, and ranged between 9% and 21% during the final three FR1/FR1 sessions of the Reversal Phase.

The middle panel of Figure 4 shows the percentages of switches for Tyler. Percentages of switches remained variable throughout all sessions of the Alternating Treatment Phase. During FR1/FR1 sessions percentages of switches ranged from 0% to 59%. During FR3/FR1 sessions percentages of switches ranged between 2% and 50%. During FR9/FR1 sessions percentages of switches ranged between 3% and 20%, and during FR27/FR1 sessions percentages of switches ranged between 9% and 29%. The percentages of switches remained variable in the Reversal Phase, but were somewhat greater during FR50/FR1 sessions than during FR1/FR1 sessions. Percentages of switches ranged between 1% and 22% during the

initial eight FR50/FR1 sessions, between 0% and 11% during the three FR1/FR1 sessions, and between 3% and 24% during the final three FR50/FR1 sessions.

The bottom panel of Figure 4 shows the percentages of switches for Vin. Percentages of switches during the Alternating Treatments Phase were greatest during the FR9/FR1 sessions, ranging between 29% and 50%. Percentages of switches were variable during the FR3/FR1 and FR27/FR1 sessions ranging between 5% and 32% and between 5% and 27% respectively. During the FR1/FR1 sessions percentages of switches remained at 0% for all sessions except for one session during which the percentage increased to 5%. Percentages of switches during the FR1/FR1 sessions were less than all other sessions of the Alternating Treatments Phase. During the initial three FR1/FR1 sessions of the Reversal Phase percentages of switches ranged between 0% and 11%, between 10% and 23% during the three FR50/FR1 sessions, and between 11% and 16% during the final FR1/FR1 sessions. The figures in Appendices C, D, and E display switches by showing each mand 1 and mand 2 response in sequential order of occurrence for Jake, Tyler, and Vin respectively during each session of the Alternating Treatments Phase.

Figure 4. The percentage of switches recorded for each session of the Alternating Treatments and Reversal Phase. For the Alternating Treatments Phase, closed circles represent FR1/FR1 sessions, closed triangles represent FR3/FR1 sessions, open circles represent FR9/FR1 sessions, and open triangles represent FR27/FR1 sessions. For the Reversal Phase closed squares represent FR1/FR1 sessions and open squares represent FR50/FR1 sessions.



### *Demand Function*

Figure 5 shows own price demand curves for mand 1 and cross price demand curves for mand 2 for all three participants during the Alternating Treatments Phase. Plotted on the abscissa are all sets of FR values in ascending order of the FR value for mand 1, and plotted on the ordinate are mean rates of reinforcement for both mand 1 and mand 2 during each condition. Each data point represents the mean rate of reinforcement for all sessions of the corresponding condition plotted on the abscissa. Vertical bars through data points show the standard error of the mean (SEM) among values obtained from all sessions of a particular condition.

For all three participants, the figure shows a negative own price demand slope for rate of mand 1 reinforcement and a positive cross price demand slope for rate of mand 2 reinforcement. The top and middle panels for Jake and Tyler respectively show that both participants earned a greater mean rate of reinforcement for emitting mand 1 than for emitting mand 2 during FR1/FR1 and FR3/FR1 sessions, and a greater mean rate of reinforcement for emitting mand 2 than for emitting mand 1 during FR9/FR1 and FR27/FR1 sessions. The bottom panel shows that Vin earned all reinforcements for emitting mand 1 during the FR1/FR1 sessions and earned all reinforcements for emitting mand 2 during FR3/FR1, FR9/FR1, and FR27/FR1 sessions. The mean rate of reinforcement obtained from mand 1 for Jake was 3.27 during the FR1/FR1 condition, 2.46 during the FR3/FR1 condition, 0.80 during the FR9/FR1 condition, and 0.22 during the FR27/FR1 condition. The mean rate of reinforcement obtained from mand 2 for Jake was 0.00 during the FR1/FR1 condition, 0.16 during the FR3/FR1 condition, 1.59 during the FR9/FR1 condition, and 1.86 during the FR27/FR1 condition. For Tyler, the mean rate of reinforcement obtained from mand 1 was 2.48 during the FR1/FR1 condition, 1.53 during the

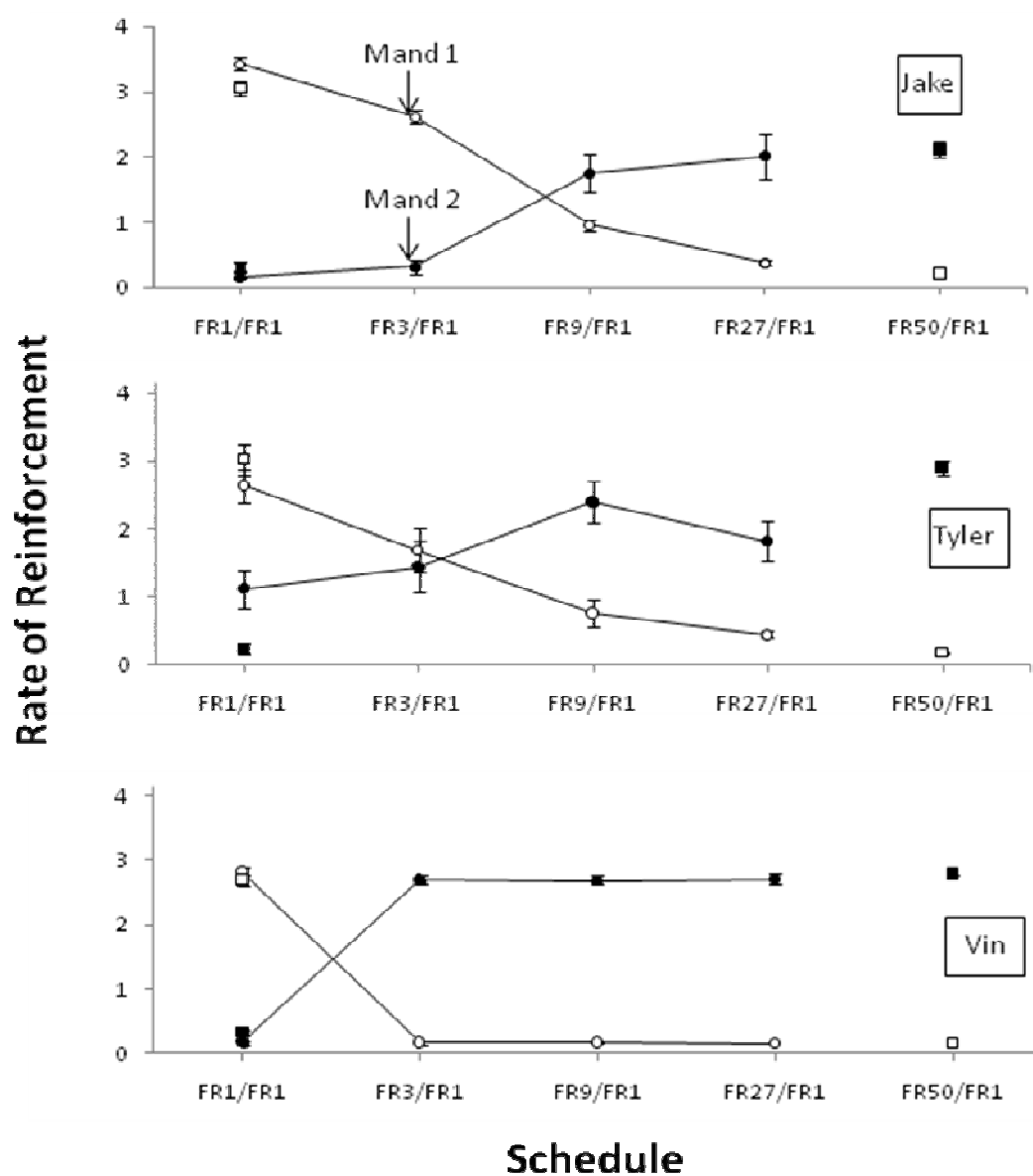
FR3/FR1 condition, 0.61 during the FR9/FR1 condition, and 0.28 during the FR27/FR1 condition. The mean rate of reinforcement obtained from mand 2 for Tyler was 0.96 during the FR1/FR1 condition, 1.30 during the FR3/FR1 condition, 2.24 during the FR9/FR1 condition, and 1.67 during the FR27/FR1 condition. For Vin, the mean rate of reinforcement obtained from mand 1 was 2.66 during the FR1/FR1 condition and 0.00 during the FR3/FR1, FR9/FR1, and FR27/FR1 conditions. The mean rate of reinforcement obtained from mand 2 for Vin was 0.03 during the FR1/FR1 condition, 2.54 during the FR3/FR1 condition, 2.53 during the FR9/FR1 condition, and 2.56 during the FR27/FR1 condition.

Open and closed squares in Figure 5 show the mean rate of reinforcement for mand 1 and mand 2 respectively during the FR1/FR1 and FR50/FR1 sessions of the Reversal Phase. Vertical lines through these data points show SEM's for the mean rate of obtained reinforcement for each condition of the Reversal Phase. All three participants earned a greater mean rate of reinforcement for mand 1 compared to mand 2 during the FR1/FR1 sessions of the Reversal Phase and a greater mean rate of reinforcement for mand 2 compared to mand 1 during the FR50/FR1 sessions. For Jake, the mean rates of reinforcement during the FR1/FR1 condition were 2.90 and 0.16 for mand 1 and mand 2 respectively, and during the FR50/FR1 condition 0.07 and 1.97 for mand 1 and mand 2 respectively. For Tyler, the mean rates of reinforcement earned during the FR1/FR1 condition were 2.87 and 0.09 for mand 1 and mand 2 respectively, and during the FR50/FR1 condition 0.02 and 2.75 for mand 1 and mand 2 respectively. For Vin, the mean rates of reinforcement during the FR1/FR1 condition were 2.54 and 0.18 for mand 1 and mand 2 respectively, and during the FR50/FR1 condition 0.00 and 2.62 for mand 1 and mand 2 respectively. Reversal phase means comprise unequal numbers of FR1/FR1 and FR50/FR1 sessions both within and across participants. Appendix F shows own price and cross

price demand functions for each of the five blocks of sessions of the Alternating Treatments

Phase for each participant.

Figure 5. The own price and cross price demand functions for mand 1 and mand 2 respectively during the Alternating Treatments Phase. Open circles represent the rate of mand 1 reinforcement and closed circles represent the rate of mand 2 reinforcement. Open squares represent the rate of mand 1 reinforcement and closed squares represent the rate of mand 2 reinforcement during the Reversal Phase. Vertical bars through data points represent the standard error of the means.



### *Work Function*

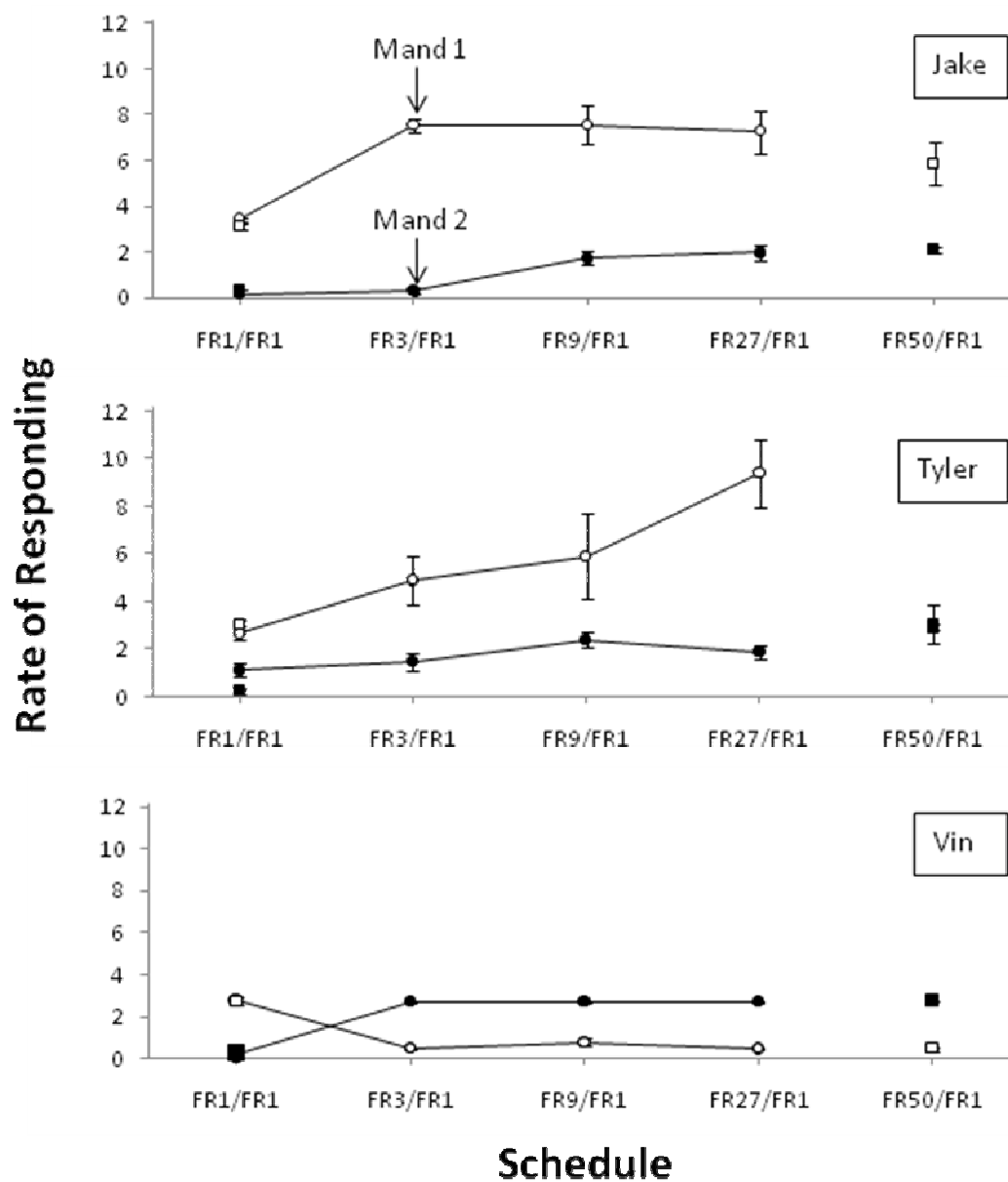
Figure 6 shows work functions for mand 1 and mand 2 for all three participants during the Alternating Treatments phase. Plotted on the abscissa are all sets of FR values in ascending order of the FR value for mand 1, and plotted on the ordinate are the mean rates of both mand 1 and mand 2 responses during each corresponding condition. Each data point represents the mean rate of responding for all sessions of the corresponding condition plotted on the abscissa. Vertical bars through the data points show the SEM's among values obtained from all sessions of a particular condition.

For Jake, the rate of mand 1 responding increased across the FR1/FR1, FR3/FR1 and FR9/FR1 conditions and subsequently decreased during the FR27/FR1 condition. The mean rate of responding for Jake was 3.30 during the FR1/FR1 condition, 7.38 during the FR3/FR1 condition, 7.39 during the FR9/FR1 condition, and 7.12 during the FR27/FR1 condition. The mean rate of mand 2 responding for Jake increased across all conditions with rates of 0.00, 0.16, 1.59, and 1.86 during the FR1/FR1, FR3/FR1, FR9/FR1, and FR27/FR1 conditions respectively. For Tyler, the mean rate of mand 1 responding increased across all conditions with mean rates of 2.51, 4.73, 5.74, and 9.23 during the FR1/FR1, FR3/FR1, FR9/FR1, and FR27/FR1 conditions respectively. The mean rate of mand 2 responding for Tyler increased across the FR1/FR1, FR3/FR1, and FR9/FR1 conditions with mean rates of 0.96, 1.33, and 2.24 during those conditions respectively. The mean rate of mand 2 responding for Tyler decreased from the FR9/FR1 condition to the FR27/FR1 condition with a mean rate of 1.73 during the FR27/FR1 condition. For Vin, the mean rate of mand 1 responding decreased from a mean rate of 2.66 during the FR1/FR1 condition to mean response rates of 0.03, 0.02, and 0.00 during the

FR3/FR1, FR9/FR1, and FR27/FR1 conditions respectively. The mean rate of mand 2 responding for Vin increased from a mean rate of 0.03 during the FR1/FR1 condition to mean rates of 2.54, 2.53, and 2.56 during the FR3/FR1, FR9/FR1, and FR27/FR1 conditions respectively.

Open and closed squares show the mean rate of responding for mand 1 and mand 2 respectively during the FR/FR1 and FR50/FR1 sessions of the Reversal Phase. Jake emitted a greater mean rate of mand 1 responses, 2.99, than mand 2 responses, 0.16, during the FR1/FR1 condition. Jake also emitted a greater mean rate of mand 1 responses, 5.71, than mand 2 responses, 1.97, during the FR50/FR1 condition. Tyler emitted a greater mean rate of mand 1 responses, 2.87, than mand 2 responses, 0.09, during the FR1/FR1 sessions. Mean rate of mand 1 and mand 2 responses were similar for Tyler during FR50/FR1 sessions at 2.90 and 2.75 respectively. Vin emitted a greater mean rate of mand 1 responses, 2.54, than mand 2 responses 0.18, during the FR1/FR1 condition and a greater mean rate of mand 2 responses, 2.62, than mand 1 responses, 0.00, during the FR50/FR1 condition. The mean rate of mand 2 responses was greater during the FR50/FR1 condition than during the FR50/FR1 condition for all three participants. Appendix G shows the work functions for each of the five blocks of sessions of the Alternating Treatments Phase for all three participants.

**Figure 6.** The work functions for the Alternating Treatments Phase. Open circles represent the rate of mand 1 responding and closed circles represent the rate of mand 2 responding. Open squares represent the rate of mand 1 responding and closed squares represent the rate of mand 2 responding during the Reversal Phase. Vertical bars through the data points represent the standard error of the means.



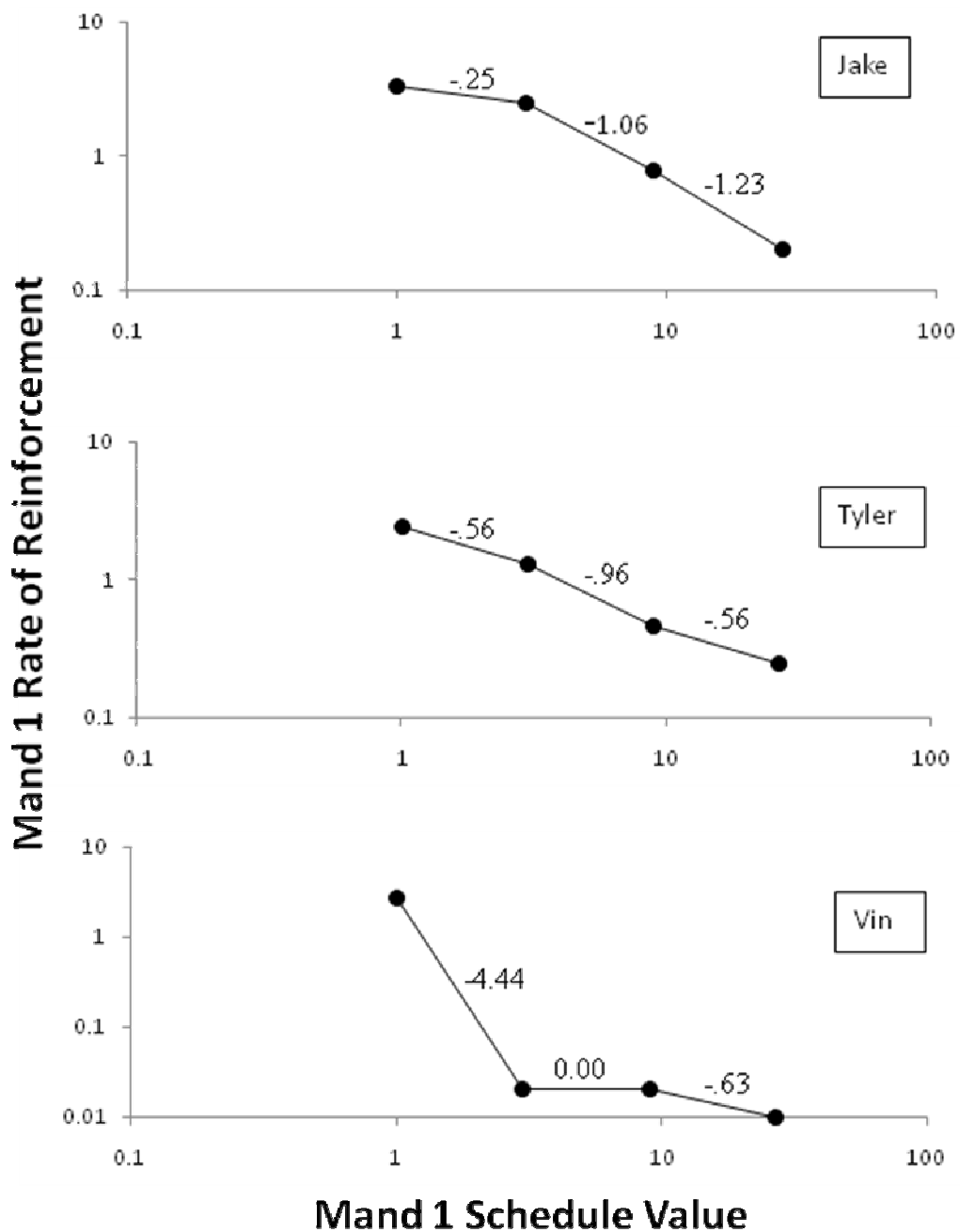
### *Elasticity Calculations*

Figure 7 shows the mean rate of mand 1 reinforcement for each condition plotted on double logarithmic coordinates. The abscissa shows a log scale of the schedule values for mand 1 in ascending order and the ordinate shows a log scale of the mean rate of reinforcement obtained for mand 1 during each of those schedule values. The experimenter added a value of 0.01 to the rate of reinforcement obtained by Vin only for every session in every condition because during a number of sessions when the mand 1 schedule value was greater than FR1 Vin did not earn any reinforcers for mand 1. The experimenter added the value of .01 to obtain log values from those sessions because the log of zero is undefined.

For Jake the slope values decreased across all three line segments as the mand 1 schedule values increased. Slope values for Jake were -0.25 along FR1 and FR3 mand 1 schedule values, -1.06 along FR3 and FR9 mand 1 schedule values, and -1.23 along FR9 and FR27 mand 1 schedule values. For Tyler the steepest slope lies along the FR3 and FR9 mand 1 schedule values with a slope value of -0.96. Slope values for Tyler along the FR1 and FR3 and along the FR9 and FR27 mand 1 schedule values were both -0.56. The function for Vin had the steepest slope value for all three participants with a value of -4.44 along the FR1 and FR3 mand 1 schedule values. The slope value for Vin was 0.00 along the FR3 and FR9 mand 1 schedule values and -0.63 along the FR9 and FR27 mand 1 schedule values.

Figure 7. The rate of mand 1 reinforcement during all conditions of the Alternating Treatments

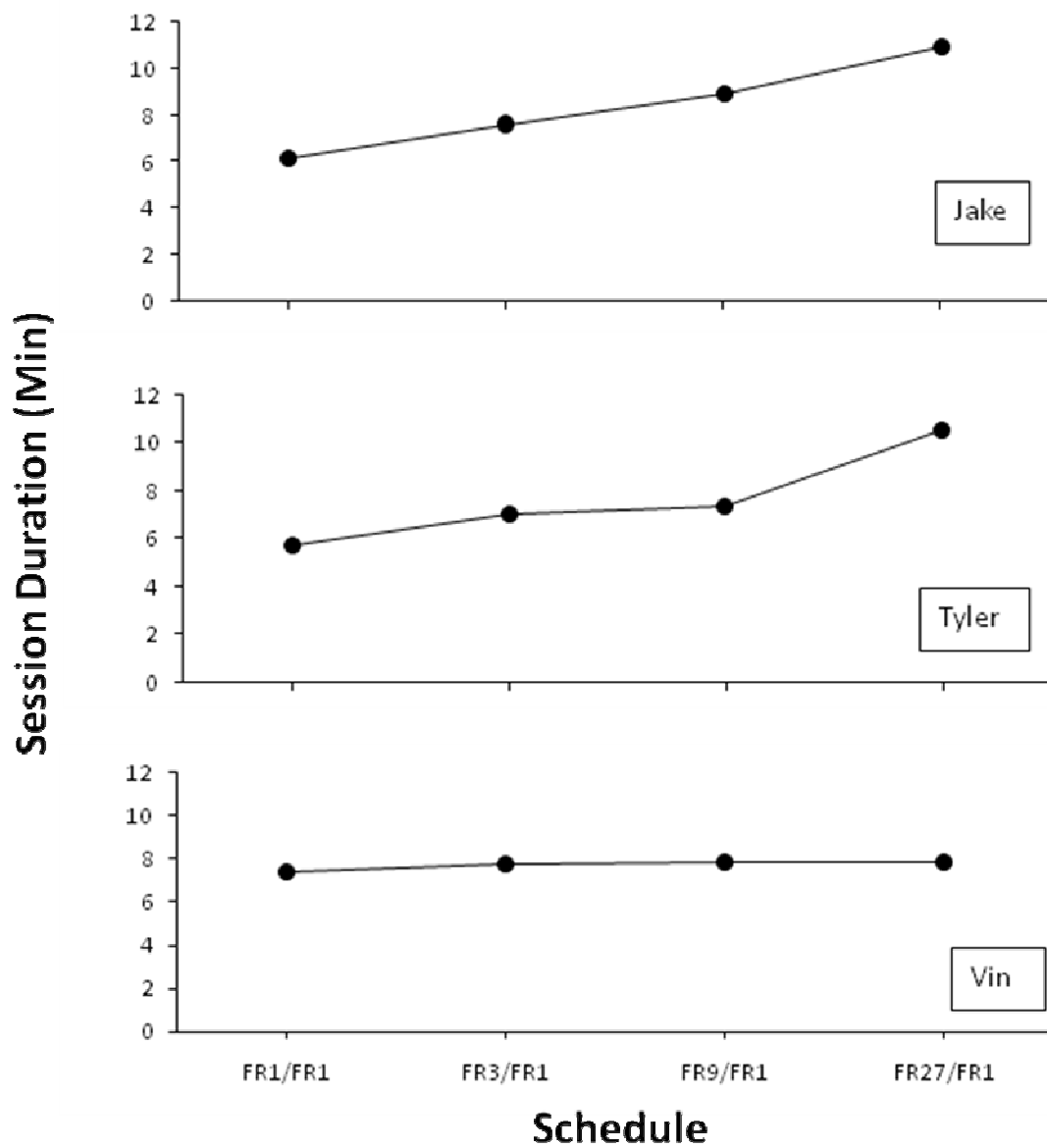
Phase in log/log coordinates. Values along the function show the slope of that line segment.



### *Session Duration*

Figure 8 shows the mean session duration, or amount of time in minutes to earn 20 reinforcers, for each of the sets of schedule values. Plotted on the abscissa are all sets of FR values in ascending order of the FR value for mand 1, and plotted on the ordinate are mean session durations in minutes for each of the conditions. For both Jake and Tyler mean session duration steadily increased as the schedule values for mand 1 increased. Mean session durations for Vin increase only minimally across conditions.

Figure 8. The mean session duration in minutes for each set of schedule values for all participants during the Alternating Treatments Phase.



## Discussion

Increasing schedule values for mands for a highly preferred item was effective at increasing the rate of mands for a less preferred item for three children diagnosed with autism. In addition, for two of the participants an increase in the schedule value for mands for the highly preferred item resulted in an increase in switching from mand 1 to mand 2, a measure of variability in manding. Both of these results indicate that manipulating schedule values for mands alters response allocation when two items of unequal preference are concurrently available. Rather than manding solely for the highly preferred item as observed during most equal value concurrent schedules, the participants altered mand allocation so that they manded for both the highly preferred and the less preferred items when concurrent schedule values were unequal and received some rate of reinforcement for both mands during most of those sessions. Systematic changes in concurrent schedule values resulted in predicted shifts in mand allocation.

The results of the Functional Analysis Phase of this experiment replicate the Lerman et al. (2005) functional analysis of verbal behavior. Few studies have conducted functional analyses of verbal behavior during examinations of language in children with autism. The present study utilized a functional analysis to determine whether the term “mand” was an appropriate label for the dependent variable. It may be important for future studies to also determine functional relationships prior to labeling and analyzing verbal behavior.

Results of the Alternating Treatments and Reversal Phases are consistent with previous literature on concurrent schedules (Bernstein & Sturmey, 2008; Bernstein, Brown & Sturmey, 2009; Hoch et al., 2002; Horner & Day, 1991; Richman, Wacker, & Winborn, 2001) in that increased response requirements for a highly preferred reinforcer affected response rate for a less

preferred reinforcer that was concurrently available. During the Alternating Treatments Phases there was an increase in the rate of mand 2 responding for two out of the three participants during schedule values for mand 1 greater than FR1, and during the Reversal Phase there was a higher rate of mand 2 responding during the FR50/FR1 condition compared to the FR1/FR1 condition for all three participants. Therefore, increasing the schedule of reinforcement for mand 1 above a value of FR1 altered response allocation, and some schedule value for mand 1 other than FR1 for all three participants increased the rate of mand 2 responding despite an unchanged schedule value for mand 2 throughout the experiment. In addition, there was an increase in switching behavior at mand 1 schedule values greater than FR1 for two out of the three participants, indicating that the altered schedule value for mand 1 increased variability in responding.

Demand functions in Figures 5 replicate the demand functions reported by Tustin (1994). The Tustin study as well as the present study demonstrated a negative own price demand slope for a reinforcer with increasing response requirements, accompanied by a positive cross price demand slope for an alternatively available reinforcer on an unchanged reinforcement schedule. Tustin demonstrated shifts in response allocation for visual versus auditory displays in adults with intellectual disabilities through schedule manipulation. The present study extends those findings to children with autism responding for various musical toys and tactile activities. In addition, Tustin examined rate of button pressing as dependent measures. The present study extended their findings to a more socially significant behavior, manding in children with autism.

Figure 2 shows that Jake and Vin both increased mand 2 responding when the schedule value for mand 1 increased above FR1. For Tyler, it is not clear in the Alternating Treatments

Phase of Figure 2 that mand 2 response rates were greater during the FR3/FR1, FR9/FR1, and FR27/FR1 sessions compared to FR1/FR1 sessions. Figure 5, however, shows for Tyler an increasing mean number of obtained reinforcements for emitting mand 2 as the schedule value for mand 1 increases, indicating an increase in the rate of mand 2 responses during those sessions. Data shown in Figure 2 from the Reversal Phase for Tyler show a clear increase in mand 2 responding during the FR50/FR1 condition compared to the FR1/FR1 condition. A possible reason for the lack of difference in the rate of mand 2 responding across conditions during the Alternating Treatments Phase for Tyler in Figure 2 is the occasional mand 2 responses emitted by Tyler during some FR1/FR1 sessions. These mand 2 responses increased the response rate for mand 2 during the FR1/FR1 sessions to levels similar to that of mand 2 during the other experimental conditions. Jake and Vin emitted few to no mand 2 responses during the FR1/FR1 sessions. Mand 2 responding during the FR1/FR1 sessions for Tyler could be due to a minimal difference in the preference for either of the two items chosen during the preference assessment over the other item, possibly because the items were usually similar in type (music toys).

Figure 3 shows that Jake emitted fewer mand 1 responses during the FR1/FR1 sessions of the Alternating Treatments Phase than during the other sessions. While the FR3/FR1, FR9/FR1, and FR27/FR1 sessions each had distinct effects on the mand 2 response rate for Jake, the mand 1 response rate remained stable throughout all of those sessions. For Tyler, however, there are clear effects of mand 1 schedule value on rate of responding during all sessions except FR9/FR1 sessions. While all four response rate functions show a decreasing trend across consecutive sessions, response rate is greater during all five FR27/FR1 sessions than during each of the five FR1/FR1 sessions and each of the five FR3/FR1 sessions. In addition, response rate is greater during each of the FR3/FR1 sessions than during each of the FR1/FR1 sessions. Therefore, the

conditions appear to have had a greater effect on mand 1 responding than mand 2 responding for Tyler. For Vin, any value above FR1 for mand 1 almost completely eliminated mand 1 responding, while mand 2 responding remained at elevated rates during all sets of schedule values except FR1/FR1 during which the rates were near zero.

The experimenter included the Reversal Phase to further examine parameters of the schedule value for Mand 1, in particular for Tyler where the values of FR1, FR3, FR9, and FR27 for mand 1 did not result experimental control over mand 2 responding as shown in Figure 2. Due to a lack of stability in mand 2 data during the Alternating Treatments Phase for Tyler, the experimenter exposed Tyler to eight FR1/FR1 sessions during the initial block of FR1/FR1 sessions in the Reversal Phase. Mand 2 responding for Tyler appears relatively stable during the initial FR1/FR1 sessions of the Reversal Phase. It is unclear whether the additional five FR1/FR1 sessions affected either mand 1 or mand 2 responding during the Reversal Phase for Tyler. A comparison of FR1 and FR50 schedule values for mand 1 did show experimental control over mand 2 responding for Tyler as well as for Jake and Vin. During the Alternating Treatments Phase conditions changed across individual session while during the Reversal Phase conditions changed across blocks of sessions. For Jake and Vin schedule changes across individual sessions were sufficient in altering response allocation across the various schedule values; however for Tyler this was not the case. Systematic changes in response allocation for Tyler only occurred during the Reversal Phase of Figure 2 where conditions changed across blocks of sessions. Possible reasons for the effectiveness of the schedule change in altering response allocation for Tyler during the Reversal Phase are the increase in the value of the FR schedule to 50 for mand 1 and also the fact that concurrent schedule values remained the same across blocks of consecutive sessions. A schedule value of FR50 for mand 1 may have resulted

in ratio strain for mand 1 responses for Tyler, but there also may have been carryover effects across consecutive sessions with the same schedule values. Bernstein and Sturmey (2008) and Bernstein, Brown, and Sturmey (2009) both showed that manipulation of schedule values across blocks of sessions was effective at altering response allocation. The present study showed that such a manipulation was effective across sessions for two participants as well as across blocks of sessions for all three participants. This finding may be important in applied settings as some situations may require immediate behavior change and others may require more stable behavior change over time.

#### Demand and Substitutability

Figure 5 replicated the Tustin (1994) own price and cross price demand functions for all three participants, further supported by the demand functions for each block of sessions shown in Appendix F. All three participants substituted the highly preferred reinforcer for the less preferred reinforcer at some set of schedule values. This substitution illustrates a degree of elastic demand for the highly preferred reinforcer for all three participants.

All three participants showed differing degrees of demand elasticity by the various conditions at which stimulus substitution occurred in Figure 5. Demand was most elastic for Vin in that there was a near complete switch from obtaining reinforcements for mand 1 responding to obtaining reinforcements for mand 2 responding in all conditions other than FR1/FR1. Vin typically switched from emitting mand 1 to emitting mand 2 following only one or two non-reinforced mand 1 responses. While not displayed in the figures, the data shown in Appendix E support this notion. Therefore, an FR2 value for mand 1 would have likely yielded the same effect on response allocation for Vin as FR3, FR9, FR27, and FR50 values for mand 1 did.

Demand was less elastic for Jake than for Vin in that the rate of reinforcement for mand 2 responding typically remained low during both the FR1/FR1 and FR3/FR1 sessions, and increased only during the FR9/FR1 and FR27/FR1 sessions. Also, mand 1 responding increased at schedule values greater than FR1 and remained at an increased level despite concurrent increases in mand 2 responding, however reinforcement for mand 1 decreased during those sessions. Figure 5 shows for Tyler a positive cross price slope for obtained reinforcements for mand 2 and a negative own price slope for reinforcements obtained for mand 1. Tyler showed the least degree of demand elasticity as the slopes of the functions for obtained reinforcement for mand 1 and mand 2 are less than that for Jake and Vin. The fact that the demand functions for mand 1 and mand 2 cross over each other at different intercepts for all participants in Figure 5 indicates that elasticity varied across participants. In an individual and group analysis of demand elasticity for supermarket products, Oliveira-Castro, Foxall, and Schrezenmaier (2006) found that individual differences in demand elasticity are consistent over time but not across products, or reinforcers. The variability in elasticity across participants in this study could be a result of differences in the effects of the schedule values on the individual participants, differences in the demand elasticity of the various reinforcers chosen by each participant during the preference assessments, or some interaction of both. While Figure 5 does not illustrate the demand functions for the Reversal Phase, it does show that the means of obtained reinforcement for all three participants are greater for mand 1 during the FR1/FR1 conditions and greater for mand 2 during the FR50/FR1 conditions.

All three participants eventually substituted the less preferred item for the highly preferred item as a reinforcer, shown by the inverse relationship of the functions in Figure 5. Despite sustained manding for the highly preferred item throughout almost all sessions of both

phases for Jake and Tyler, the decrease in rate of reinforcement for mand 1 responses resulted in an increase in the rate of and reinforcement obtained from mand 2 responses at higher schedule values for mand 1. During all sessions of the Alternating Treatment Phase Jake and Tyler obtained some reinforcement for emitting mand 1 despite the schedule value. This intermittent reinforcement may have maintained mand 1 responding for Jake and Tyler throughout the Alternating Treatments Phase, however, it was not sufficient to prevent substitution by some mand 2 responding. Vin typically substituted the less preferred item for the highly preferred item following the first non-reinforced occurrence of mand 1. Vin obtained reinforcement for mand 1 responding during only two of all F3/F1, FR9/FR1, and FR27/FR1 sessions and only obtained a single reinforcement for mand 1 in each of those sessions. Therefore, Vin rarely contacted the response-reinforcer contingency for mand 1 during mand 1 values greater than FR1. The lack of intermittent reinforcement of mand 1 responding for Vin may have caused the near complete switch in response allocation for Vin from mand 1 to mand 2. It is important to note that the experimenter did not provide any programmed signals as to the specific schedules of reinforcement in effect during a given session. Participants only encountered the schedule values in effect by manding sufficiently to come into contact with that response-reinforcer contingency. Contact with the response-reinforcer contingency for mand 1 during all sessions for Jake and Tyler resulted in intermittent reinforcement of mand 1 and the occurrence of both mand 1 and mand 2 responding when the value for mand 1 was greater than FR1. Lack of contact with the response-reinforcer contingency for mand 1 during most sessions for Vin resulted in almost no reinforcement of mand 1 responding when the value for mand 1 was greater than FR1 and a near complete switch in response allocation from mand 1 to mand 2. This is important because aside from altering response allocation, a major prediction of this study was

the occurrence of increased response variability measured as percentage of switches.

According to Hursh (1984) concurrently available stimuli are more likely to be substitutable in an open economy than a closed economy. In the present experiment the participants did not have access to the specific items presented during the preference assessment and subsequently available for manding outside of the experimental sessions. Nevertheless, physically similar items such as other music toys were available to the participants outside of experimental sessions. Therefore, one can look at the experimental sessions as an open economy in which topographically similar reinforcers were available and substitution occurred as predicted. The experimenter observed Vin, who frequently chose a bin filled with beans as the highly preferred item, to find similar items around the house to engage in tactile play with outside of session. Vin was also the participant to substitute reinforcers more readily than the other two participants, perhaps due to the abundance of substitutable reinforcers outside of the experimental sessions.

The demand function shown in Figure 7 calculates the elasticity of mand 1 across all conditions of the Alternating Treatments Phase. The variation in slope values along the functions for mand 1 reinforcement rates supports the notion that degree of elasticity may shift as reinforcement schedules change. Demand is elastic when the slope of the function is  $-1$  or less Hursh (1988). Therefore, the slope value of  $-0.24$  in the function for Jake along the FR1 and FR9 schedule values does not show elastic demand for mand 1. The slope decreases to values less than  $-1$  along the FR3 and FR9 and along the FR9 and FR27 schedule values for Jake indicating that demand for mand 1 shifted from inelastic to elastic at the FR9 schedule value for mand 1. Johnson and Bickel (2006) predicted peak responding, or  $P_{max}$ , to occur when demand

initially shifts from inelastic to elastic. The work function for Jake in Figure 5 shows that peak mand 1 responding occurred during the FR9/FR1 condition.

For Tyler, none of the slope values in Figure 7 fall below -1, therefore demand for mand 1 is inelastic. The function in Figure 7 never shifts from inelastic to elastic; therefore the function cannot predict the condition in which peak mand 1 responding would occur. The work function for Tyler in Figure 6 shows that mean mand 1 responding increased across all schedule values, with peak mand 1 responding occurring during the FR27/FR1 condition. There is no reason to conclude that the rate of mand 1 responding would not have further increased with further increments in mand 1 schedule value, in fact Figure 3 shows that mand 1 responding persisted for Tyler even under an FR50 schedule. While Figure 7 seems to indicate that demand for mand 1 for Tyler was inelastic, there is some evidence for the elasticity of mand 1 in the inverse relationship between the mand 1 own price and the mand 2 cross price demand functions in Figure 5. Tyler clearly substituted reinforcement from mand 1 for reinforcement from mand 2 across increasing mand 1 schedule values. Substitutable reinforcers indicate that there must be some degree of demand elasticity in the cross price demand function. In addition, Figure 7 shows that the slope value between the FR3 and FR9 schedule values for Tyler closely approaches -1 at -0.96.

The function for Vin in Figure 7 clearly shows elastic demand along the FR1 and FR3 mand 1 schedule values with a slope value of -4.44. During the FR1/FR1 condition Vin obtained reinforcement solely from mand 1, shown in Figure 5, however, demand for mand 1 became elastic as soon as the mand 1 schedule value shifted to FR3. Johnson and Bickel (2006) would predict peak mand 1 responding to occur during the FR3/FR1 condition, however because Vin

emitted few to no mand 1 responses at mand 1 schedule values greater than FR1 peak mand 1 responding occurred during the FR1/FR1 condition. The work function for Vin in Figure 6 shows peak mean mand 1 responding during the FR1/FR1 condition. The slope values in Figure 7 along the FR3 and FR9 and along the FR9 and FR27 mand 1 schedule values do not fall below -1. These values of greater than -1 may be a result of floor effects as the rate of reinforcement for mand 1 was either zero or near zero during most of these sessions, therefore could not decrease any further.

### Work Function

Work functions shown in Figure 6 show an overall increasing trend in mand 2 response rate as the schedule value for mand 1 increases. Despite this trend, the mand 1 response rate remains greater than the mand 2 response rate during all sessions of the Alternating Treatments Phase for Jake and all but two sessions for Tyler. As mentioned earlier, intermittent reinforcement maintained mand 1 responding for Jake and Tyler during mand 1 schedule values greater than FR1 despite eventual substitution by mand 2 responding. It is difficult to draw any other conclusions regarding the work function for mand 1 for Jake and Tyler because of the absence of a consistent trend. There tends to be an increase in mand 1 responding from FR1/FR1 to FR3/FR1 conditions, however, mand 1 responding during FR9/FR1 and FR27/FR1 sessions was variable across participants. For Vin, the mand 1 response rate decreased to nearly zero for all FR3/FR1, FR9/FR1, and FR27/FR1 sessions and the mand 2 response rate increased from zero to steady rates throughout the FR3/FR1, FR9/FR1, and FR27/FR1 conditions. Johnson and Bickel (2006) reported an inverse relationship between the work functions for cigarettes and

money as response requirements for money increased, however, participants continued responding for cigarettes at FR values into the hundreds.

### Maximization

Hursh (1980) and Green and Freed (1993) assert that behavior economics may be superior to matching theory in analyzing response allocation during concurrent schedules. Analyses of matching typically utilize qualitatively identical reinforcers, such as food, available on concurrent schedules of reinforcement; therefore the available reinforcers are perfectly substitutable. In such instances relative response rates will closely resemble relative rates of obtained reinforcement during concurrent interval schedules because organisms will readily switch back and forth among substitutable reinforcers as schedule values change. During concurrent ratio schedules, organisms achieve maximization by responding solely to the denser of two schedules to obtain the maximum number of available reinforcers in a given time. If the available reinforcers are not qualitatively identical and thus not perfectly substitutable; however, organisms may not achieve maximization. In the present study, the manner of response allocation for Vin maximized reinforcement more efficiently relative to Jake and Tyler. In Figure 8 for both Jake and Tyler, session length increased as the schedule value for mand 1 increased due to non-reinforced occurrences of mand 1 when the schedule value was greater than FR1. Both Jake and Tyler eventually, within those sessions, began to emit more mand 2 responses and obtained the twenty reinforcers required to end the session. Vin, on the other hand, by immediately switching to mand 2 following a non reinforced occurrence of mand 1, maintained a steady session length regardless of experimental condition. There is a slightly increasing trend in session length for Vin, yet almost all mands emitted by Vin obtained

reinforcement. Along with the degree of demand elasticity, the extent to which maximization occurs allowed for determination of stimulus substitutability. The available reinforcers were more substitutable for Vin than for Jake and Tyler based on Vin's ability to maximize more efficiently. Demand elasticity measures, however, provide a more detailed account of changes in response allocation across various schedule changes.

While Vin maximized more efficiently than Jake and Tyler, all three participants eventually increased mand 2 responding during those sessions in which mand 2 was more efficient at obtaining reinforcement than mand 1. Had Jake and Tyler persisted with mand 1 responding despite schedule changes, as predicted in a closed economy where substitutable reinforcers are not available, session lengths would have been much greater at higher schedule values for mand 1. The open economy may have lent to the substitutability of the available reinforcers.

It is also important to note that a number of alternative reinforcers often became available to the participants following each experimental session. Therefore, a naturally occurring multiple schedule may have been operating during which response requirements for reinforcement prior to and following the session were much less than response requirements for reinforcement during the session. Therefore, by maximizing reinforcement participants could end the session as quickly as possible so that alternative reinforcers would become more easily accessible than those available during the session. Without knowledge of the contingencies in effect outside of the experimental session, however, this possibility remains unknown.

## Variability

The present study examined variability in responding by recording the percentage of mands that were switches from the previously occurring mand. Figure 4 shows experimental control over the percentage of switches by the conditions of the Alternating Treatments Phase for Jake and Vin. Figure 4 also shows experimental control over the percentage of switches in the Reversal Phase for Jake only. This is consistent with findings by Bernstein and Sturmey (2008) in which the total number of alternative items the participant's manded for during individual sessions increased above 1 when the schedule value for that item was greater than FR1. The present study's measure of variability is more precise than Bernstein and Sturmey (2008) in that each individual mand within each session accounted for the variability measure; however, it is limited in that only two items were available. Figure 4 does not show experimental control over percentage of switches by the schedule values for Tyler in either the Alternating Treatments or the Reversal Phases. Percentage of switches for Tyler remains variable throughout. Also, the Reversal Phase in the bottom panel of Figure 4 for Vin does not show experimental control over percentage of switches. Switching behavior was minimal for Vin throughout the experiment, due to maximization of reinforcement. A lesser number of total mands comprise percentages for Vin compared to Jake and Tyler (shown in Appendices C, D, and E), therefore small differences in percentages appear as large differences across conditions. The Alternating Treatments condition shows experimental control over these small differences; however the Reversal Phase does not.

## Limitations

In order to obtain experimental control over the dependent variables and relate the results of this study to behavior economic theory, it was necessary to limit the effects of extraneous variables on the behavior of the participants as much as possible. Due to these constraints the experimental setting may not entirely reflect a natural environment. The experimenter limited participants' choice of reinforcers to only two per session, and examined manding only while the participants sat in chairs at a table in a controlled setting with few environmental distractions. Also, the study evaluated the effects of only five sets of fixed-ratio schedules; however, in more natural teaching situations there are many possible schedule values.

The Alternating Treatments Phase did not result in experimental control over mand 2 responding for Tyler. The Reversal Phase, however, did show experimental control over mand 2 responding for Tyler. During the Alternating Treatments Phase, mand 1 schedule values changed across individual sessions, while during the Reversal Phase mand 1 schedule values changed across blocks of sessions. Therefore, the FR50/FR1 sessions of the Reversal Phase did not conclusively cause the increase in mand 2 responding for Tyler during those sessions. It is possible that the manner in which schedule changes took place during the Reversal Phase, across blocks of sessions as opposed to across individual sessions in the Alternating Treatments Phase, caused the increase in mand 2 responses for Tyler. Perhaps if schedule values of FR3, FR9, and FR27 for mand 1 changed across blocks of sessions rather than across individual sessions those schedule values might have achieved experimental control over mand 2 responding for Tyler as well. In addition, both the Alternating Treatments Phase and the Reversal Phase failed to show experimental control over the measure of variability for Tyler.

Response rates reported throughout this study derive from total session length, including the time the participants were in possession of one or both of the reinforcers. The probability of a participant manding for an item while the participant had access to that item is likely to be less than the probability of a participant manding for an item when the participant did not have access to it. Therefore, response rates derive from a length of time that may include unequal intervals of response probability. It was not possible, however, to subtract reinforcement time for the calculation of response rate. The experimenter recorded all mands that occurred during reinforcement time. Some of those mands obtained reinforcement, while the others counted towards the response requirement for obtaining reinforcement. In particular, during FR9/FR1, FR27/FR1, and FR50/FR1 sessions Jake and Tyler would often emit a number of mand 1 responses during mand 2 reinforcement. Subtracting reinforcement time from response rate calculations would result in eliminating these mands from the data. Also, participants did occasionally mand for an item during access to that item, although most mands during reinforcement time were for the alternative item.

Participants selected reinforcers during preference assessments at the start of each session, therefore the items serving as reinforcers could differ across sessions. Jake consistently selected the same item as highly preferred during every session, however, Tyler and Vin did not. On some occasions both Tyler and Vin selected the highly preferred item from the previous session as the less preferred item during the subsequent session. It is possible that particular items became associated with the schedule of reinforcement for mands for that item during a given session, affecting participants' item selection during the preference assessment of the subsequent session. Examination of the items selected across sessions in Appendix A, however, does not reveal any systematic selection process across experimental sessions.

Finally, all three participants occasionally emitted some repetitive and stereotypical behaviors throughout the study. The experimenter attempted to disrupt these behaviors and redirect the participants towards the experimenter and the experimental materials when possible; however, was often unable to do so while also recording data and applying the contingencies in effect. The experimenter did not record repetitive or stereotypical behaviors emitted by the participants, nor did the experimenter attempt to determine their function. It is possible that these behaviors operated under an independent response-reinforcer contingency. Because the experimenter was unable to prevent these behaviors, they were available to the participants concurrently with the two available mands and may have at times affected mand responding.

#### Future Research

Teachers may not be able to apply a fixed reinforcement schedule consistently in a natural setting due to distractions, therefore an examination of concurrent variable-ratio schedules, while difficult to implement by an experimenter, may be more relevant to applied human settings. Also, many teaching situations entail the acquisition of new language skills as opposed to an examination of already acquired language skills, therefore future research may evaluate the effects of schedule manipulation during the acquisition of novel mands, or compare effects on novel mands versus already acquired mands. Future studies may want to develop from the procedures used here specific interventions that teachers and caregivers can carry out in applied settings to increase low-level mands or any other appropriate behaviors occurring at a low frequency. The present study only examined the effects of schedule changes on the variability of two concurrent behaviors in a controlled environment that strictly limited the number of possible behavior that could occur. In a more natural environment many behaviors

are possible. If an increase in the schedule of reinforcement for a high-rate behavior results in increased variability in overall behavior, it is possible that undesirable behaviors would emerge. Further evaluation of schedule effects on response variability during concurrent schedules is necessary to resolve this issue. Also, examination of the social validity of the variability measures used here is important as the changes in mand allocation may not be of sufficient social importance to warrant the use of the procedures described here. In addition, while the experimenter assessed preference for particular stimuli prior to each session, the experimenter did not assess whether or not changes in schedule values affected preference along with response allocation as has been found in previous research (Roane, Lerman, & Vorndran, 2001). Response rate may not be the only valid measure of mands. Changes in concurrent schedules may affect some other property of mands such as response strength, perhaps measured by the level of volume of a vocalization or the force involved in the use of PECS. Finally, it may be interesting to further evaluate mand allocation in a concurrent paradigm within a matching framework. The present study was unable to do this as it employed concurrent ratio schedules rather than concurrent interval schedules. An analysis of matching within the concurrent ratio schedules used here was also not possible because the FR1/FR1 condition does not allow for deviations from matching, and a zero number of mand 2 responses during some FR1/FR1 sessions does not allow for log transformation of that data.

### Conclusions

This study demonstrated the use of schedule changing procedures to increase the rate of a low-rate behavior during a concurrent schedule. The study extended behavior economic findings to a socially relevant response, manding, in children with autism. The study illustrated how

research can use demand and work functions as well as concepts of elasticity, stimulus substitutability, and open/closed economies to examine and make predictions regarding choice making in individuals with disabilities. Knowledge of the degree of demand elasticity for a particular reinforcer can aid in developing methods to alter behavior choices. Demand elasticity determines whether or not the availability of substitutable reinforcers will alter response allocation. This study also introduced an examination of variability within a behavior economic framework. Results show systematic changes both within and between participants in rate and variability of manding as a function of varying concurrent fixed-ratio schedules both across individual sessions and across blocks of sessions. Interventions designed to alter the behavior of individuals with disabilities can benefit from analyses of the variables that control concurrent response rates and variability in behavior.

## Appendix A

The highly preferred and less preferred items selected by each participant during each of the Alternating Treatments Phase preference assessments.

Session	Jake		Tyler		Vin	
	Highly Preferred	Less Preferred	Highly Preferred	Less Preferred	Highly Preferred	Less Preferred
1	ABC	Bus	Music	Elmo	Beans	Guitar
2	ABC	Elmo	Music	Spin Toy	Beans	Coloring
3	ABC	Bus	Ball	Spin Toy	Beans	Puzzle
4	ABC	Elmo	Elmo	Music	Beans	Coloring
5	ABC	Elmo	Leap Frog	Bus	Beans	Coloring
6	ABC	Elmo	Leap Frog	Elmo	Beans	Coloring
7	ABC	Elmo	Leap Frog	Elmo	Beans	Coloring
8	ABC	Elmo	Elmo	ABC	Coloring	Guitar
9	ABC	Elmo	Elmo	ABC	Beans	Coloring
10	ABC	Elmo	Elmo	Leap Frog	Beans	Guitar
11	ABC	Elmo	Elmo	Leap Frog	Beans	Coloring
12	ABC	Elmo	Elmo	Leap Frog	Coloring	Guitar
13	ABC	Elmo	Leap Frog	ABC	Beans	Coloring
14	ABC	Elmo	Leap Frog	Music	Beans	Coloring
15	ABC	Elmo	Leap Frog	Music	Beans	Coloring
16	ABC	Elmo	Leap Frog	Music	Beans	Laptop
17	ABC	Elmo	Leap Frog	Music	Beans	Coloring
18	ABC	Elmo	Leap Frog	Music	Beans	Coloring
19	ABC	Elmo	Leap Frog	Music	Beans	Coloring
20	ABC	Elmo	Leap Frog	Music	Beans	Coloring

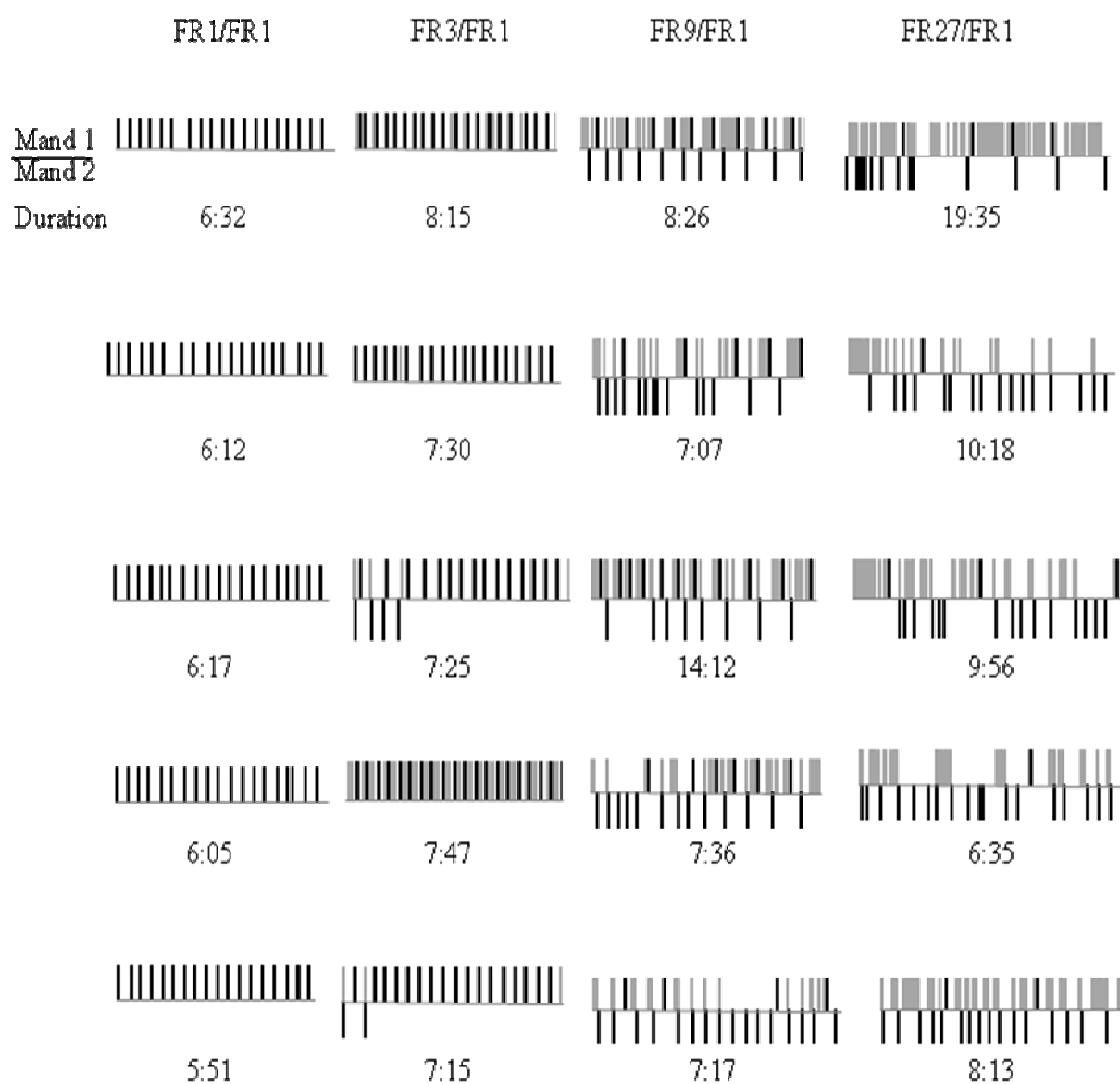
## Appendix B

The sequential order of conditions within each block of sessions for each participant.

	Jake	Tyler	Vin
Block 1	FR3/FR1	FR27/FR1	FR27/FR1
	FR27/FR1	FR9/FR1	FR3/FR1
	FR1/FR1	FR3/FR1	FR1/FR1
	FR9/FR1	FR1/FR1	FR9/FR1
Block 2	FR27/FR1	FR1/FR1	FR27/FR1
	FR9/FR1	FR3/FR1	FR9/FR1
	FR1/FR1	FR9/FR1	FR3/FR1
	FR3/FR1	FR27/FR1	FR1/FR1
Block 3	FR1/FR1	FR3/FR1	FR27/FR1
	FR9/FR1	FR27/FR1	FR1/FR1
	FR27/FR1	FR1/FR1	FR9/FR1
	FR3/FR1	FR9/FR1	FR3/FR1
Block 4	FR27/FR1	FR1/FR1	FR3/FR1
	FR1/FR1	FR3/FR1	FR9/FR1
	FR9/FR1	FR27/FR1	FR1/FR1
	FR3/FR1	FR9/FR1	FR27/FR1
Block 5	FR1/FR1	FR1/FR1	FR27/FR1
	FR27/FR1	FR9/FR1	FR1/FR1
	FR9/FR1	FR27/FR1	FR3/FR1
	FR3/FR1	FR3/FR1	FR9/FR1

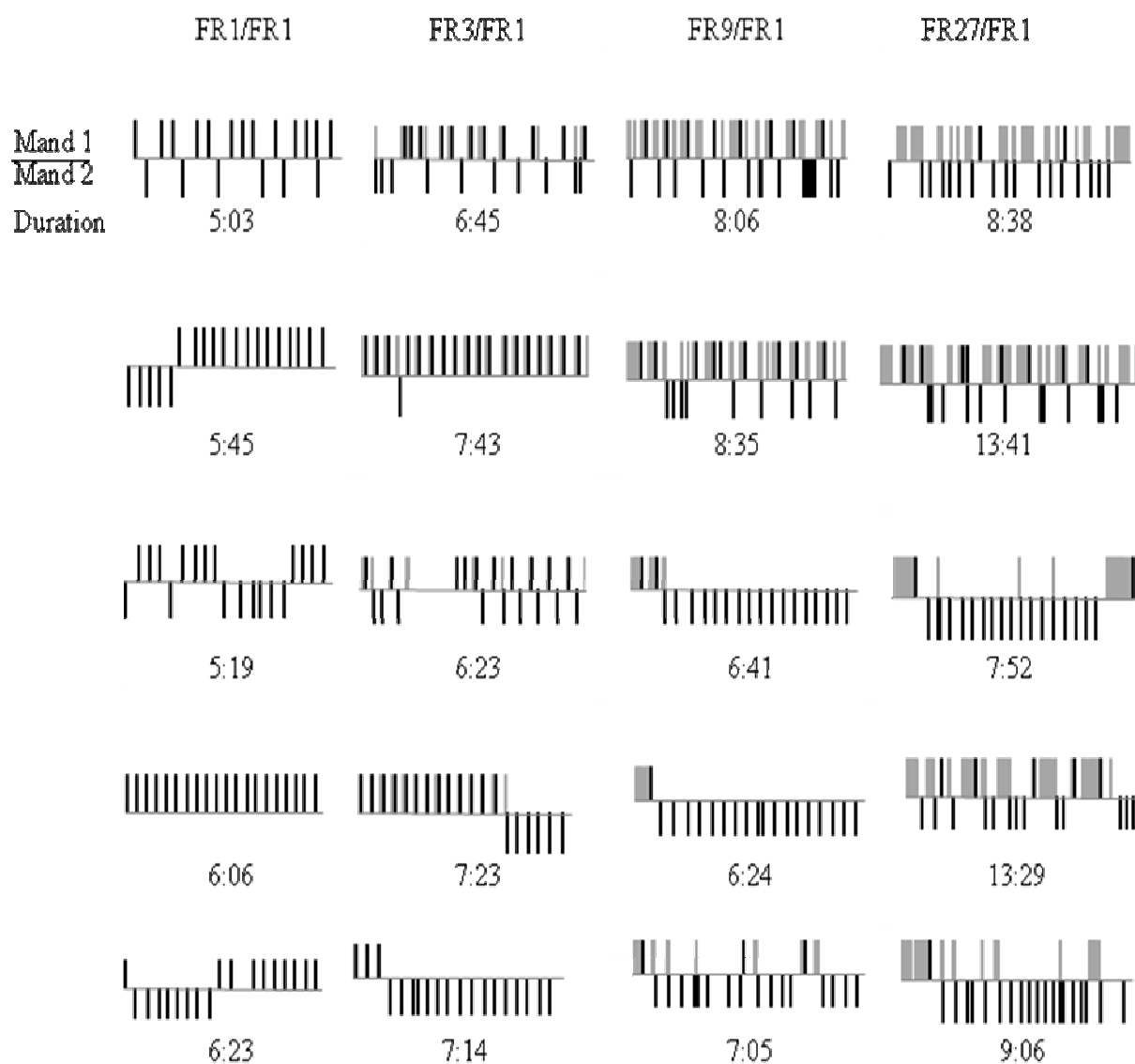
## Appendix C

Consecutive mands and session durations for Jake for every session of the Alternating Treatments Phase. Each line represents a single mand. Grey lines represent non-reinforced mands and black lines represent reinforced mands. Lines above the abscissa represent mand 1 and lines below represent mand 2.



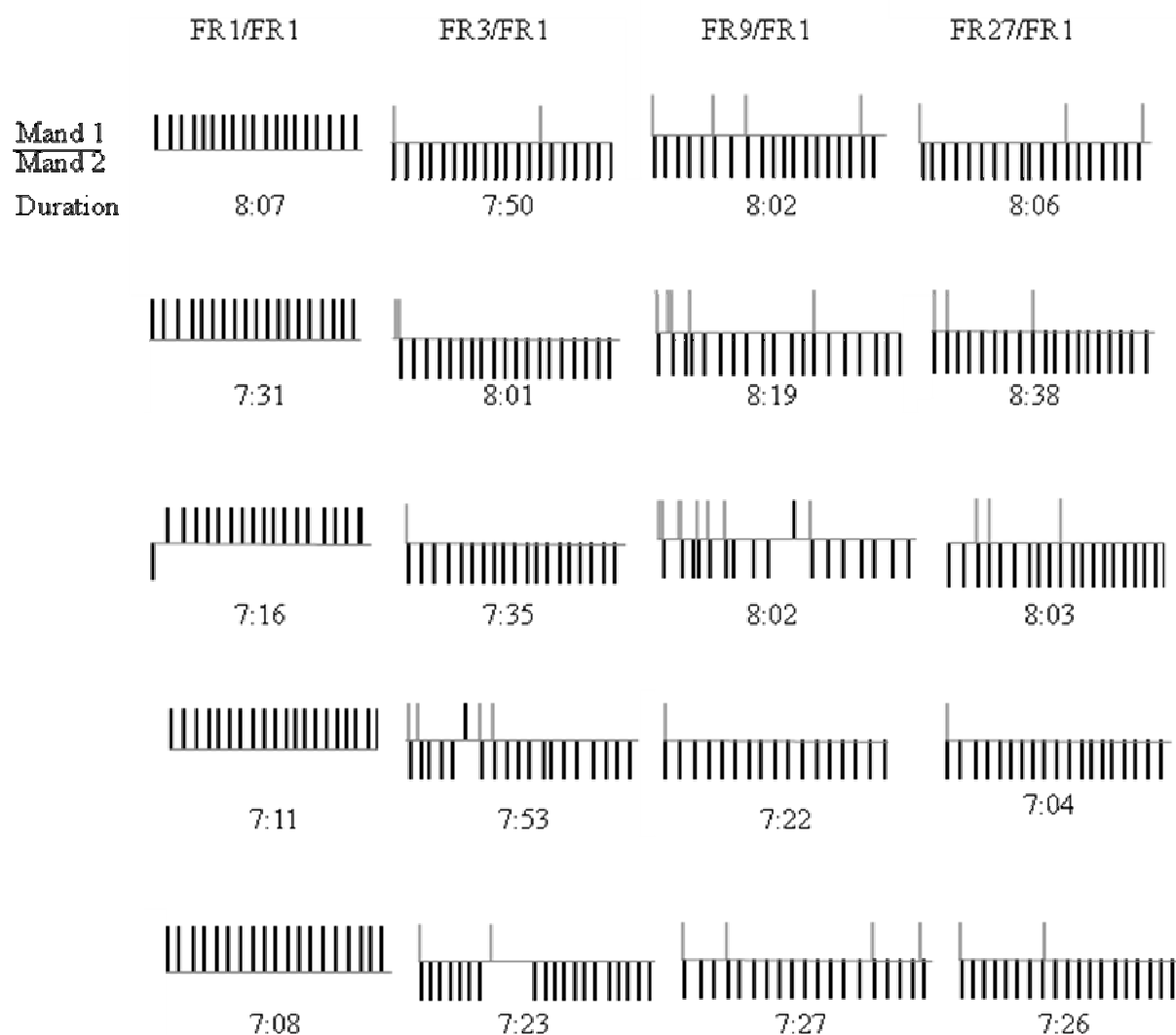
## Appendix D

Consecutive mands and session durations for Tyler for every session of the Alternating Treatments Phase. Each line represents a single mand. Grey lines represent non-reinforced mands and black lines represent reinforced mands. Lines above the abscissa represent mand 1 and lines below represent mand 2.



## Appendix E

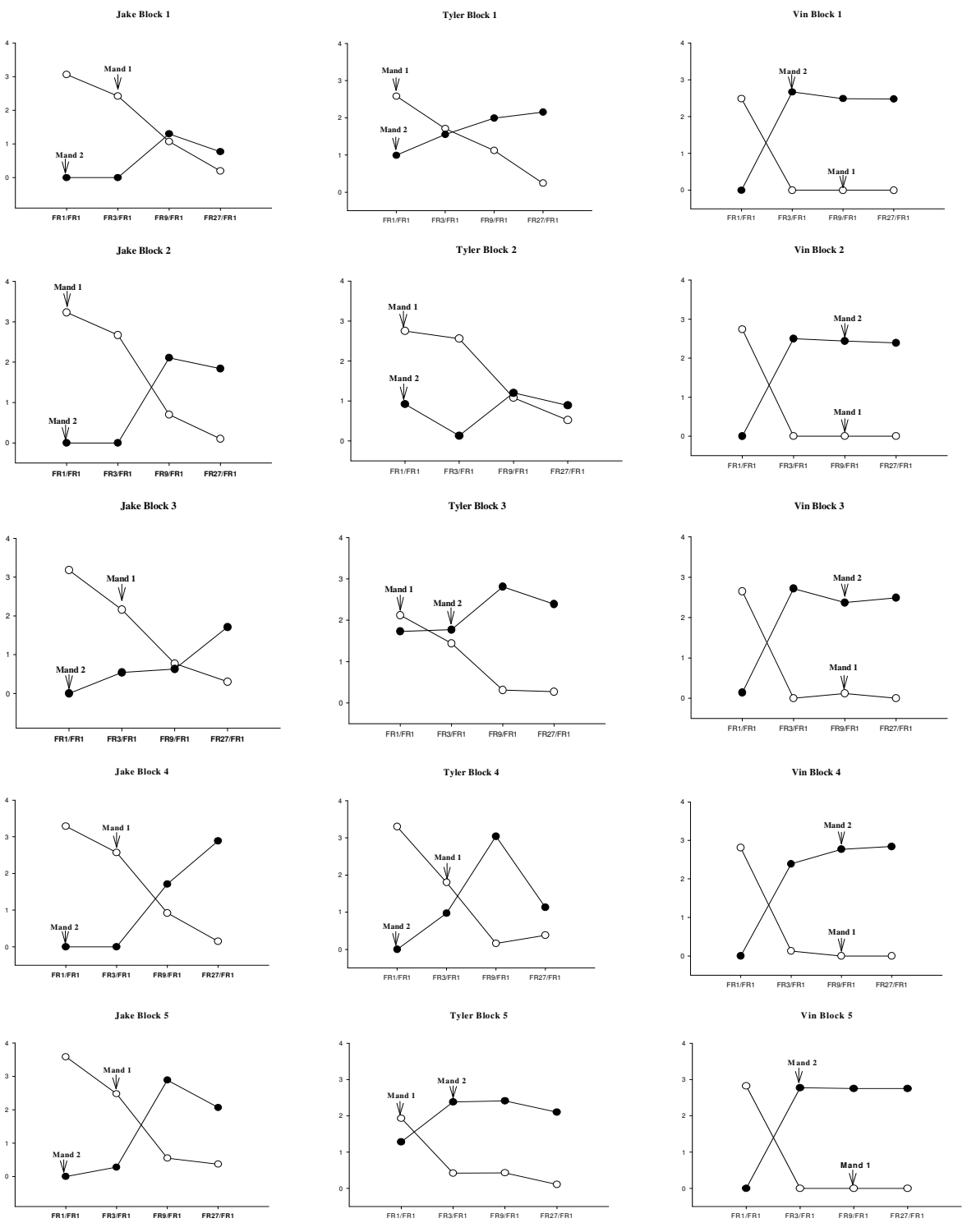
Consecutive mands and session durations for Vin for every session of the Alternating Treatments Phase. Each line represents a single mand. Grey lines represent non-reinforced mands and black lines represent reinforced mands. Lines above the abscissa represent mand 1 and lines below represent mand 2.



### Appendix F

Demand functions for each block of the Alternating Treatments Phase.

Rate of Reinforcement

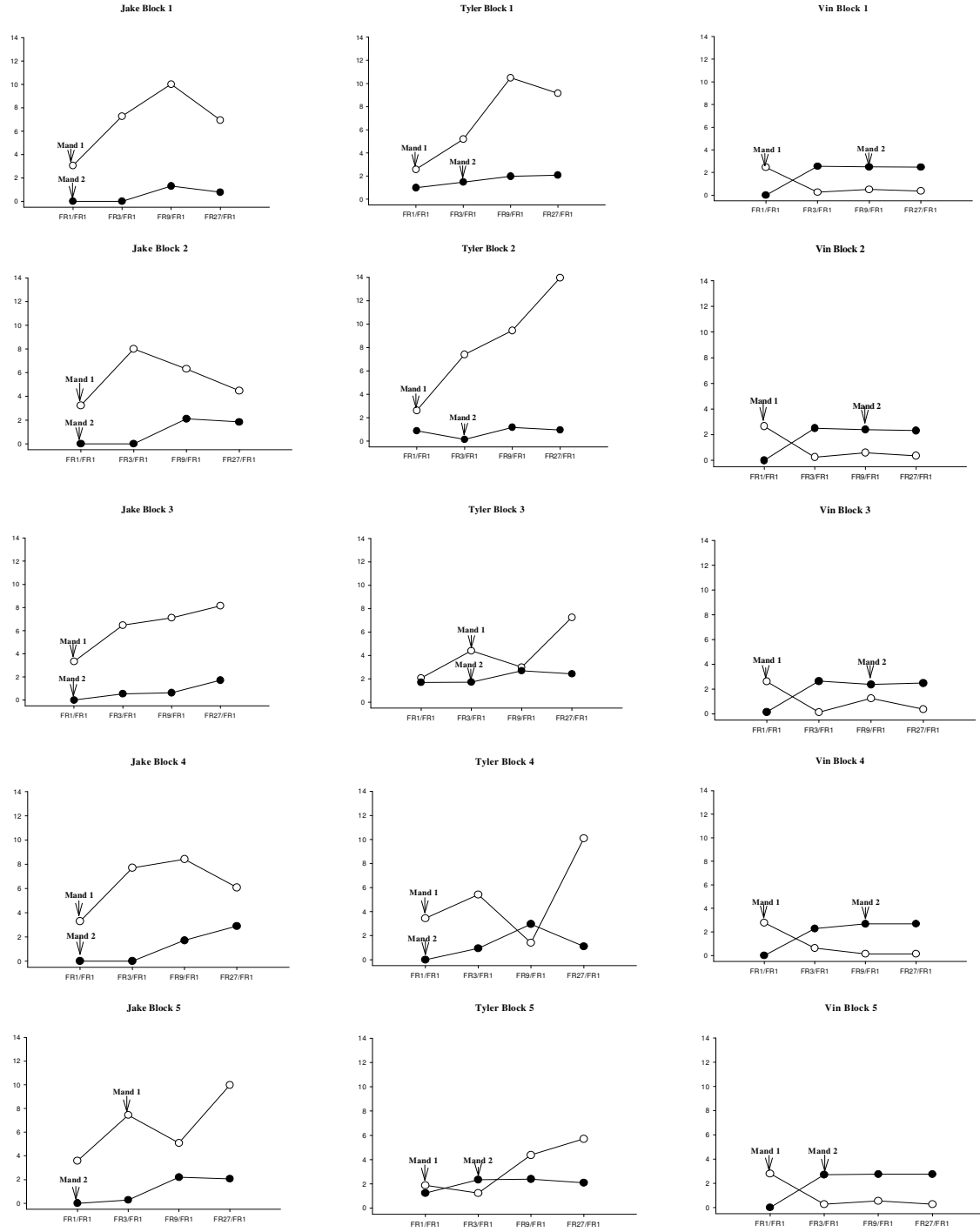


Schedule

### Appendix G

Work functions for each block of the Alternating Treatments Phase.

Rate of Responding



Schedule

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