ANALYZING CONTINGENCIES OF BEHAVIORAL AND CULTURAL SELECTION

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A choice paradigm was used to evaluate allocation of interlocking behavior of two groups of two participants between responses having operant consequences only and responses having cultural consequences. In a discrete trial BABABAB design, each participant could select one of three options, which delivered either 3 or 5 points. In B (cultural consequence) conditions, two of the options had additional effects: the 3-point option also added 3 points to the other participant's earnings, and one of the 5-point options also subtracted 5 points from the other participant's earnings. The third option was unchanged in both conditions and delivered 5 points to the participant who selected it. Results indicated that participants in both groups initially frequently produced response combinations that earned 8 points for one or the other individual (and 0 or 3 points for the other), but allocation of responding increasingly changed to combinations that produced 6 points for each individual. This shift in performances away from maximum individual reinforcement towards maximum group reinforcement indicates cultural contingencies did not act in concert with operant contingencies, suggesting they are different mechanisms of selection.

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INTRODUCTION

Behavior analytic research is concerned with the environment and behavior of single organisms. This is because behavior is something that individuals do, not groups. However, situations exist in the natural environment in which the behavior of one organism provides discriminative or consequential stimuli for the behavior of another organism (Skinner, 1953). Similarly, behavior of two individuals may affect the environment differently than if each behaved alone. In these scenarios, the behavior and environment of both individuals must be studied together. This occurs regularly in research examining verbal behavior, but verbal behavior is only a subset of possible interactions between organisms.

Another approach is to study nonverbal interactions, and the environment they share, in order to formulate principles having generality. In such preparations the experimenter may specify unique dimensions of interaction such as the order of responding, the antecedents and consequences for the behavior of all participants, and whether those antecedents and consequences are generated by the behavior of another participant, or by the experimental apparatus. Each of these factors may affect the behavior of organisms in a common environment. As the number of interacting participants increases, it becomes increasingly difficult to account for the effects of these factors on the behavior of each participant.

Experimentation with multiple individuals is difficult for other reasons. As described by Weingarten and Mechner (1966), there are *independent contingencies*, which are directly manipulated by the experimenter, and *dependent contingencies*, which come from the participants themselves, and are not directly manipulated by the experimenter. The function and effects of behavior generated under dependent contingencies may not be understood until after the experiment, if at all, causing extraneous variability that may affect results. This difficulty can be addressed by limiting the forms and functions of potential interactions between participants, thereby facilitating measurement, analysis, and ultimately control.

The question remains, why study verbal or nonverbal interactions between multiple organisms in the first place? Why should behavior under these conditions be different from any other conditions? Some have observed (e.g., Azrin & Lindsley, 1956; Glenn, 1988, 1991, 2004) that the behavior of two individuals may affect the environment in ways that one individual cannot. This allows the environment to select not just individual behaviors, but behaviors with contingencies that interlock (Glenn, 1988, 1991, 2004). Certain *interlocking behavioral contingencies* (IBCs) can affect the environment differently than others, and may recur. This selective recurrence of IBCs by their consequences is designated here as *cultural selection*. The effect on the environment produced by an IBC is an aggregate of the interlocking behavior of all participants, termed the *aggregate product*. The contingency between a set of IBCs and their aggregate products has been called a *metacontingency*. Metacontingencies describe the process by which lineages of IBCs are formed and persist across time (Glenn, 2004).

There has been some debate about the units of selection in this model of cultural selection. Houmanfar and Rodrigues (2006) reclassified the IBC as an antecedent that occasions the aggregate product, which they identify as the unit of replication in cultural selection (p. 17). This same logic at the operant level would assert that switch closures, rather than lever presses, are selected by food delivery. The unit replicated in cultural selection, rather, is the contingency relations constituting IBCs and aggregate products (Glenn & Malott, 2004b).

Houmanfar and Rodrigues (2006) also asserted that interlocking behavioral contingencies, because they consist of operants, are subject to a lower level of selection than other cultural phenomena (p. 16). Similarly, others (e.g., Mattaini, 2004; Salzinger, 2004;

Ulman, 2004) have questioned the need for an emergent level of selection to explain the interlocking behavior of multiple organisms. Skinner (1987) stated “no new [behavioral] processes” (p. 74) are needed to explain cultural selection. However, while IBCs do include operant behavior, the mechanism that selects this operant behavior may not be the same mechanism that selects the IBC as a whole (e.g., Glenn & Malott, 2004c; Glenn, 2004). Confusion arises, however, when operant contingencies and cultural contingencies work in concert—essentially “selecting the same thing.” Similarly, redundancy in operant and gene-based selection occurs when a behavior is both reinforced and species-specific. In these situations, the distinction between levels of selection is best made in the laboratory. Only recently has such laboratory research been reported at the cultural level (e.g., Vichi, Andery, & Glenn, 2008).

Experimentation on the related behavior of organisms occurred before the concept of metacontingencies was introduced. Can any of these studies be re-interpreted in terms of this mechanism of cultural selection? See Table 1 for a summary. Azrin and Lindsley (1956) developed a procedure whereby two children received a single reinforcer for completing a task that neither child could complete alone. Participants sat opposite each other with a mesh screen between them to prevent physical (but not visual or auditory) contact. Each side of the table had three holes, and each participant had a stylus. If the participants inserted the styli into holes directly across from each other (e.g., both middle, both left, or both right holes) within 0.04 seconds, “a red light flashed…and a single jelly bean dropped into a cup accessible to both children” (p. 100). The children then had to decide between themselves how to distribute the candy (e.g., taking turns eating the jelly bean, splitting jelly bean in half, stockpiling for later distribution, etc). A period of continuous reinforcement (CRF) for coordinated responding was followed by a period of extinction for coordinated responding, after which CRF was reinstated. Each period lasted at least 15 minutes, and ended when cumulative records indicated steady rate for at least 5 minutes. Without instruction, all ten groups of two children (matched in age from 7-12 years) emitted successful coordinated responses at high rates within ten minutes. Extinction produced gradual reductions in rates similar to individual extinction curves, while reinstatement of CRF quickly increased rates of coordinated responding.

To reinterpret Azrin and Lindsley (1956) using terminology of cultural selection, both styli placed into holes resembles an IBC-aggregate product relation. The selective environment then differentially delivered a cultural consequence (i.e., a single jelly bean) for IBCs in which styli were placed in opposite holes within 0.04 seconds. Azrin and Lindsley described the structure of these IBCs, observing, "leader-follower relationships were developed and maintained in most cases" (p. 101). Additionally, the process by which the children distributed the candy may be considered another IBC, if it recurrently produced the same aggregate product (e.g., taking turns eating the jelly bean, each eating half of the jelly bean, etc).

The effect of stimuli created by the other participant on coordinated responding was studied by Lindsley and Cohen (1964). Four groups of two participants sat in adjacent rooms, each facing an apparatus with a plunger and a tray into which penny reinforcers were dropped. A plexiglass window between the participants could be blocked by a sliding partition; next to this window in both rooms were two stimulus lights. When the participant in the other room pulled the plunger, a red light flashed; when the participant in the other room received a penny, a white light increased in brightness for 5 seconds. White noise masked sounds produced by participants and the apparatus. If both plungers were pulled within 0.5 seconds, this was termed a social response, and was reinforced. If both plungers were pulled after 0.5 seconds elapsed, this was termed a nonsocial response, and was not reinforced. Two plunger pulls by a single participant was termed an individual response, and resulted in a loud tone and darkness for 2.5 seconds. Leader-follower relations could be either social or nonsocial, and were termed AB or BA, depending on whether Participant A or Participant B responded first. In the first phase of all experiments, social responses were reinforced, and leader-follower relations were allowed to develop freely. In subsequent phases, however, reinforcement was delivered for social responses with specific leader-follower relations: either AB or BA. At various points during the session, the partition covering the window would be opened for a brief period of time to allow participants to see each other, termed "human stimulation" (p. 121) by the authors.

Lindsley and Cohen (1964) found that all groups developed steady rates of contingency-specific leader-follower social responding in the absence of human stimulation. Responding was initially suppressed in all groups during brief (15-to 35-sec.) access to human stimulation, but rate resumed and accuracy increased or remained constant immediately following these periods. When one of the group members had prior exposure to experimental conditions, brief access to human stimulation reduced the frequency of the naïve participant's nonsocial responses and incorrect leader responses. When both of the group members had prior exposure to experimental conditions, periods of human stimulation restored performance that had degraded after the coordination requirement had been reduced to 0.1 sec.

In Lindsley and Cohen's (1964) procedure, both plungers pulled resemble an IBC-aggregate product relation wherein a cultural consequence (pennies) was delivered contingent upon IBCs with aggregate products of 0.5 or 0.1 seconds between plunger pulls. Order of responding, another dimension of the IBC, was also shown to be controlled by manipulation of the cultural consequence when leader-follower relations could be specified by differential reinforcement. Nevertheless, as observed by Schmitt and Marwell (1968), a coordinated or "social" response could have resulted from non-discriminated, high-rate responding by both participants. This pattern of responding obviates the need for interlocking behavior and metacontingencies to generate the coordinated responding shown by Lindsley and Cohen (1964).

To test this alternative explanation, Schmitt and Marwell (1968) modified Lindsley and Cohen's (1964) procedures to determine if the coordinated response was dependent upon social stimuli (i.e. the behavior of the other participant), or simply a side effect of concurrent individual contingencies. Performance under the original coordination requirement of no more than 0.5-sec. between plunger pulls was compared to a modified coordination requirement of 3- to 3.5-sec. between plunger pulls. This was done to prevent high-rate responding from generating a coordinated response. The original and modified tasks were then evaluated under two new stimulus conditions: one condition without response lights, and one condition without timeout lights. Removing the response lights prevented discriminative control by the other participant's responses; removing the timeout lights prevented discriminative control by the apparatus on both participants' responses.

Results showed a high rate of coordination under the 0.5-sec. time requirement in all conditions except the conditions wherein response and timeout lights were deactivated. When the time requirement was modified to a 3- to 3.5-sec. delay, response rates remained high during conditions in which response lights were active, but rates dropped in conditions wherein the response lights were deactivated and conditions wherein both response and timeout lights were deactivated. These results showed that formation of interlocking behavioral contingencies was dependent upon response-produced stimulation by the other participant.

In an experiment reported by Skinner (1962), pigeons had to peck a correct set of buttons within 0.5 seconds of each other for individual access to food. Buttons were arranged vertically in two columns of three buttons each, with a clear divider in between. A random schedule determined which pair of buttons (top, middle or bottom) were active each trial. Pecks to the active set of buttons occurring within 0.5 seconds of each other were reinforced. This produced what Skinner described as a “leader-follower relation” wherein the follower bird closely imitated the pecking behavior of the leader bird (p. 533). Additionally, the leader was observed to wait for the follower to respond before sampling other buttons.[1] Altering relative deprivation between subjects reversed the relation so that the more food-deprived bird reliably became the leader. Similar to Schmitt and Marwell (1968), this intervention at the operant level was sufficient to establish the interlocking behavioral contingencies that developed between participants and to alter them when motivational variables were manipulated (i.e., the birds switched leader-follower roles when relative deprivation levels were altered). Unlike Schmitt and Marwell, however, this change in the IBC did not disrupt formation of the aggregate product (e.g., pecking the correct keys together), and thus did not alter selection at the cultural level. These divergent effects support the notion that cultural selection is a different mechanism than operant selection.

Skinner’s (1962) report included a second experiment to study behavioral interactions between organisms. Pigeons were trained to “play ping-pong” on a table that was 8 in. wide by 16 in. long by 8 in. tall. As Skinner described, “A pigeon standing at one end could conveniently peck a ball as it arrived at the edge of the table. If the ball rolled over the edge, it fell into a trough and tripped a switch which operated a food dispenser under the opposite edge and thus reinforced the pigeon which ‘won the point’” (p. 531). Shaping procedures developed ball-

[1] This discriminative control was analyzed systematically with rats in Hake, Donaldson, & Hyten (1983).

pecking repertoires individually for each subject before they performed together. Skinner found that putting the subjects together disrupted the ball-pecking performance of both—possibly due to the increased delay to reinforcement caused by the behavior of the other subject. This result is not surprising when examined at the cultural level of selection. A ball pecked by one pigeon prompted the other pigeon to peck the ball, which prompted the first pigeon to peck the ball again, and so on. The behavior of each pigeon resulted in extended delay of reinforcement for the other until the ball no longer functioned as a discriminative stimulus for pecking. The behavioral contingencies interlocked, but the interlocking contingencies with an aggregate product of sustained volleying were not selected. An intervention was conducted at the operant level by manually reinforcing pecking the ball, which was successful. An alternative intervention could be made at the cultural level of selection. For instance, consequences could be made contingent upon an IBC-aggregate product relation, such as food delivery for both pigeons contingent upon a certain number of volleys. Such a modification would limit external validity, however, by altering the "competition" game to a "cooperation" task. Nevertheless, a comparison of this cultural intervention with Skinner's operant intervention could provide useful empirical data.

Boren (1966) developed a procedure wherein a monkey could press a lever to provide food for another monkey, and vice-versa. Both monkeys performed within their own operant chamber, but an open grill between them allowed aural, physical, and visual interaction. After pre-training in tolerating delays to reinforcement and responding discriminatively to white (S^D) but not red (S^Δ) lights, the monkeys' chambers were linked together. When the white light was on in one chamber, responses would produce food for the other subject, and the light would change to red. The red light in the other chamber would then change to white, and the process was repeated. This alternation procedure produced stable performance in which both subjects fed each other. Boren then removed the alternation requirement, allowing both subjects to respond freely in order to produce food for each other. This caused performance to degrade until the subjects were near starvation. Reinstating the alternation requirement restored the interlocking performances.

Cumulative records from the free-response condition indicated development of an unexpected set of interlocking behavioral contingencies. When the alternation requirement was removed, one subject responded for some period of time. This reinforced “non-responding” (i.e., anything other than lever pressing) in the other subject, which in turn extinguished responding by the active subject as food was no longer delivered. Reciprocity of feeding became reciprocity of starving. An intervention could have been made at the cultural level that resembles the modification proposed above for Skinner’s (1962) ping-pong experiment. Instead of one subject’s responses delivering food to the other, both of them could have received access to the same food at the same time (e.g., Azrin & Lindsley, 1956; Grott & Neuringer, 1974) for a set of alternating responses. These alternating responses may be forced, or allowed to vary, as in Boren’s original procedure. The difference is that in Boren’s preparation, consequences for each subject depended only on responses of the other. In the metacontingent preparation, consequences for both are contingent on the interlocks.

Applying theory of metacontingencies involves a shift from altering operant contingencies within interlocking contingencies to altering consequences external to the IBC unit. Wiggins (1966) offered an experimental method to investigate such manipulations, although he did not discuss his experiment using the present terminology. Ten groups of three participants completed a task together in order to receive pennies, which they then had to distribute amongst themselves. The pennies were not contingent upon the group's performance in the task, but on whether the pennies had been distributed equally or unequally in the previous trial. This external consequence was controlled by the experimenter. Internal contingencies were set up by assigning different resources, response classes, and response costs to each participant, and were constant throughout the experiment. All other interactions between participants were unrestricted. Control over IBCs (equal or unequal distributions) by external consequences would be apparent when the distributions (equal or unequal) changed as a function of changes in the experimenter controlled relation, overriding in some conditions the internal contingencies established at the outset. Results indicated that the external consequences contingent on IBC products (equal or unequal distributions) overrode internal contingencies. When metacontingency requirements changed (from one condition to another), cumulative records of distributions show periods of vacillation marking the transition to IBCs required by the metacontingency. When the cultural contingencies changed, so did the aggregate products of the interlocking behavioral contingencies. For instance, when the aggregate product was unequal reward distribution, larger portions of pennies were distributed to higher-contributing participants in 94% of 2030 trials.

Vichi, Andery and Glenn (2008) explicitly analyzed selection by metacontingencies by modifying Wiggins' (1966) procedures. Participants invested tokens, completed a task, and received token reinforcers that were contingent not upon performance in the task, but on whether tokens were distributed equally or unequally (depending on the condition) in the previous trial. Unlike Wiggins (1966), participants were able to freely invest between 3 and 10 tokens, and no differentiation was made regarding roles or unique access to resources for each participant. If the previous trial's reward distribution matched the specification of the external contingency (i.e., the metacontingency), the group's total investment was doubled; if previous distribution did not match that specified by the external contingency, the group's investment was halved. Conditions were changed when a stability criterion of ten successive successful trials was met. Results indicate that both groups distributed tokens equally or unequally to match the external contingency in effect. Stability was reached in fewer trials with each reversal of conditions. Interlocking behavioral contingencies, while required, were not measured. Instead, evidence for selection of particular IBCs was provided by a) anecdotal descriptions of distribution strategies and b) similar changes in the total number of tokens each participant invested and earned in each session of each condition. The degree to which different IBCs produced these similar outcomes is unknown.

Grott and Neuringer (1974) also examined the effects of external contingencies on group behavior. Groups of three rats responded freely on a single lever to receive 2.5-sec access to water from a single dispenser. The water dispenser was shielded by a 10- by 10- by 14.5 cm wire tube that limited access to one subject at a time, and prevented simultaneous lever pressing and drinking by a single subject. The collective lever presses by the group were treated as a unit and subjected to various schedules of reinforcement. Group performances were compared to performances by individual rats under the same conditions. These schedules were fixed-ratio (5, 50, &150), extinction, satiation, fixed-interval (2 min.), fixed-time (2 min.), DRL, cued DRL, and discriminated FR-10.

Results show that groups performed similarly to individuals in all FR schedules, the cued DRL schedule, and discriminated FR-10. Group performances were slightly less effective than individual performances under extinction, satiation, FI, FT, and non-cued DRL schedules. These less effective performances were likely due to differences in delay to reinforcement as each subject pressed the lever at a different time with respect to the schedule. As Grott and Neuringer observed, the behavior of one member in a group affected the reinforcement schedules of the other members of the group. This changed the FI and FT schedules to variable-interval and variable-time schedules for each group member (p. 319). Performance under ratio schedules was less affected, possibly because the lever presses of each rat reduced the ratio requirement for the other group members and enriched the schedule. Despite this variability in internal contingencies, consistency between group performances matched consistency between individual performances, indicating that group performance was sensitive to schedules of reinforcement.

While the relation between collective lever presses, aggregated switch closures, and the cultural consequence (e.g., communal access to water) resembles a metacontingency, there was no evidence that an IBC was selected in Grott and Neuringer's (1966) experiment. This is because individual behavior was not measured. Reliance on aggregate product records (e.g. Vichi, Andery & Glenn, 2008) is insufficient evidence of a metacontingency in this case because the schedule could have been completed without interlocking behavior. Nevertheless, this experiment was an early shift from analyzing contingencies controlling behavior of individuals to analyzing contingencies controlling behavior of multiple individuals.

The related behavior of multiple organisms in a shared environment, then, can be subject to both internal and external contingencies. Either contingency is capable of overpowering the other; operant contingencies can disrupt cultural selection, while metacontingencies can subsume and shape operant selection contingencies. Rather than attempting to demonstrate control by one or the other, this experiment was designed to examine consequences that underlie selection at both levels concurrently. To do this, multiple internal and multiple external contingencies were made available simultaneously. Allocation of responding within and across each type of contingency indicated the relative control by each. Unlike previously published experiments, the most advantageous option for the group was not the most advantageous option for each individual, preventing redundant operant and cultural accounts of selection. Additionally, all aspects of interactions between organisms that could not be quantified were eliminated. This included limiting response forms, interlocking only one response from each participant, and prohibiting verbal behavior. All remaining quantitative dimensions of interaction were allowed to vary. This included order of responding, latency of responding, individual choices, aggregate choices, potential individual consequences, and potential aggregated consequences.

METHOD

Participants

Four adults participated in groups of two (one male and one female in each group) for this experiment. Participants were recruited by an ad in the university newspaper and were paid for their time. All participants gave informed consent, and this study was approved by the University of North Texas Institutional Review Board (# 08259). The members of Dyad 1 did not know each other previously; the members of Dyad 2 were married to each other.

Setting and Apparatus

The experiment took place in a small lab room on campus with enough space for a 3 ft. by 3 ft. table and three chairs. The table featured a 2 ft. wide x 3 ft. tall opaque divider in the center, with a computer monitor and keyboard on either side of the divider. Participants sat across from each other, each facing a computer monitor and keyboard, with the divider preventing the participants from seeing each other. The experimenter sat to the side of the table in view of both participants in order to monitor the session.

Both computer monitors and keyboards were connected to an Apple, Inc.® PowerBook® computer running Mac OS® operating system, version 10.4.11 (Apple, Inc., Cupertino, CA, www.apple.com). The software used in the experiment was custom designed and written using the Python™ programming language, version 2.4.4 (Python Software Foundation, www.python.org). The displays on each computer monitor were identical during the entire experiment; that is, the same stimuli appeared on the screen of each participant. See Figure 1 for screenshots of the display used in the experiment.

Split into three sections, the left column of the screen of both monitors was labeled as that of Participant A, and the right column as Participant B. In the left and right columns were three crystal-shaped icons, one each colored red, white, and green. Above these icons were the total points earned by Participant A on the left column, and the total earned by Participant B on the right column. The central area of the screen was blank until a response occurred. When a colored crystal icon was selected, it appeared next to the column of the participant who had chosen it, and was visible to both participants. Once both participants had responded, the points delivered to each participant were displayed beneath the colored crystal icons that represented each choice.

The two keyboards were modified using a label for each response option. Red, white, and green "crystal" (cube-shaped) figures were placed over the letters W, S, X and the word "Next" covered the T key on Participant A's keyboard. The keys I, K, M, and B were similarly adapted on Participant B's keyboard. All other keys on the keyboards were disabled; presses on those keys produced no effects.

Procedures

Each experiment occurred during a single session on a weekday and lasted about one hour. Participants were instructed not to talk to each other once the experiment began. The experimenter read aloud these instructions, which were also displayed in the center of both monitors:

> "You and your partner are going on a mining expedition across the galaxy to replenish your Energy Crystals. There are 3 kinds of crystals, found in different amounts on each planet. Travel from planet to planet and choose which kind of crystal you would each like to mine. Each kind of crystal is worth the same amount."

This paragraph was cleared from the screen once the experiment began. Each participant started with 20 points, termed here the *bank*. When the trial started, the numbers in each participant's bank changed from black to red in color, and started decreasing at a rate of 1 point every 2 seconds. At the same time, the red, white, & green crystal icons changed from an "inactive" button appearance to an “active” button appearance on the screen. Participants could then respond at any time, in either order, by pressing one of the three colored keys. This increased the response cost of waiting for the other participant to respond. If either participant’s bank reached zero, the session would end, although this did not happen.

Once a response occurred, that participant’s red, white, and green buttons were inactivated (in both on-screen appearance and function), and his or her bank stopped decreasing and changed back to black in color. The stimulus corresponding to that participant’s key press was then displayed in the center of the computer screen. This is shown in the top image of Figure 1. The bottom image of Figure 1 shows the display after both participants had responded. The points earned by each appeared below the colored crystal icons that represented each participant’s choice. At the same time, these points were added to each participant’s bank totals. Additionally, a button reading “Press Next to Continue” appeared on the screen, which when pressed on the keyboard, cleared all feedback and began the next trial. Only one participant needed to press this button.

Experimental Design

The experiment used a reversal design with discrete trials. Each experimental condition lasted 70 trials and was ordered BABABAB. A conditions will be called *independent* because the consequences for the two participants’ responses were determined independently. B conditions will be called *interdependent* in that the contingencies for each of the two participants’ responses depended in part on the behavior of the other. Table 2 summarizes the points delivered for each response option in each condition.

Interdependent conditions

During interdependent conditions, each of the three response options had two distinct effects. The first was to deliver points to the selecting participant's bank. The second effect was to add or remove points from the other participant's bank. The number of points added or removed for each response was not displayed; only the calculated point totals were shown on the screen. The response option with the simplest effect was the red icon, designated by the experimenter as *neutral* (because it was neutral with respect to points for the other player). Five points were gained when this option was chosen. The green (s*teal)* option also delivered 5 points when chosen, but subtracted these points from the other participant's Bank. The white (*share)* option provided 3 points when chosen, and also provided 3 points to the other participant. The points contingent on both players' choices were added together at each round. For example, if both participants chose white (share), they both earned 6 points—three points generated by themselves, and three points generated by the other's response. If, instead, one of them chose red (neutral) and the other white (share), then the participant choosing red earned 8 points (5 + 3) while the participant who chose white earned only 3 points (3 + 0). In this way, choosing white (share) could result in -2, 3, or 6 points; choosing red (neutral) could result in 0, 5, or 8 points; and choosing green (steal) could result in 0, 5, or 8 points.

It is important to note that while an individual participant could receive maximum (8) points in a trial by selecting red (neutral) or green (steal), both participants could not earn 8 points by selecting red or green in the same trial. In order for both participants to maximize reinforcement, they both must have chosen white (share), but they only earned 6 points each for doing so. In addition, the first participant to select white (share) in a trial risked earning fewer points if the other participant then selected red (neutral) or green (steal). Thus, for a coordinated maximization response to occur, the first participant to respond risked receiving less reinforcement, while the second participant to respond could receive greater reinforcement with no risk.

Independent Conditions

During independent conditions, the contingencies for each participant were separate. Therefore, white (share) did not add 3 points to the other participant's bank, and green (steal) did not take away 5 points from the other participant. Red (neutral) was effectively unchanged. The points possible during this phase were: white (share), 3 points; red (neutral), 5 points; and green (steal), 5 points. Note that in these conditions the consequences for the red (neutral) and green (steal) options were identical, whereas the consequence for the white (share) option was always less advantageous (i.e., produced less reinforcement). This condition was designed as a control to determine if patterns of responding would persist in the absence of cultural contingencies.

RESULTS

Figures 2 – 4 present the data for Dyad 1. Figure 2 shows the cumulative responses of each participant. During the first four phases, participants selected primarily red and green (neutral and steal), regardless of condition. However, early in Phase V (an interdependent condition), responding to these options paused, and both participants switched to white (share) exclusively for the remaining 65 trials. Upon entering the next independent condition (Phase VI), both participants quickly switched to the red (neutral) key, which they pressed exclusively until the interdependent condition was again instated, whereupon they returned to selecting the white icon that resulted in sharing gains. Thus, in the last three phases, participants in Dyad 1 maximized gains by adapting to the externally imposed conditions.

When both participants selected the same option in a single trial, this coordination can be described as a dyadic response and treated as a unit (Azrin & Lindsley, 1956; Skinner, 1962; Wiggins, 1966; Schmitt & Marwell, 1968; Vichi, Andery & Glenn, 2008). Figure 3 shows dyadic responses of Dyad 1 during the course of the experiment. The first type of dyadic response, *dyadic neutral* (both pressed red keys), occurred at steady rates during the first phase and all independent phases, but almost never occurred during subsequent interdependent phases. The *dyadic steal* (both pressed green) response showed a positively accelerating change in rate until Phase V, wherein rate of response dropped to zero, and remained low until the end of the session, regardless of which condition was active. In contrast, the *dyadic share* response (both pressed white) occurred at very low rates until interdependent conditions were present in Phase V. A clear reversal then occurs between conditions as rates of dyadic share dropped to zero in Phase VI and accelerated again in Phase VII. In summary, interdependent contingencies eventually supported selection of dyadic share, whereas independent contingencies eventually supported selection of dyadic neutral. Thus, participants in Dyad 1 were able to coordinate their behavior both individually and as a dyad to meet the externally imposed conditions.

Given the little difference between individual and dyadic performances of Dyad 1, the question arises as to whether the data represent the result of contingencies governing individual performances, or contingencies governing the dyad's performance as a whole. In other words, is Dyad 1 performing as a unit, or as two independently performing individuals? Figure 4 attempts to answer this question by cumulating the trials in which an individual participant maximized reinforcement (e.g., earned 8 points) against the trials in which the dyad had maximized reinforcement (e.g., earned 6 points each). Dyadic maximization resulted from two white (share) responses in a trial while individual maximization resulted from a share response from one participant and either a red (neutral) or green (steal) response from the other participant in a single trial. No data are shown during independent phases because the dyad is not able to maximize reinforcement in these conditions.

Figure 4 shows that in the first two interdependent conditions (Phases I and III), the rate of maximization responses was higher for individual participants than for the dyad. This is to be expected because more points are available for individual maximization (8 points) than for dyadic maximization (6 points). However, in the last two interdependent conditions, the rate of dyadic maximization responses accelerated well beyond that of the individuals. Overall, this indicates that the contingencies governing maximizing reinforcement for the group were more powerful than the contingencies governing maximizing reinforcement for any single participant in Dyad 1.

The data are not so clear for Dyad 2, presented in Figures 5–7. As seen in Figure 5, Participant B showed similar rates of responding for all three selections, regardless of condition.

Participant A, however, seemed to show break-and-run patterns of selecting a single key for many trials before switching to a different key. Consequently, for Participant A, pressing green (steal) and red (neutral) occurred often for most of the experiment until Phases V and VI, when pressing white (share) began to increase significantly. Interestingly, both participants selected white (share) in extended bursts during independent phases IV and VI despite the lower reinforcement it provided in comparison to red (neutral) or green (steal) in these conditions.

Figure 6 shows the cumulative dyadic responding. The only response option that was clearly responsive to condition changes was dyadic steal, when the rate of response was positive during interdependent Phases V and VII but dropped to zero in Phase VI. However, frequencies of dyadic neutral and dyadic share eventually adapted to match the external conditions in the last three phases. This indicates that the dyad as a unit was responsive to the condition changes, but as individuals, the participants were not.

Figure 7 shows responses that maximize reinforcement for the individual against responses that maximize reinforcement for the dyad. As described above, only the interdependent conditions may be compared. Participant A maximized individual reinforcement frequently during all of these conditions. Participant B, however, maximized reinforcement often during the first and last phases (I and VII) but much less frequently during the middle of the session (Phases III and V). Dyadic maximization response combinations increased throughout the session, occurring more frequently during the first and last phases (I and VII) and less frequently during the middle phases (III and V). Overall, this indicates that the independent conditions disrupted the performance of Participant A and the Dyad during subsequent interdependent conditions, although rates of maximization responses did recover by the end of the experiment. Unlike Dyad 1, Dyad 2 did not “switch” from individual to dyadic maximization responding; rather, Dyad 2 increased dyadic maximization responses while continuing to frequently maximize reinforcement as individuals. Thus, it is unclear the extent to which Dyad 2's performance was governed more by operant or cultural contingencies, because both appear to have exerted influence during interdependent conditions.

The points earned or lost in each trial by each participant from experiments 1 and 2 are shown in Figures 8 and 9. During independent conditions, when consequences did not interact, participants in Dyad 1 earned maximum reinforcement available (5 points) in 185 out of 210 trials (88%). Participants in Dyad 2, however, quite often did not earn maximum reinforcement. Participant A maximized only 62.9% of trials in Phase II, and Participant B maximized in 52.9% of trials in Phase IV; together, they only maximized reinforcement in 151 of 210 trials, or 71.9%. This indicates that Dyad 1 was more responsive to independent conditions than Dyad 2. During interdependent conditions, Dyad 1 "switched" from occasional individual maximization (8 points for 1 participant) to mostly dyadic maximization (6 points for both participants) as the experiment progressed. Dyad 2, on the other hand, gradually increased the number of dyadic maximization responses while continuing to frequently maximize at the individual level across all interdependent conditions.

"Leader-follower relations" (e.g., Azrin & Lindsley, 1956; Lindsley & Cohen, 1964; Skinner, 1966), wherein one participant reliably responds before the other, are shown in Figure 9 for both dyads. Only data for Participant B in each dyad are shown because this is the reciprocal of the data for Participant A. In Dyad 1, after initial exploration during Phase 1, the first response was emitted by Participant B in most trials. After Trial 174, the leader-follower relation reversed, and Participant A responded first in the majority of trials until the end of the experiment. Variability in leader-follower trends occurred more during interdependent conditions than independent conditions for Dyad 1. Dyad 2 differed in that clear leader-follower relations did not develop. However, rates of leader responses were higher for Participant B during independent conditions, while rates of leader responses where higher for Participant A during interdependent conditions. This difference became more pronounced as the session progressed. Additionally, smooth scalloping curves of leader responses across conditions indicates orderly shifts occurred in leader-follower relations between participants of Dyad 2.

DISCUSSION

The author feels that the choice paradigm used in this experiment was effective for evaluating the effects of individual and cultural contingencies. Initially, participants most frequently selected the options that produced greater reinforcement (or higher probability of reinforcement), such as red (neutral) and green (steal). As the sessions progressed, however, participants increasingly selected white (share), which produced relatively less reinforcement at the individual level. However, this option maximized reinforcement at the dyadic level. Allocation of responding shifted from the most reinforcing option for an individual, to the most reinforcing option for both individuals. This shift occurred despite producing less reinforcement for each response, more risk for the leader, and less than maximum reinforcement for the follower. This contrasts with previous experimental procedures (e.g., Azrin & Lindsley, 1956; Skinner, 1962; Lindsley & Cohen, 1964; Wiggins, 1966; Vichi, Andery & Glenn, 2008) wherein group responses produced reinforcement, but individual responses did not. In those experiments, operant and cultural contingencies exerted redundant selection effects. In the current experiment, operant and cultural contingencies were not clearly redundant, making it easier to distinguish selection by each.

Alternative explanations may account for the observed shift in responding from individual to dyadic maximization options, however, that do not require a cultural mechanism of selection. For instance, participants may have had a prior reinforcement history that supported equal distribution of rewards, despite the decreased reinforcement for doing so in this experiment. This hypothesis could be tested by using subjects whose histories can be controlled, such as pigeons, rats, or monkeys. Additionally, despite efforts to limit possible interactions between participants, verbal behavior may have been emitted which exerted discriminative or reinforcing control over responding. Extraneous control by these dependent contingencies could be mitigated in future experiments by isolating participants from each other (e.g., using different rooms).

Of interest is the degree to which the results indicate cultural selection by metacontingencies. In all conditions of this experiment, the contingency between the selections of both participants and the resulting aggregate product of colored stimuli combinations constituted a relation between the Interlocking Behavioral Contingency (IBC) and the aggregate product. Cultural consequences of different magnitudes were delivered contingently upon occurrences of different IBC-aggregate product relations. However, the effect of a particular IBC on the cultural consequence differed in A and B conditions. During independent (A) conditions, consequences could not be altered by the other participant's behavior. During interdependent (B) conditions, consequences could be altered by the other participant's behavior, or not, depending on the IBC that occurred. Thus, all performances were interlocking behavioral contingencies, and all generated aggregate products, but a contingency between IBCs having particular products and cultural consequences existed only in the interdependent conditions. Selection by metacontignencies was apparent in this experiment as cultural consequences resulted in dyadic IBCs when in effect. Additionally, development of specific leader-follower relations in each dyad indicates specific IBCs were selected. For Dyad 2, different conditions appeared to select different leader-follower IBCs.

Alternating the activation and deactivation of the cultural consequence resulted in additional effects. Patterns of responding that developed during interdependent conditions sometimes continued during independent conditions despite the lack of external cultural contingencies. Three out of four participants ceased to select green (steal) as often as red (self) in

Phase VI compared to Phase IV, even though each option produced the same amount of reinforcement in these conditions. This unexpected pattern of responding likely would not have developed if participants were insensitive to the contingencies interlocking their responses in previous conditions. Sensitivity to controlling variables was confirmed in verbal reports after the experiment, shown in Figure 10. Three out of four participants (but not Participant B in Dyad 2) reported observing the points delivered to the other participant, and could tact the general effects of each response option on the other participant's earnings. All participants reported comparing the total points in each participant's bank. Only one participant (Participant A in Dyad 1) came close to tacting the manipulation of the independent variable, saying, "Sometimes we would get six points for [both] choosing white, and sometimes we didn't."

Overall, there was a large amount of between-group variability in responding. The most orderly patterns of responding were generated by Dyad 1, whose members did not have a prior history of interaction with each other. Dyad 2 exhibited less orderly behavior, and the members of this dyad already had extensive histories of interaction with each other. Limiting interactions between participants in future experiments may reduce between-group differences in response patterns.

Table 1

Application of Metacontingency Terminology to Previous Research

Study	Interlocking Behavioral Contingency	Aggregate Product	Cultural Consequence
Azrin & Lindsley (1956)	Both styli inserted into holes	Styli in opposing holes within 0.04s of each other	1 Jellybean
Skinner (1962a)	Ball pecked back and forth	Repeated volleys	None
Skinner (1962b)	Keys pecked in both columns	Correct set of keys pecked within 0.5s	Individual access to grain
Lindsley & Cohen (1964)	Both plungers pulled	Both plungers pulled within 0.5s or 0.1s	1 Penny each
Schmitt & Marwell (1966)	Both plungers pulled	Both plungers pulled within 0.5s or 3.0s to 3.5s	1 Penny each
Wiggins (1966)	Rewards distributed	Equal or unequal distributions	Pennies
Boren (1966)	Forced: alt. lever presses Unforced: none	Forced: both levers pressed Unforced: none	Forced: food pellets Unforced: none
Grott & Neuringer (1974)	None	Communal lever presses	Communal access to water
Vichi, Andery & Glenn (2008)	Rewards distributed	Equal or unequal distributions	Points

Table 2

Response Options and Resulting Points

Condition B: interdependent consequences

Participants A / B	A: White (*Share*) A: 3 / B: 3	A: Red (*Neutral*) A: 5 / B: 0	A: Green (*Steal*) A: 5 / B: -5
B: White (*Share*) A: 3 / B: 3	6 / 6	8 / 3	8 / -2
B: Red (*Neutral*) A: 0 / B: 5	3 / 8	5 / 5	5 / 0
B: Green (*Steal*) A: -5 / B: 5	-2 / 8	0 / 5	0 / 0

Condition A: independent consequences

Participants A / B	A: White (Share) A: 3 / B: 0	A: Red (Neutral) A: 5 / B: 0	A: Green (Steal) A: 5 / B: 0
B: White (Share) A: 3 / B: 0	3 / 3	5 / 3	5 / 3
B: Red (Neutral) A: 0 / B: 5	3 / 5	5 / 5	5 / 5
B: Green (Steal) A: 0 / B: 5	3 / 5	5 / 5	5 / 5

Figure 1. Sample screenshots of the display used in the experiment. The top image shows a response made by one participant; the bottom image shows responses made by both participants.

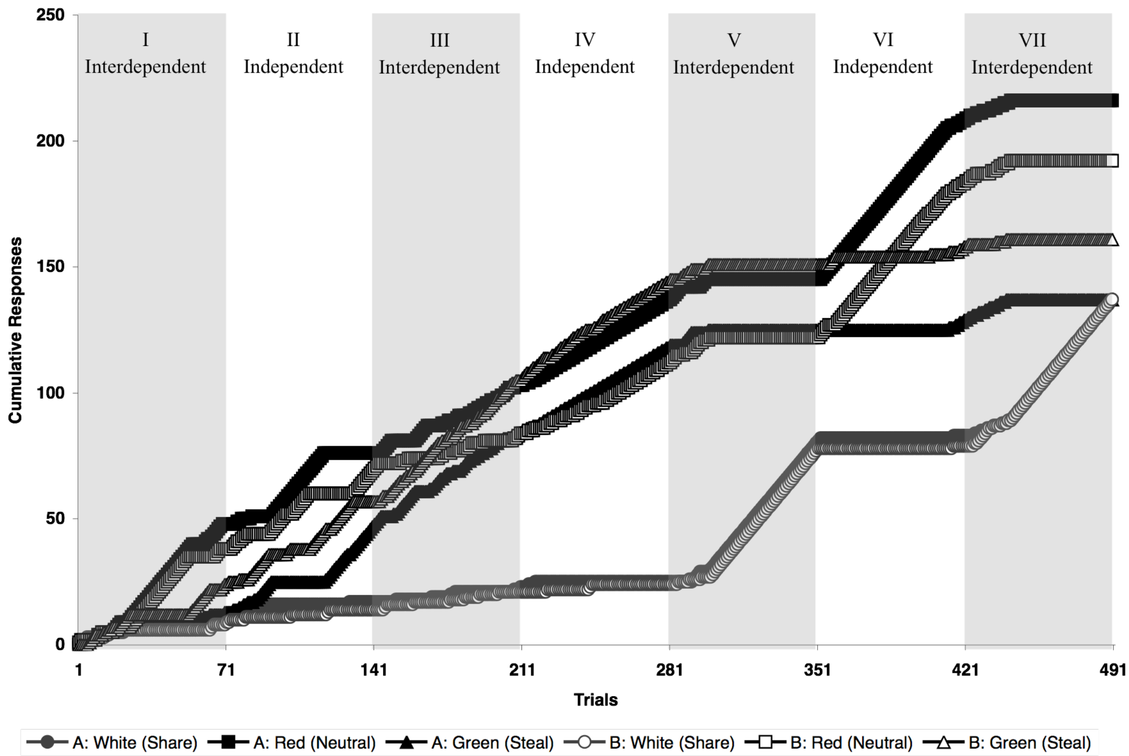

Figure 2. Cumulative individual responding, Dyad 1. Interdependent conditions (Phases I, III, V, & VII) are denoted by a grey background.

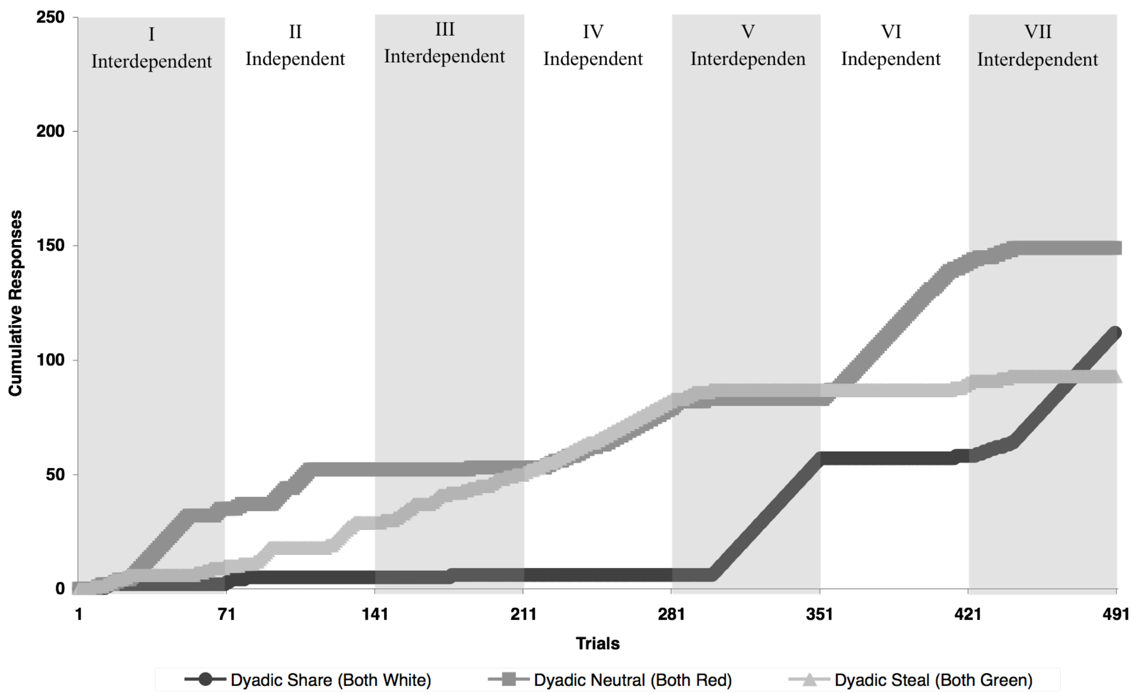

Figure 3. Cumulative dyadic responding, Dyad 1. Interdependent conditions (Phases I, III, V, & VII) are denoted by a grey background.

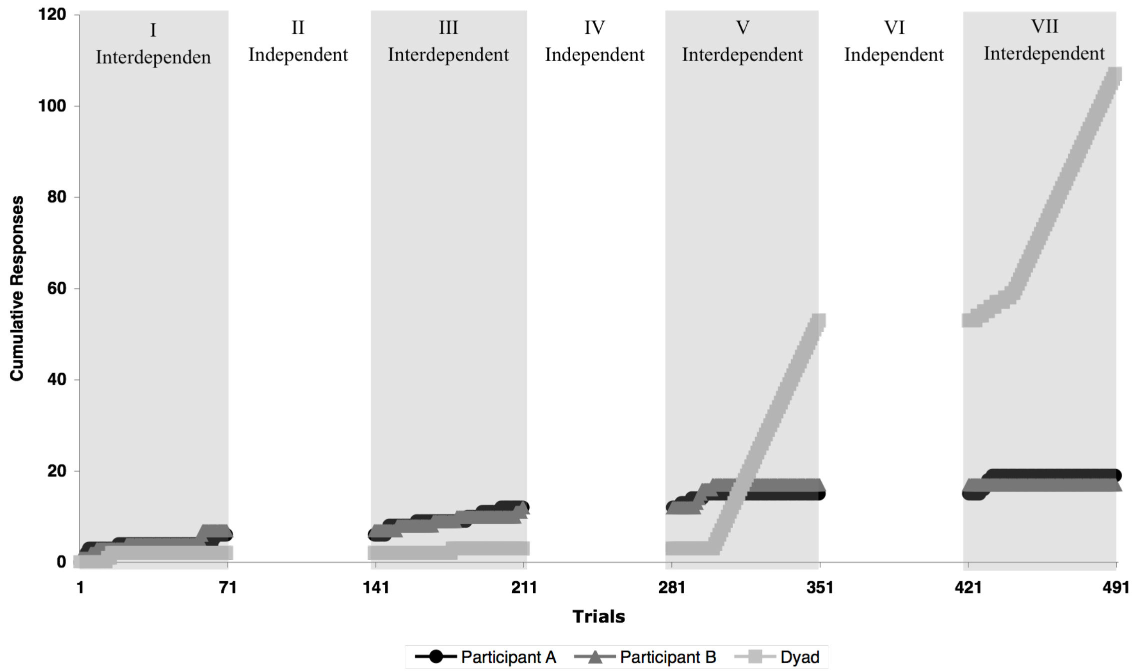

Figure 4. Responding that maximized points, Dyad 1. Interdependent conditions (Phases I, III, V, & VII) are denoted by a grey background. No data are shown during independent conditions (Phases II, IV, & VI) because participants could not maximize points in these conditions.

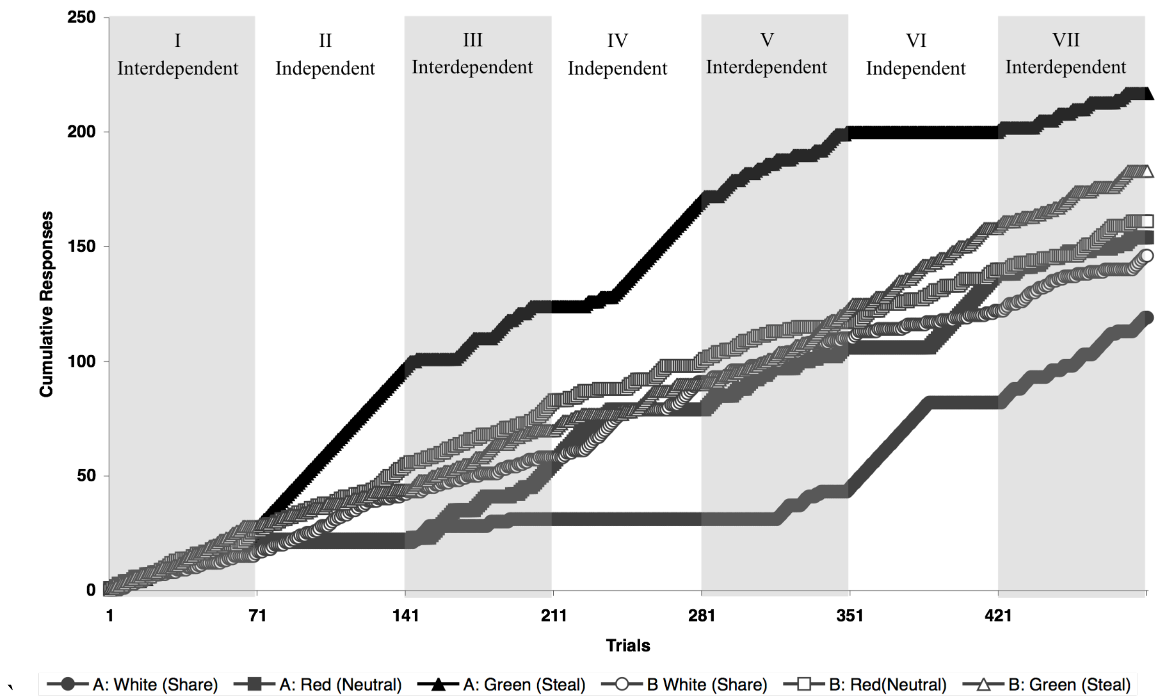

Figure 5. Cumulative responding, Dyad 2. Interdependent conditions (Phases I, III, V, & VII) are denoted by a grey background.

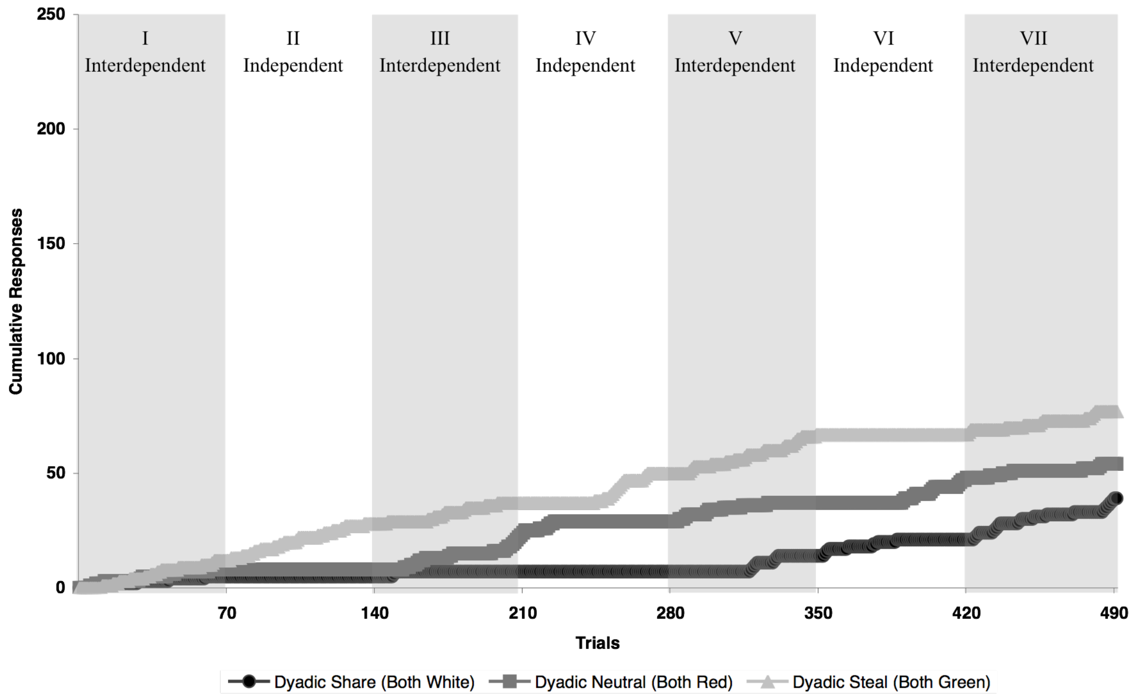

Figure 6. Cumulative dyadic responding, Dyad 2. Interdependent conditions (Phases I, III, V, & VII) are denoted by a grey background.

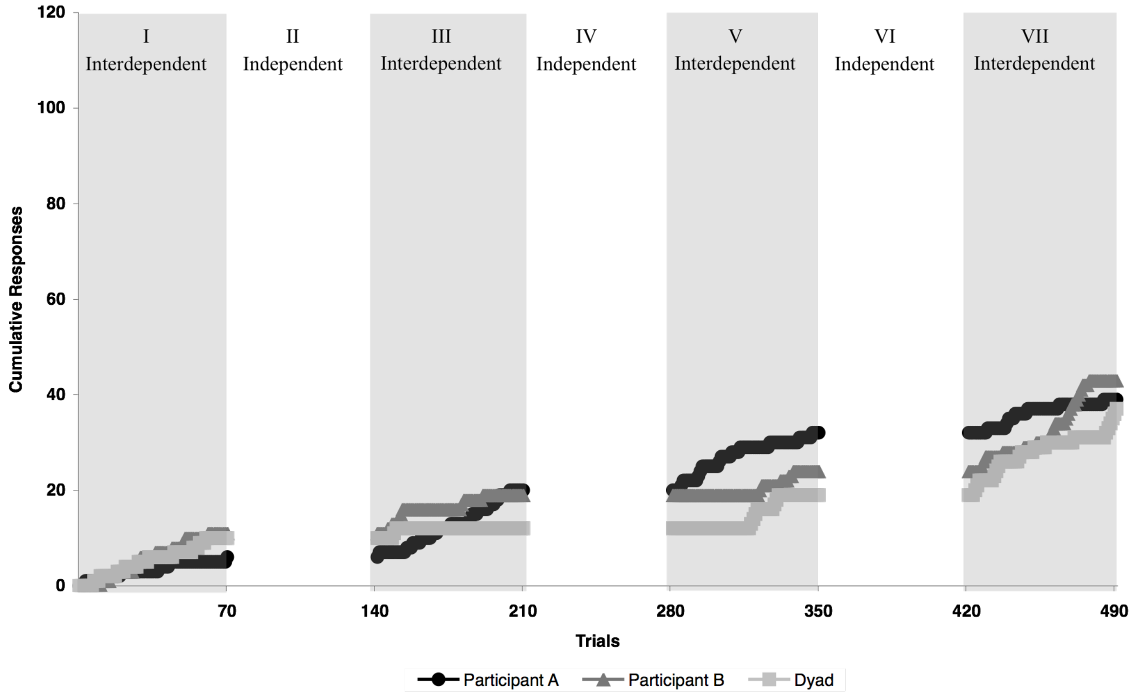

Figure 7. Responding that maximized points, Dyad 2. Interdependent conditions (Phases I, III, V, & VII) are denoted by a grey background. No data are shown during independent conditions (Phases II, IV, & VI) because participants could not maximize points in these conditions.

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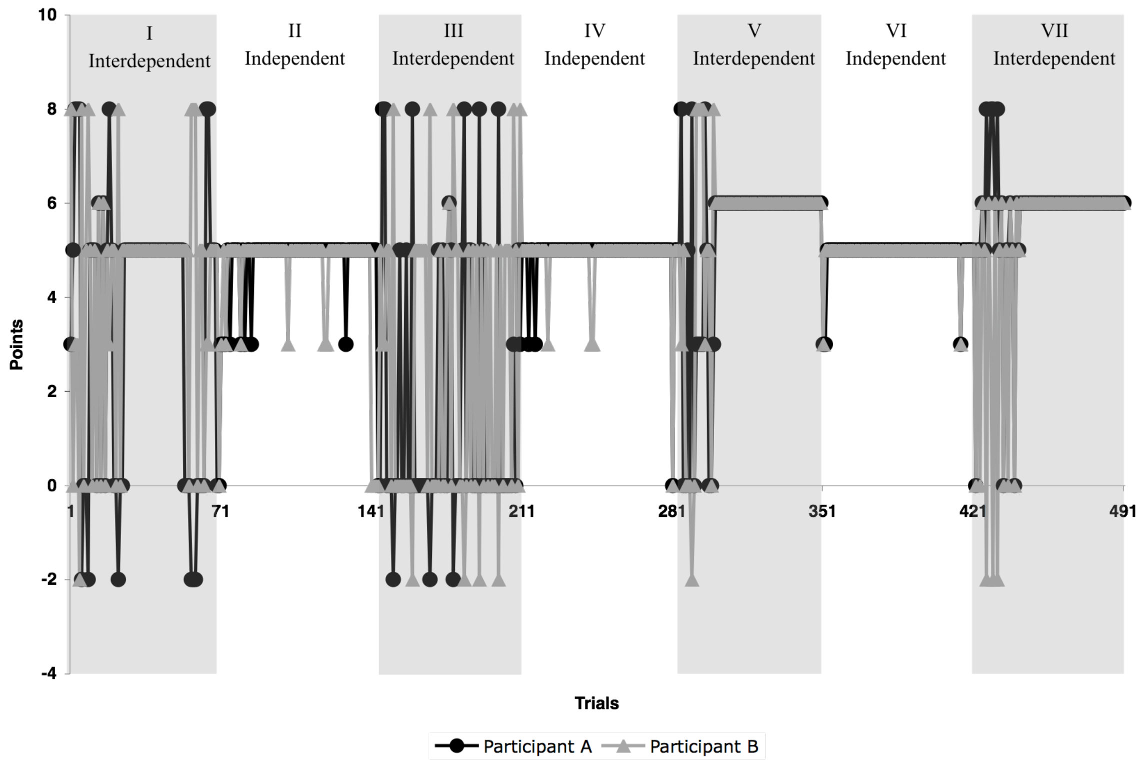

Figure 8. Points earned each trial, Dyad 1. Interdependent conditions (Phases I, III, V, & VII) are denoted by a grey background.

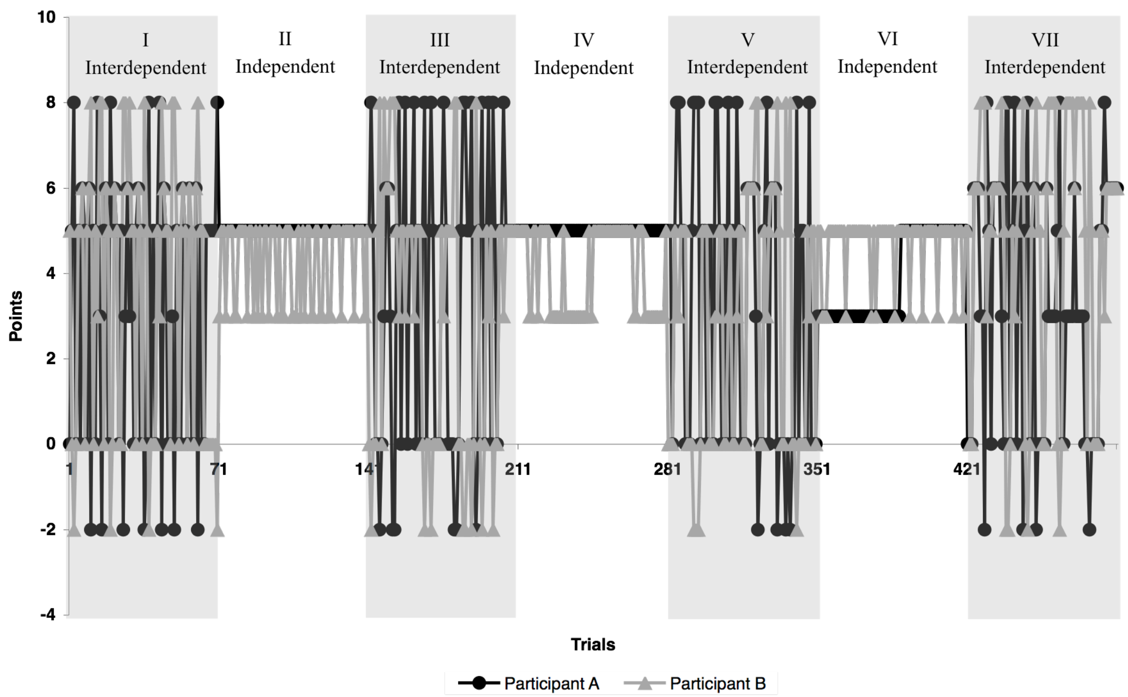

Figure 9. Points earned each trial, Dyad 2. Interdependent conditions (Phases I, III, V, & VII) are denoted by a grey background.

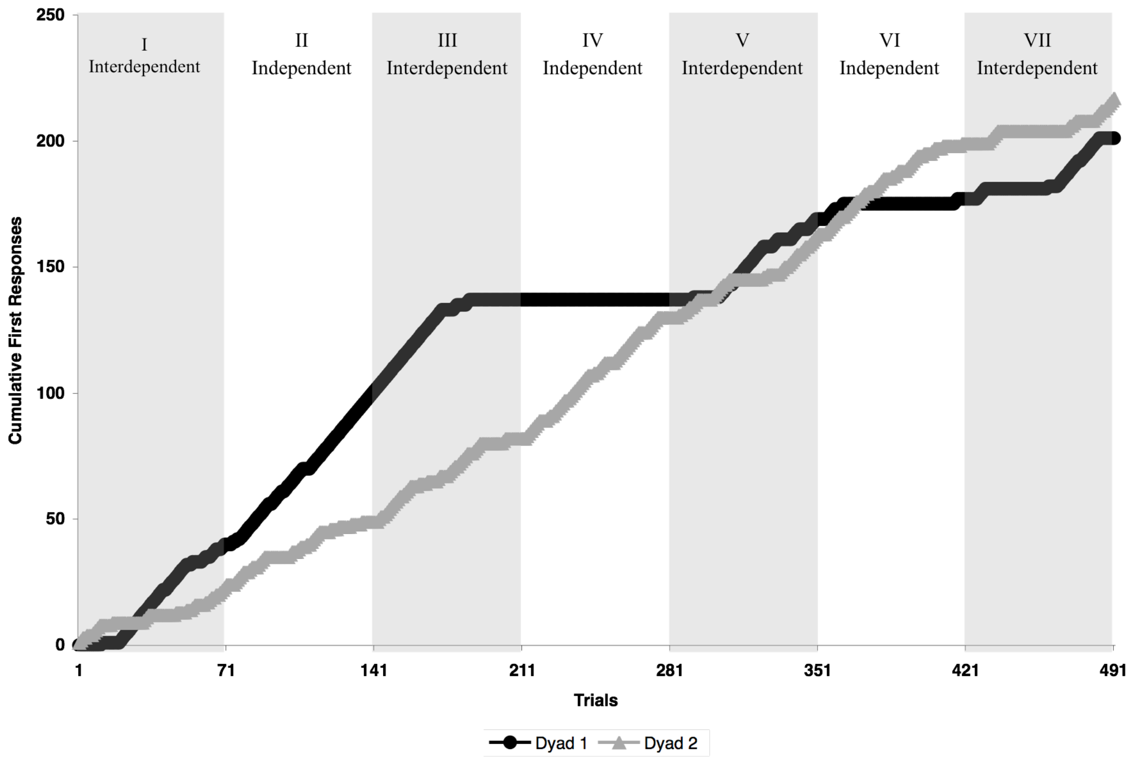

Figure 10. Cumulative trials wherein Participant B responded first. Interdependent conditions (Phases I, III, V, & VII) are denoted by a grey background.

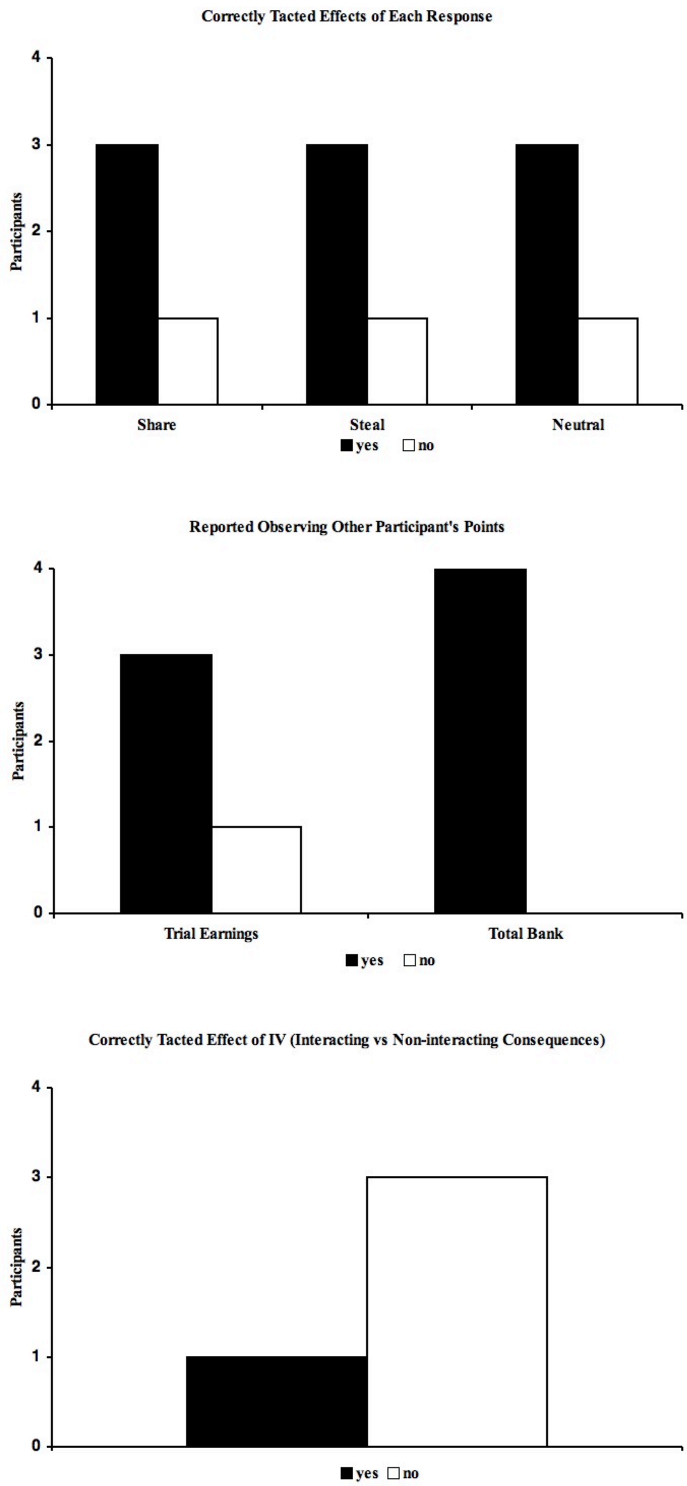

Figure 11. Verbal reports of participants in post-experimental debriefing. Black bars indicate the number of participants that reported each item; white bars indicate the number of participants that did not report each item.

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