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EFFECTS OF SOCIAL STIMULI ON OPERANT BEHAVIOR

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Mirror, Mirror in the Chamber: Effects of Social Stimuli on Operant Behavior

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at West Virginia Universityin partial fulfillment of the requirements for
the degree of Masters of Science in Psychology.**

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ABSTRACT

Effects of Social Stimuli on Operant Behavior

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The variables affecting social behavior are myriad, making the prediction and control of behavior occurring in social contexts relatively difficult. One can attempt to create a controlled social context in the laboratory by introducing a second organism into an operant chamber. To investigate effects of social stimuli on operant responding, key pecking responses of three pigeons were maintained on a variable-interval (VI) schedule of reinforcement in Experiment 1, and the key pecking responses of three additional pigeons were maintained on a three-component multiple schedule in Experiment 2. The components included a variable-ratio (VR) schedule, a fixed-interval (FI) schedule, and a differential reinforcement of low rate behavior (DRL) schedule. No social stimuli were present in the operant chamber during the baseline conditions of either experiment. During experimental conditions a mirror was introduced into the operant chamber to simulate the presence of another organism. The mirror covered one side wall of the chamber adjacent to the work panel containing the response key. Relative decreases in rates of responding were observed during each experiment when the pigeons had access to their reflections compared to when no mirror was present. Response rates returned to baseline levels when the mirror was removed in the subsequent conditions, suggesting that access to visual-social stimuli disrupted pigeon behavior controlled by different schedules of reinforcement.

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Effects of Social Stimuli on Operant Behavior

In the experimental analysis of behavior, it is virtually paradigmatic to study the behavior of organisms isolated from other organisms for the sake of experimental control, but much of behavior outside the laboratory occurs in the context of other organisms. Experimentally speaking, relatively little is known about the latter. This is perhaps due to the challenge of isolating controlling variables in natural-social environments, which often have a high density of uncontrolled variables. In the case of social stimuli, one can attempt to control them in a laboratory setting by using the presence of another organism to create a rudimentary social context. Secord and Backman (1964), describe the social context as one in which "the behavior of an individual in the presence of another person is at once a response and a stimulus to that other person. Because the other person (*O*) reacts to the behavior of an individual (*S*), the behavior of *S* is likely to be tempered by the presence of *O*." (Secord & Backman, 1964, p. 1). For the present experiment, "organism" has to be substituted for "person" in their definition, and the ways in which one organism's presence "tempers" the behavior of another is the question posed in this thesis. Social interactions are myriad, but a basic observation is that if the mere presence of that organism produces an observable change in the behavior of the individual, a compresence effect has been defined.

According to Zajonc (1972) compresence effect is a general term for an effect that one organism's presence may have on another. If such effects can be quantified as an increase in the dimensional quantities of ongoing behavior, they are called social facilitation effects. According to Crawford (1939; see also Hake & Laws, 1967) "social facilitation may refer to any increment of individual activity which results from the presence of another individual, and can be regarded as one of the most basic forms of social interaction" (Crawford, 1939, pp. 410-411).

Alternatively, if compresence effects can be quantified as a decrease in the dimensional quantities of the ongoing behavior, they are called social impairment effects (Zajonc, 1972.) For the purposes of this thesis, those categories of compresence effects will be referred to in terms of response potentiation or attenuation.

This thesis describes two experiments conducted to assess compresence effects in the context of different schedules of reinforcement when social stimuli are intruded into what Farmer and Schoenfeld (1966) called the behavior stream. To establish the conceptual and research framework for these experiments, it first is useful to consider previous research on social contingences, specifically those that investigate the effects of parameters of social stimuli on compresence effects. Methodological details, findings, and discussion of the current experiments follow the literature review.

Literature Review

The interest of the current experiments lies with compresence effects regardless of whether they are quantified as potentiation or attenuation of the ongoing behavior; however, much of the literature on the compresence focuses on the former. That is, social potentiation has greater representation than social attenuation in social psychology journals and behavior-analytic journals alike. Therefore, this review consists mostly of descriptions of experimental investigations of social potentiation, incorporates examples of social attenuation where examples are available, and concludes with an evaluation of the relevant parameters of social stimuli therein.

Compresence Effects

One of the earliest experiments conducted in social psychology was a demonstration of social potentiation of a response. In that experiment (Triplette, 1898) participants were tasked to

turn fishing reels at high speeds for a competition in a race against either a time limit or a

competitor depending on the active condition of the experiment. Rates of wheel turning were

regularly higher in the competitor condition relative to the timed condition. That experiment

generated a long line of research in social psychology including demonstrations of social

potentiation involving recognition tasks (Cottrell, Wack, Sekerak, & Rittle, 1968), meal

consumption (Clendenen, Herman, & Polivy, 1994), and observation (Claypoole & Szalma,

2017; Lui & Yu, 2017) to name a few. In contrast, Forgas, Brennan, Howe, Kane and Sweet

(1980) conducted naturalistic observations of squash players both in the private practice and in

the presence of an audience and found that the presence of an audience attenuated squash

performance relative to private play.

 Zajonc (1965) suggested two classes of compresence effects: audience and co-action

effects. If behavior change relies only on the presence of another organism, it is labelled an

"audience effect". Alternatively, if behavior change in the presence of a conspecific relies not

only on that organism's presence, but also on the *behavior* of that organism it is labeled a "co-

action effect." Co-action effects usually occur when a conspecific "co-actor" is engaged in the

same behavior as the primary organism, or actor, (Zajonc, 1965).

 Hake and Laws (1967) investigated both audience and co-action effects using a two-

compartment chamber separated by a clear plastic partition. During baseline sessions, a

conditioned suppression procedure (Estes & Skinner, 1941) was in effect for the actor pigeon.

This pigeon's keypecking was maintained on a variable-interval (VI) schedule in the presence of

a *safety* stimulus. A *warning* stimulus lasting 1.5 min occurred according to a variable-time

(VT) 15-min schedule; VI reinforcement remained available during the warning stimulus. The

warning stimulus terminated with a brief shock. Responding during the warning stimulus was

suppressed relative to that occurring during its absence, thereby providing two baselines of responding (VI and suppressed VI.)

During alternate sessions, a conspecific, labeled the co-actor, was present in the other compartment. The co-actor's keypecking was reinforced only during the warning stimulus on a fixed-ratio (FR) 1 schedule. Responding by the co-actor in the absence of the warning stimulus was never reinforced. When the co-actor was present, the response rate of the actor increased in the presence of the safety stimulus, demonstrating an audience effect. Furthermore, responding during the warning stimulus was suppressed less in the presence of the co-actor, which during this stimulus was engaged in the same topographical response, the key peck, as the actor. This latter result defines a co-action effect.

Although Hake and Laws's (1967) results demonstrate both audience and co-action effects in a single experiment, Hake, Powell, and Olsen (1969) suggested that the results may have been confounded by the use of a procedure involving electric shock. In a systematic replication of Hake and Laws (1967), Hake et al. (1969) compared audience and co-action effects before and after the introduction of shock, and at different shock intensities. The magnitude of potentiation in the presence of another organism increased as a function of shock intensity, suggesting that the conditioned suppression procedure may provide an unusually sensitive baseline for detecting those effects. The results of the two experiments conducted by Hake and colleagues elegantly demonstrate both audience and co-action effects in a single procedure, but rarely are both effects demonstrated simultaneously in other research reports. Reports such as those are considered in the sections that follow.

Co-Action Effects. As already noted, co-action effects are said to occur when the behavior of a co-actor potentiates or attenuates the behavior of the actor. It is important to note

that co-action is distinct from imitation, because co-action does not necessarily involve the acquisition of new behavior. Nor are the responses of the actor and co-actor required to be of the same topography (Hake & Laws, 1967), although they often are. These effects also are different from audience effects in that the behavior change depends not on the mere presence of a conspecific, but rather on the specific behavior in which the conspecific is engaged.

In a classic demonstration, Skinner (1962) separated actor and co-actor pigeon by a clear plastic partition within a single operant chamber. On each side of the partition were three response keys, arranged vertically and near the plastic partition. Responses on only one key would be reinforced in a trial, and the correct response key on a given trial was determined randomly. For a response to be reinforced "pigeons had to cooperate in two tasks: (1) discovering the effective pair" [of response keys] "and (2) pecking both buttons at the same time" (Skinner, 1962, p. 533). The actor pecked the buttons in some order and the co-actor pecked the key opposite the actor's most recent response. Skinner did not report quantitative data, but did report the following:

The visual stimulation supplied by one pigeon pecking on a button became a discriminative stimulus controlling a response to the corresponding button on the part of the other. Prolonged exposure to these conditions made pigeons strongly imitative in other respects. They would often drink from glasses of water in the compartments at the same time, for example. The extent to which their behaviors were mutually controlled was informally demonstrated when the experiment was shown to a group of biologists, one of whom suggested putting the birds in the opposite compartments. The birds immediately lined up alongside the glass plate, facing away from the buttons. They thus assumed their previously effective positions relative to each other, but were now facing the audience through the transparent front wall of the

apparatus. Though no buttons were available, they immediately began to cooperate in exploring a corresponding area, bobbing up and down in a perfect mirror-image pattern under the control of each other's behavior. Possibly because the leader-follower relation had frequently been shifted, each bird was evidently largely controlled by the behavior of the other. (Skinner, 1962, p. 533)

Skinner's (1962) demonstration of social relations was one of the earliest descriptions of co-action in the behavior-analytic literature. Others have extended the line of research concerned with isolating the discriminative-social stimuli provided by the behavior of a co-actor that control an actor's behavior. One example is Millard (1979), who conducted two experiments in which two pigeons in a single operant chamber were separated by a clear plastic partition. In Experiment 1, pairs of pigeons were exposed to multiple schedules in which reinforcement on one component was correlated with high-rate responding and reinforcement on the other component was correlated with low-rate responding. For the co-actor the schedule components were correlated with visual-nonsocial stimuli that were hidden from the actor, and for the actor the only stimuli correlated with the schedule component were the responses of the co-actor (responding rapidly or slowly depending on which visual stimulus was in effect and visible only to the co-actor). In a second experiment, Millard exposed the co-actor to a chained schedule with the discriminative stimuli for the co-actor arranged as described for Experiment 1 above. The co-actor's behavior during the components differentially controlled behavior of the actor in both experiments.

Systematic replications of Skinner (1962) have been conducted with monkeys (Fushimi, 1990) and rats (Hake, Donaldson, & Hyten, 1983) as subjects. Each of these replications involved two organisms separated by a partition in a single operant chamber, allowing access to

visual-social stimuli in the form of the responses of the co-actor. Reinforcement of the actor's responses occurred contingent on the matching of the most recent response of the co-actor. In those replications, discrimination of co-actor behavior and correct matching to sample occurred at accuracies exceeding 80 percent correct (Hake et al., 1983) and 90 percent correct (Fushimi, 1990).

In contrast to the experiments described above, other investigations of co-action involving actor and co-actor competition have resulted in social attenuation. For example, Martens and Landers (1972) measured participant performance on the "roll up game", a task that required participants to roll a ball up a ramp that had obstacles and holes in it. Each hole was associated with a point value which increased as distance up the ramp increased. Points were earned by rolling the ball into those holes. Participants earned fewer points in the presence of a co-actor than when they performed in private. Similarly, Baumeister (1984) reported social attenuation of video game performance when participants played in the presence of a competitor compared to when they were playing alone. However, attenuation of the responses measured in those experiments cannot be attributed solely to co-action because competition involves contingencies of reinforcement and punishment that confound an isolated analysis of compresence effects.

Those experiments highlight some of the difficulties in isolating compresence effects when competing contingencies are present in the social context. Another issue in the analysis of compresence effects, and specifically audience effects, is the presence or absence of discriminative-social stimuli emitted by a conspecific. That is, an analysis of audience effects might be confounded if conspecific responses, and not the mere presence of the conspecific, function as controlling stimuli. Although the focus of the research proposed below is not

narrowed to a specific category of compresence effect, understanding the relevant discriminative stimuli operating in both co-action and audience effects is important for a thorough discussion of compresence effects. What follows is a review of the literature that demonstrated audience effects in isolation of co-action and a discussion of the relevant stimulus properties associated with compresence effects.

Audience Effects. As defined earlier, an audience effect occurs when behavior change can be attributed to the mere presence of another organism (Zajonc, 1965). Audience effects have been reported often with human participants (Claypoole & Szalma, 2017; Liu & Yu, 2017). One potential caveat to such reports is that, because experimenters cannot control for human participants' behavioral histories, one cannot be sure that the effects observed are attributable to the mere presence of another organism rather than being a function of previous social consequences (e.g. booing, hissing, applauding, cheering, et cetera.) Because a conspecific can control the behavior of an actor by implementing or signaling social consequences, learned relations between those stimuli and actor behavior may confound audience effects, and, in fact, relegate them to the previously described co-actor effects. Such potential confounds must be addressed and eliminated from, or at least minimized in, experimental analyses of audience effects. To this end, nonhuman-animal research may offer an alternative. By limiting historical variables through isolated housing and controlling/eliminating the presence of social consequences, audience effects can be investigated in relative isolation with nonhuman-animal subjects.

Many of the investigations of audience effects with nonhuman animals have targeted phylogenetically maintained behavior such as eating (Keeling & Hurnik, 1993), aggressive displaying (Falsarella, Brandão, & Gonçalves-de-Freitas, 2017), and alarm calling (Evans &

Marler, 1991) in the presence of a conspecific audience. Evans and Marler (1991) investigated audience effects related to alarm calls of a male chicken. To elicit an alarm call, a pulley system was used to move a silhouette of a hawk over an operant chamber divided into two compartments by a wire partition. The independent variable was the presence or lack of an audience in the adjacent compartment to that of the actor. At different points in the experiment, videos of the following were used as simulated audiences in the adjacent chamber: a female conspecific, a [heterospecific] female bobtail quail, and an empty cage. Videos were accompanied by auditory stimuli recorded at the same time as the videos. Live female organisms also were used in another condition to allow for comparison of the relative effects of live-social stimuli and simulated-social stimuli on alarm calling. The males' alarm calls occurred most frequently in the presence of the female conspecific, followed by those occurring in the presence of a heterospecific, and alarm calls occurred the least frequently when the adjacent compartment was empty. This pattern of results held true during video presentations of the conspecific, heterospecific, and empty cage as well.

Others have investigated audience effects with operant behavior using aversive contingencies, as in Hake and Laws (1967). The co-actor was trained in Hake & Laws (1967) only to respond during the warning stimulus, but some co-actor responses still occurred in the presence of the safety stimulus, potentially relegating the audience effect to one of co-action. It also may be that actor responding was, in part, maintained by conditioned reinforcement when the co-actor's food tray was presented in the adjacent compartment. Hake et al. (1969) attempted to control for those extraneous stimuli. After establishing a baseline of social facilitation using the same procedure as Hake & Laws (1967), they restricted the relevant stimuli to only the presence of the conspecific in different ways. First, the co-actor's response key was

covered with a metal plate to prevent co-actor responses that might otherwise produce co-action effects. Second, to prevent nonsocial stimuli (such as those related to the apparatus) from functioning as discriminative stimuli controlling actor behavior, co-actor food tray presentations were discontinued for 16-20 sessions. This extinction procedure ensured that changes in the actors' behavior could be described as audience effects and not attributed to conditioned reinforcement delivered by the conspecific's food tray presentations. After controlling for co-action and extraneous stimuli with the control procedures described above, the actor's response rates were higher during the safety stimulus when a conspecific audience was present compared to when one was not, demonstrating an audience effect.

Hake et al.'s findings demonstrate some of the challenges associated with isolating the controlling variables of audience effects. To claim that an audience effect has taken place, it is not sufficient to demonstrate that changes occur in the presence of another organism when other, potentially confounding, variables are part of the complex profile of stimuli introduced with the conspecific. The importance of identifying the controlling parameters of those stimulus profiles is highlighted in Sasfsky and Okun's (1974) systematic replication of Martens and Landers (1972). Safsky and Okun used a procedure in which participant performance on the "roll up game" was measured under several distinct audience conditions. The participant was either (1) alone, (2) in presence of an *expert* audience, or (3) in the presence of a *nonexpert* audience. The expert audience member was a confederate disguised as a visiting professor and introduced as an expert on motor performance and acquisition, and the nonexpert audience member was a confederate disguised and introduced as an undergraduate student. Audience members were instructed not to disturb the ongoing behavior of the participant, but to observe and evaluate performance. Audience members evaluated participant performance either (1) directly though

observation of participant behavior in real time, (2) indirectly through observation of data being recorded on a blackboard when a wooden partition was placed between the audience and participant, or (3) not at all when the partition was in place and data were not recorded on the board. Participant performance was attenuated in the expert audience condition when evaluation was both direct and indirect, but not when evaluation did not occur. No systematic change in performance occurred in the nonexpert audience condition regardless of the evaluation condition. Sasfy and Okun (1974) concluded that audience characteristics may play a vital role in social potentiation and attenuation because they may signal differential-social consequences for good or bad performance. If that is the case, the term audience effect would be an inaccurate label for the behavior change that occurred in that experiment, because it was not reliant on the mere presence of the audience, but rather the discriminative stimuli associated with social evaluation of performance.

Although audience effects have been demonstrated in multiple settings and with a variety of different responses, it remains unclear which specific stimuli are functioning to control behavior. Based on the definition of audience effects (Zajonc, 1965), the mere presence of another organism should be producing behavior change of the actor, but the presence of another organism includes many stimuli, any or all of which may be controlling behavior. If audience effects are caused by the mere presence of an organism, then a social stimulus in isolation should be sufficient to produce a change. If, instead, behavior change relies on compounded dimensions of social stimuli, such as the behavior or characteristics of an organism in conjunction with any consequences those stimuli may signal or impose (e.g. audience behavior such as booing and applauding), then the term *audience effect* may be an inaccurate characterization of the interaction. This potential confound leads to the next topic of discussion.

Dimensions of Social Stimuli

The preceding discussion points to the complexity of "simply intruding" a second organism into a behavior stream. One way of isolating social stimuli from potentially confounding sources of stimulation is by using a simulated conspecific. Several variables related to simulating social stimuli are relevant to the proposed project.

Salience of social stimuli. Social stimuli may develop from any of the sensory modalities, and they share the same measurable dimensions that define other stimuli. Of the various modalities, however, Hake et al. (1983) suggested that visual-social stimuli may be the most salient stimuli and the most critical for establishing discriminative control over social behavior.

Hake et al. (1983) investigated co-action effects using the same procedure as Hake et al. (1969) when only visual-social stimuli were available to an actor compared to when only auditory-social stimuli were available. That is, auditory stimuli were masked with an exhaust fan in the visual stimuli condition and line of sight was blocked with an opaque partition in the auditory condition. The unblocked stimuli in the visual condition consisted only of those visual stimuli emitted by the co-actor's physical presence including the location responses. The unblocked stimuli in the auditory condition were only the sounds of co-actor responding. The accuracy of matched to sample actor responses was greater than would be expected by chance in the auditory stimuli condition, but the relative accuracy was less than that observed during the visual stimuli condition. Accuracy was higher when visual stimuli were available relative to when auditory stimuli were available by margins ranging from 10 – 40%, offering mixed but helpful results to those considering the use of the visual-sensory modality in social experiments.

Evans and Marler's (1991) second experiment similarly attempted to isolate the relative contributions of auditory and visual stimuli to social facilitation. Using the same methods and apparatus as those in Experiment 1, described above, an analysis was conducted using a video of: (1) a conspecific with sound, (2) a conspecific without sound, (3) a an empty cage without sound, and (4) an empty cage with the sound from the video described in (1) overlaid. Alarm calls occurred at the highest frequency when videotapes with both the image and sounds of a conspecific were presented, followed by the silent videotape of a conspecific, the video of an empty cage with sound from a conspecific, and, lastly, the silent video of the empty cage. These results are relevant to the current experiment because they show that simulated-social stimuli function as social stimuli and provide additional evidence that visual-social stimuli may be the most salient social stimuli.

Challenges with Using Social Stimuli. Evaluating the role of visual-social stimuli in systematic, laboratory settings comes with a unique set of challenges because two or more living organisms must be placed in close proximity to one another. Baumeister and Showers (1986) point out that "the audiences is not a simple, homogenous, or dichotomous variable in relation to performance." (p. 370) and one of the challenges associated with conducting investigations of social behavior is the additional variability introduced by the behavior of a second organism relative to that which is present when an organism is isolated. Although this source of variation is more difficult to control relative to the kinds of static stimuli that often are used in laboratory experiments, such variation is characteristic of social environments and has to be accounted for in social experiments.

Another, more practical, concern is the possibility of aggression that occurs when two organisms are in the same environment, a concern which is especially present in nonhuman-

animal research. Separating organisms by a partition, as was done in several of the experiments described above (Millard, 79; Hake & Laws, 1967; Hake et al., 1969; Hake et al., 1983), minimizes aggression that might otherwise result in harm or injury to the animal subjects. Though partitions prevent aggression in the form of physical contact, they do not prevent animals from engaging in aggressive displays and other behavior that competes with the task against which the social interaction is being measured. The use of a partition may allow an analysis of behavior in the presence of a conspecific without the threat of harm or injury but it eliminates the possibility of social interactions involving physical contact. Control is an important feature of any experiment and introducing social stimuli may mean introducing greater variability because aggression and other types of social interactions occur, but this is the very nature of social interaction and cannot be eliminated without presenting risks to construct validity. The investigator has an obligation to minimize harm but controlling too much changes the nature of the social interactions under investigation.

Other techniques of presenting conspecifics can reduce the risk of harm but may also change the nature of the social interaction. Those include the use a photo of a conspecific (Thompson 1964), video of a conspecific (Turnbough & Lloyd, 1973; Evans & Marler, 1991), a taxidermic model of a conspecific (Cohen & Looney, 1975), and/or the reflection of an organism in a mirror (Thompson & Sturm 1965, Cohen & Looney, 1975) in lieu of using a conspecific.

Those techniques come with limitations as well. For example, no matter how high the resolution, a photo cannot interact with the actor (that is, in a typical social context, the co-actor responds when the actor acts), which may limit the validity of social research that uses such stimuli. Videos share that limitation, with the added concern that, though variation of social stimuli is limited to that behavior which is recorded on tape, the behavior of the recorded

organism remains uncontrolled. Taxidermic models have the same strengths as photos and

videos with the added benefit that the model may provide similar or at least more closely related

tactile feedback to that of a live organism, if the actor touches it. Such models, however, do not

provide behavioral feedback to the actor, resulting in the same limitation as the photos and

videos. By contrast, mirror images offer (1) the same visual feedback provided by that of a live

conspecific, (2) a stimulus that *interacts* (covaries) with the behavior of the actor, (3) a stimulus

with relatively less risk in terms of harm/injury than that of a live conspecific, and, for that

reason, (4) a stimulus that experimenters need not prevent physical contact with.

Mirror images, unlike the other simulated-social stimuli, are not behaviorally static

because the reflection varies isomorphically with the behavior of the actor. That feature offers a

degree of social validity in the sense that reflections offer an interaction with the actor that is not

offered by those other techniques described above. However, it comes with a familiar challenge.

That is, the introduction of additional variability that takes place when a social stimulus is

introduced is not prevented, but rather it is limited to that which occurs in conjunction with the

behavior of the actor.

Comparing results obtained with mirrors to those obtained using live organisms (Cohen

& Looney, 1975) reveals similar patterns of social behavior, suggesting that an organism's

reflection may be functionally similar to other social stimuli. Mirror images have been used to

investigate behavioral processes such as self-recognition (Epstein, Lanza, & Skinner, 1981;

Uchino & Watanabe, 2014) and aggression (Thompson & Sturm, 1965; Cohen & Looney 1975;

Lattal & Metzger, 1994; Elcoro, da Silva, & Lattal, 2008). The evidence suggesting that social

stimuli can function as reinforcers for some organisms (Lattal & Metzger, 1994; Elcoro, da

Silva, & Lattal, 2008) may have implications for compresence effects on of operant behavior as

well, as those experiments using mirrors provide additional evidence that visual-social stimuli may play an important role in the control of social behavior.

Statement of the Problem

Most experimental analyses to date of compresence effects have involved respondent behavior such as feeding (Clendenen, Herman, & Polivy, 1994; Keeling & Hurnik, 1993), engaging in aggressive displays (Falsarella, Brandão, & Gonçalves-de-Freitas, 2017), and making alarm calls (Evans & Marler, 1991). The potentiation of operant behavior in the presence of a conspecific was investigated in three experiments by Hake and colleagues (Hake and Laws, 1967; Hake et al., 1969; Hake et al. 1983), but few experiments have systematically investigated compresence effects with operant behavior outside the context of aversive control.

The research reviewed above suggests that simulated conspecifics may evoke behavior similar to that occurring in the presence of a living conspecific (e.g., Cohen & Looney, 1975). Of the simulation options used, an organism's reflection in a mirror as a simulated-social stimulus seems to have several advantages, and visual-social stimuli may be the most salient social stimuli (Hake et al., 1983; Evans & Marler, 1991). The purpose of the present experiments therefore was to investigate compresence effects on operant behavior by introducing a mirror into streams of behavior maintained by different schedules of reinforcement.

Experiment 1

The purpose of Experiment 1 was to investigate compresence effects of a simulated-social stimulus, in this case a mirror, on operant responding maintained by a VI schedule of reinforcement.

Method

Subjects. Three adult male White Carneau pigeons maintained at approximately 80 percent of their respective free feeding weights were used. Each pigeon had previous experience responding on schedules of positive reinforcement, but none had previous exposure to the simulated-social stimuli used in the experiment. Each was housed individually in a vivarium with a 12-hour light/dark cycle.

Apparatus. An operant conditioning chamber located in a sound attenuating enclosure was used. The chamber work area was 32 cm long by 32 cm high by 38 cm wide. An aluminum work panel, comprising one wall of the chamber, displayed a 2 cm diameter response key centered on the midline of the panel. This key was transilluminated by a white light located behind it. The key was operated by a force of approximately 0.15N. Reinforcement periods were 3-s access to mixed grain from a hopper located behind a 5 cm by 4.5 cm rectangular feeder aperture located on the midline of the work panel 15 cm from the floor. The hopper was raised into the square aperture, which was illuminated by a white light during periods of reinforcement. General chamber illumination was provided by a fluorescent houselight located above the chamber. Its light passed through a 10 cm wide by 32 cm long hole in the top of the chamber, which was partially covered with a tinted sheet of glass to avoid masking the keylight. A GoPro Session 4 video camera was mounted in that hole as well, pointed downward to capture the chamber's interior. The houselight remained on for the duration of each session, including periods of reinforcement. White noise generators and a ventilation fan masked extraneous noise. A computer operated MedPC software, which in turn controlled the experiment.

Procedure. Sessions occurred daily at approximately the same time. Each session began with a 180-s blackout period, during which the chamber was dark and the response key

inoperative, and terminated automatically after 60 reinforcers were delivered, or after 60 minutes elapsed, whichever occurred first.

Because each pigeon had previous experience responding on schedules of reinforcement, each was exposed at the experiment onset to a VI 30-s schedule constructed using the distribution described by Fleshler and Hoffman (1962). This schedule remained in effect during all phases of the experiment.

The following conditions were arranged according to an ABABAC design. These conditions changed after a minimum of 10 sessions and only when response rates were stable according to the following criterion: the variation between the response rates for five consecutive sessions had to be less than 10% different (upward or downward) from the mean response rate for those five sessions. The A phases were Baseline conditions during which the wall to the right of the response panel was covered with an opaque black plastic insert. During the B phases, a 30.5 cm by 30.5 cm square reflective mirror replaced the opaque black plastic inset on the wall to the right of the response key. The C phase was a control phase in which the opaque black plastic insert that was present during A phases was removed, leaving the white wall of the operant chamber exposed instead. This allowed a comparison between effects of social stimuli on behavior (B phase) and the effects of an arbitrary stimulus change on behavior (C phase.)

Data Analysis. Primary dependent measures were overall response rates (calculated as total responses in a session divided by total session duration (excluding reinforcement time)), average postreinforcement pause (PRP) time (total postreinforcement pause time of a session divided by the number of reinforcers earned in that session), and reinforcement rate (total reinforcers earned in a session divided by total session duration). The secondary dependent measures were time spent facing the plastic insert (during A phases) and mirror (during B

phases), pecks at the plastic insert and mirror, and wing flaps. Those responses were captured via video analysis of three sessions at the end of each A phase and three sessions at the beginning and end of each B phase. Those sessions were recorded using the GoPro Session 4 video camera mounted above the operant chamber.

Observational data were coded using Behavior Logger™ software for 5-minute samples of the recorded sessions. The samples were taken from the middle of each session (minutes 12-17). Time facing the mirror was measured as continuous duration when (1) the subject's head was facing the mirror and (2) at least 50 percent of the subject's body was oriented towards the mirror. Pecks at the wall and mirror, and wing flaps, were recorded as frequency counts.

Inter-Observer Agreement. Inter-observer agreement (IOA) was calculated using the partial agreement method in 3-sec bins for 33% of sessions in each phase and for each subject. Average agreement for time spent was 91% (range = 82-99%). Average agreement for pecks was 89% (range = 80-97%). Average agreement for wing flaps was 95% (range = 85-99%).

Results

Figure 1 shows responses per minute (total resp/tot time – SR time) and relative response rates calculated as a proportion to baseline (overall response rate divided by the average response rate of the last five sessions of the initial A phase) respectively. Introducing the mirror in the first B phase immediately attenuated VI responding for all three pigeons relative to response rates from the initial baseline. Pigeon 2215's response rates remained suppressed relative to the initial baseline for the duration of the first B phase, and Pigeon 8964's response rates decreased throughout the first B phase. Pigeon 1189's response rates decreased following the introduction of the mirror but then subsequently increased across the B phase, eventually approaching baseline levels at the end of the phase.

When the mirror was removed (second A phase), each pigeon's response rates immediately returned to the initial baseline levels. Pigeons 1189 and 8964's continued to increase throughout the second A phase, quickly exceeding the levels obtained in the initial baselines. When the second B phase began, response rates of each pigeon again were rapidly and systematically attenuated in the presence of the mirror once again. Response rate suppression decreased over time for Pigeons 1189 and 8964 approaching baseline levels once again toward the end of the second B phase. Pigeon 2215's response rates remained suppressed relative to baseline throughout the second B phase. Response rates for Pigeons 1189 and 8964 were on a decreasing trend during the last three sessions of the second B phase. Those trends reversed when the mirror was removed in the A phase that followed, quickly returning to baseline levels. Pigeon 2215's response rates also rapidly returned to baseline levels in the final A phase. Response rates remained at baseline levels when the opaque black plastic insert was removed during the C phase for two of three pigeons. Pigeon 8964's response rates decreased in the first session of the C phase but returned to baseline levels in the second session and remained at that level for the duration of this phase. The decrease was not a systematic function of the plastic inserts' removal, but rather a feature of ongoing variability that occurred throughout the experiment with that pigeon. Pigeon 1189's response rates decreased after four sessions of the C phase relative to the final A phase but returned to baseline levels at the end of the C phase.

Post reinforcement pauses (PRPs), defined as the time from the offset of the reinforcer access to the first subsequent response, were averaged across all reinforcers during a session. Figure 2 shows these average PRPs for Experiment 1 in the left column. No systematic change in PRP duration occurred between phases for two of three pigeons. Pigeon 8964's PRP durations were stable across phase changes. Pigeon 1189's PRP durations were variable both within and

between phases, but the variability did not track the phase changes systematically. Pigeon 2215's average PRP systematically increased during B phases relative to A phases. None of the pigeons showed systematic PRP changes between the final A phase and the following C phase.

Reinforcement rates for the last ten days of each phase in Experiment 1 are shown in the graphs in the right column of Figure 2. Approximately two reinforcers were earned per minute for each pigeon across during the initial baseline. The reinforcement rates did not change systematically between phases for any of the three pigeons. The lowest rate of reinforcement observed for Pigeon 8964 occurred during the C phase.

Observational Data

Cumulative time spent facing the opaque black plastic insert (A phases) and mirror (B phases) for three days at the end of each A phase and three days at the beginning and end of each B phase in Experiment 1 is shown on the left column of Figure 3. Time spent facing the mirror was systematically greater than time spent facing the plastic insert in each phase for all three pigeons. Time spent rapidly increased in the first B phase relative to the initial baseline for Pigeon 2215. Pigeon 1189's time spent increased slightly during the B phase and remained at that level during the three days at the end of the B phase as well. Pigeon 8964's time spent did not immediately increase in the three sessions at the beginning of the B phase but did so later during the three sessions at the end of the B phase. Time spent immediately reversed back to and below baseline levels when the mirror was removed during the second A phase for each pigeon. During the second B phase, time spent facing the mirror increased again, quickly, for each pigeon. No systematic change occurred between the three days at the beginning of the B phase and the three days at the end of the B phase for any of the pigeons. Time spent facing the mirror returned to near-zero during the final A phase for each pigeon.

Pecks that occurred at the plastic insert and mirror in Experiment 1 are shown in the middle column of Figure 3. No pecks at the plastic insert occurred during any of the A phases. Pecks at the mirror during B phases were systematically greater in count for each pigeon relative to pecks at the plastic insert present during A phases.

Wing flaps in Experiment 1 are shown in the right column of Figure 3. There was no apparent systematic relation between the presence of the mirror and the frequency of wing flapping for two of three pigeons. Wing flaps increased during the first B phase for pigeon 2215 relative to the initial baseline. No wing flaps occurred in the second A phase for pigeons 8964 and 2215. Pigeon 1189 pecked a total of 22 times during the second A phase. Increased numbers of wing flaps occurred in the second B phase for Pigeon 2215 relative to the preceding A phase, but no systematic change in wing flapping occurred for Pigeons 8964 or 1189 during that phase. No wing flaps occurred during the final A phase for Pigeons 8964 and 2215, but Pigeon 1189 engaged in a total of 24 wing flaps during that phase. Though the highest count of wing flaps during a single session for Pigeon 1189 occurred during a B phase (17), the range of variability within phases was stable across phases, suggesting that wing flapping may not have been a function of the mirror for that pigeon. Pigeon 2215, however, showed near-zero levels of wing flapping throughout each A phase and showed systematically increased counts of wing flapping in the presence of the mirror during B phases.

Discussion

Introducing a mirror into the ongoing stream of behavior maintained by the VI schedule resulted in the immediate and systematic attenuation of VI response rates for each of the three pigeons and an increase in average PRP for Pigeon 2215. Because no systematic change in VI responding occurred during the Control phase, it can be concluded that the mirror's stimulus

profile had controlling properties that are distinct from otherwise arbitrary stimulus changes, and the attenuation of VI responding during B phases was a product of pigeon interactions with the mirror.

Sidman (1960) cautioned that certain variables such as specific temporal control produced by fixed-interval (FI) schedules and spaced responding characteristic of fixed-ration (FR) schedules can counteract a shift in behavior that might otherwise result from the manipulation of an independent variable. He went on to suggest that an ideal baseline produces little to no interference from variables such as those mentioned above, which is crucial for ensuring that, once an independent variable is introduced, baseline behavior will be sensitive to any changes that occur as a function of that variable. "A variable-interval schedule, if skillfully programed, comes close to meeting this requirement" (Sidman, 1960, p.320), providing a baseline that is maximally sensitive to experimental manipulation. Using a VI schedule in Experiment 1 provided a sensitive baseline, but VI schedules of reinforcement allow pausing and alternative responses to occur, within a threshold, without changing the rate of reinforcement. Therefore, the compresence effects reported in Experiment 1 may have been potentiated by using a VI schedule which allowed an analysis of those effects in the absence of changes in reinforcement rate, but provided no account for the changes in compresence effects that might occur when behavior is maintained by schedules that involve covariance between response rate and reinforcement rate. To investigate the roles of baseline sensitivity and differential reinforcement rates in compresence effects, Experiment 2 sought to extend the findings of Experiment 1 into the contexts of different schedules of reinforcement including those that produce static and dynamic patterns of behavior.

Experiment 2

The purpose of Experiment 2 was to examine compresence when a mirror is intruded into a stream of operant behavior maintained by different schedules of reinforcement arranged as components of a multiple schedule.

Method

Subjects. Three adult male White Carneau pigeons maintained at 80 percent of their respective free feeding weights were used. Each pigeon had previous experience responding on schedules of positive reinforcement, but none had previous exposure to the simulated-social stimuli used in this experiment. Each was housed individually in a vivarium with a 12-hour light/dark cycle.

Apparatus. The same apparatus used in Experiment 1 was used for Experiment 2, with the addition of another response panel placed opposite the original. The added aluminum response panel comprised what was the rear wall of the original chamber. A 2 cm diameter response key was offset 6 cm to the left of the panel's midline and 25.5 cm from the chamber floor, center-to-center. This key was transilluminated by either a white light, red light, or green light which were located behind the key. The key was operated by a force of approximately 0.15N. Reinforcement periods were 3-s access to mixed grain from a hopper located behind a 6 cm by 4.5 cm rectangular feeder aperture located on the midline of the work panel with its lower edge 8 cm from the floor. The hopper was raised into the square aperture, which was illuminated by a white light during periods of reinforcement.

Procedure. Sessions occurred daily at approximately the same time. Each began with a 180-s blackout, during which the chamber was dark and the response key inoperative. Sessions

ended automatically after 60 reinforcers were delivered, or after 60 minutes elapsed, whichever occurred first.

Responses were maintained according to a three-component-multiple schedule of reinforcement. A multiple schedule "consists of two or more alternating schedules of reinforcement with a different stimulus present during each" (Ferster & Skinner, 1957, p. 557). The components were as follows: variable ratio (VR) 40, fixed interval (FI) 40-s, and differential reinforcement of low-rate behavior (DRL) 7-s. Those components were correlated with red, green, and white keylights respectively. A component ended after 20 reinforcers were delivered, and components alternated in random order without replacement. Each component occurred once per session, separated by a 10-s blackout in the chamber. The VR schedule values were determined using the distribution described by Fleshler and Hoffman (1962).

To train the stimulus discriminations necessary for the multiple schedule, the pigeons were exposed to each component of the multiple schedule and the key lights those components were correlated with prior to the baseline proper. The schedules in each component initially were VR 1, FI 1-s, and DRL 1-s. The schedule values then were progressively leaned in increments governed by the pigeon's performance during those components. The training phase ended once the terminal schedule values were reached.

The following conditions were arranged according to an ABA design. These conditions changed after a minimum of 15 sessions. The A phases were Baseline conditions during which the wall to the right of the response panel was covered with an opaque black plastic insert. During the B phase, a 30.5 cm by 30.5 cm square reflective mirror replaced the opaque black plastic inset on the wall to the left of the response key. The number of sessions that each phase was in effect with each pigeon is shown in Table 1.

Data Analysis. The data analysis was as described for Experiment 1 with a few changes noted herein. Response rate, average PRP, and reinforcement rate were not calculated for each session, but instead for each component of the multiple schedule. Observational data were collected from 3-min samples of each component within a session. The samples were taken from the first 3 min of those components. Videos of Pigeon 4464's initial baseline sessions were not recorded due to experimenter error. Three additional videos were taken during the three days at the beginning of Pigeon 4464's second A phase.

Inter-Observer Agreement. IOA was calculated for 39% of sessions in each phase and for each pigeon using the same method as Experiment 1. Average agreement for time spent was 87% (range = 73-98%). Average agreement for pecks was 92% (range = 61-100%). Average agreement for wing flaps was 99% (range = 95-100%).

<div align="center">

Results

</div>

Responses per minute of each pigeon during each component appear in the graphs of the left column of Figure 4. During the initial baseline, the multiple schedule produced relatively high, medium, and low response rates on the VR, FI, and DRL schedules respectively for two of three pigeons. Pigeon 1022's responding was undifferentiated between the VR and FI schedules, but its DRL response rates were lower than its VR and FI response rates. That pigeon's VR response rates were atypically low during the initial baseline, which may have been a reflection of its inefficient response topography. The observational analysis (described abocve) revealed that its key pecks frequently were off key, that is they did not operate the electric switch used to define a key-peck response.

The VR response rates of Pigeons 1022 and 4464 rapidly attenuated when the mirror was introduced during the B phase. The relatively low VR response rates at the beginning of the B

phase for these pigeons increased over successive sessions, eventually reaching rates seen in the initial baseline. Pigeon 4079's VR response rates were acutely potentiated during the first five B phase sessions. Unlike the behavior change seen with Pigeons 1022 and 4464, the level change with Pigeon 4079 did not exceed the range of variability that was present for that pigeon during the initial baseline. During the second A phase VR response rates increased relative to the previous B phase for Pigeons 4079 and 1022. The increased VR response rates for Pigeon 4079 were acute, lasting for 3 sessions before returning to the cycle of variability observed in the previous phase. Pigeon 1022's VR response rates systematically increased when the mirror was removed. These rates exceeded those observed in both the B phase and the initial baseline.

FI response rates were immediately attenuated when the mirror was introduced for Pigeons 1022 and 4464. Those reductions were acute, lasting only two sessions for Pigeon 1022 and three sessions for Pigeon 4464. Pigeon 4079's FI rates also decreased relative to baseline during the B phase, but not immediately. The level changes for each of three pigeons did not exceed the ranges of variability present for those pigeons during their initial baselines, and FI responding returned to baseline levels by the end of the B phase for each of the three pigeons. FI response rates increased in the final A phase relative to the end of B phase for two of the three pigeons. The ranges of variability present for Pigeons 1022 and 4079 obscure available comparisons between the B phase and the final A phase. No systematic change FI response rates occurred between the end of the B phase and the final A phase for any of the pigeons.

DRL responding decreased during the B phase for Pigeons 4464 and 1022. Though the level changes are slight relative to those seen during the other components, suppressed levels present throughout the B phase are regularly lower than those of the initial baseline for those pigeons. Pigeon 1022's level of suppressed DRL responding exceeded the range of variability

that was present during baseline for that pigeon. DRL response rates increased for Pigeon 4079 during the B phase relative to the initial baseline. Again, the level change is small, but DRL response rates are regularly higher in the B phase and several data points exceed the range of variability that was present during the initial baseline for that pigeon. DRL responding reversed to baseline levels for all three pigeons in the final A phase, suggesting the level changes seen during the B phase were a function of the mirror.

The left column of Figure 5 shows the average PRPs of Experiment 2 calculated as the cumulative PRP of each component divided by the number of reinforcers earned in those components for each session. During the initial baseline VR PRP tended to be the shortest relative to PRPs produced by DRL and FI schedules, which, by comparison, were medium and long respectively. Pigeon 1022's VR and DRL PRPs were undifferentiated during the initial baseline, but FI PRP was always relatively long compared to those of the other components.

No systematic change in VR PRP duration occurred between phases for Pigeons 4464 or 4079. VR PRP duration showed a systematic increase during the B phase for pigeon 1022, exceeding baseline PRP durations of all components. Pigeon 1022's VR PRP durations reversed to baseline levels during the final A phase.

FI PRP systematically decreased for Pigeons 1022 and 4079 in the presence of the mirror relative to the initial baseline. Pigeon 1022's FI PRP durations increased thereafter and eventually returned to baseline levels near the end of the phase. Note that the response rate showed no systematic change during the B phase for Pigeon 1022, suggesting that, although the number of responses remained somewhat stable during the B phase, the temporal distribution of FI responses may have been disrupted in the presence of the mirror. Pigeon 4079's FI PRP immediately decreased when the mirror was introduced. That pigeon's FI PRP levels varied

throughout the B phase but remained at or below baseline levels. Pigeon 4464's FI PRP increased for three sessions following the introduction of the mirror but decreased below baseline levels thereafter. The trends present for Pigeon 4464 did not appear to be a function of the mirror, but rather a byproduct of an ongoing cycle. No systematic change occurred in FI PRP during the final A phase relative to the end of the B phase for three of three pigeons.

There was a systematic increase in DRL PRP to levels at or near 7 s for Pigeons 1022 and 4464 during the B phase relative to the initial baseline. The level changes were small in terms of absolute value but are behaviorally significant because the DRL's inter-response time criterion was set to 7 s. DRL PRP for Pigeon 4079 showed no systematic change as a function of the mirror. No systematic change occurred in DRL PRP during the final A phase relative to the end of the B phase for three of three pigeons.

The distribution of FI responses across time can be seen in Table 2, which contains cumulative records of FI responding during the last session of the initial baseline and the first session of the B phase of Experiment 2. The temporal distribution of FI responses was disrupted in the first session of the B phase relative to the last session of the A phase for Pigeons 1022 and 4464. The pattern of 4079's temporal distribution of FI responses remained mostly unchanged on the first session of the B phase relative to the last session of the A phase.

The right column of Figure 5 shows reinforcement rates for each session of Experiment 2 and for each component of the multiple schedule. FI reinforcement rate remained constant near the optimal level at approximately 1.46 reinforcers per minute throughout each phase and for each of three pigeons. VR reinforcement rate systematically decreased during the B phase for Pigeon 1022 and a systematically increased at that time for Pigeon 4079. No systematic change in VR reinforcement rate occurred for Pigeon 4464. DRL reinforcement rate showed a

systematic increase during the B phase for Pigeons 1022 and 4464. Those increased levels, in conjunction with the increased DRL PRP that occurred during the B phase for those pigeons, provides evidence that DRL performance increased as a function of the mirror for those pigeons. Pigeon 4079's DRL reinforcement rate varied both within and across phases, but those changes did not track the presence or absence of the mirror.

Observational Data

Figure 6 shows observational data for the three sessions at the end of each A phase and the three sessions at the beginning and end of each B phase for Experiment 2. Time spent facing the mirror, during B phases, and black opaque plastic insert, during A phases, is shown in the left-column graphs of Figure 7. Time spent facing the mirror was systematically greater in each of the components during the B phase relative to time spent facing the plastic insert in A phases for each pigeon. Pigeon 4079 spent the most time facing the mirror during the FI and DRL components, and little to no time facing the mirror in the VR component. Pigeon 1022 spent the most time facing the mirror in the VR component, followed by DRL and FI in that order. Pigeon 4464 spent approximately equal time facing the mirror in the DRL and VR components in the three sessions at the beginning of the B phase but spent little to no time facing the mirror in the three sessions at the end of the B phase. Time spent facing the plastic insert in FI and DRL components did not completely reverse to the levels seen in the initial baseline for Pigeons 4079 and 1022, but those levels did decrease relative to the B phase. No systematic change between the three sessions at the end of the B phase and the final A phase occurred for Pigeon 4464.

Pecks at the mirror and plastic insert are shown in the middle column graphs of Figure 6. Zero pecks at the plastic insert occurred throughout the experiment for any of the three pigeons. Pecks at the mirror were systematically greater than pecks at the plastic insert for all three

pigeons. Pigeon 4079 pecked the mirror most frequently in the FI component during the three

sessions at the beginning of the B phase but pecked most frequently in the DRL component

during the three sessions at the end of the B phase. That pigeon pecked the mirror the least

amount of times during the VR component. Pigeon 1022 pecked the mirror most frequently in

the VR component during the three sessions at the beginning of the B phase but pecked most

frequently on the FI and DRL components in the three sessions at the end of the B phase. Pigeon

4464 pecked the mirror relatively less than the other pigeons during the B phase. That pigeon

pecked most on the VR and DRL components in the three sessions at the beginning of the B

phase, but only pecked the mirror on the DRL component during the three days at the end of the

B phase.

Wing flaps are shown on the right column graphs of Figure 6. Zero wing flaps occurred

for Pigeons 4079 and 1022 throughout the experiment. An increase in wing flaps during the DRL

component occurred during the last A phase relative to the B phase for Pigeon 4464. That pigeon

engaged in the most wing flaps in the FI component during the B phase and flapped the most in

the DRL component during the A phase. Wing flaps in the FI component appeared to decrease in

the A phase relative to the B phase, but not outside the range of variability that was present in the

B phase.

Discussion

Introducing a mirror into the streams of behavior maintained by different schedules of

reinforcement arranged in a multiple schedule resulted in the attenuation of response rates during

the VR and DRL components for Pigeons 1022 and 4464. Response rates on the FI component

did not change in a systematic fashion when the mirror was introduced, but FI PRP decreased

and the pattern of temporal distribution of FI responses was altered as a function of the mirror.

Those findings complement and extend the findings of Experiment 1 by providing analyses of compresence effects in the contexts of different schedules of reinforcement that have contrasting response rates, response patterns, and reinforcement rates. Unlike the first experiment, when the mirror was introduced response suppression was acute on the VR component which may be due to the direct relation between response rate and reinforcement rate characteristic of ratio schedules. That is, reductions in response rate resulted in a reduction of reinforcement rate as well, which may, over time, override the compresence effect. In direct contrast to VR, there is an inverse relation between response rate and reinforcement rate on DRL schedules. In that component, any reduction in response rate, within a threshold, resulted in an increase in reinforcement rate, perhaps contributing to the relative longevity of suppressed DRL responding in the presence of the mirror.

Unlike Experiment 1, where the mirror functioned to suppress VI responding for all three pigeons, VR and DRL responding were potentiated in the presence of the mirror for Pigeon 4079. On the one hand, increases in VR and did not exceed the range of variability which had been present in the initial baseline, thus it may have been part of an ongoing cycle of variability and not a function of the mirror. On the other hand, the highest recorded rates of DRL responding occurred in the B phase for that Pigeon, suggesting that potentiation in that component may have been a systematic effect of the mirror. Reinforcement rates during each component appear to be controlling variables that contribute to the mixed results obtained in Experiment 2. A discussion of those relations will follow in the general discussion.

Among the potential limitations of Experiment 2 are atypical patterns of schedule controlled responding, order effects of the multiple schedule, and experimenter error in the collection of observational data. These limitations are detailed in the paragraphs that follow.

First, the expected patterns of schedule-controlled responding were not achieved on the VR component for Pigeons 1022 and 4464. That is, VR response rates were atypically low for those pigeons in the initial baseline and Pigeon 1022's VR response rates were undifferentiated from FI response rates. Response rates in the FI components were also somewhat low relative to the expected schedule control for those pigeons. Pigeon 4079's VR and FI response rates oscillated between relatively high and low rates in a cyclical fashion, complicating and obscuring comparisons made across phases. Ideally, baseline would have continued until behavior was both schedule typical and steady but time constraints on the completion of the research precluded the continuation of baseline into steady state. Although the expected schedule performance did not occur on the VR and FI components, the baseline VR rates were relatively high compared to the other components for Pigeons 4079 and 4464, there was evidence of temporal control of FI responding for each of three pigeons (see Table 2), and DRL responding was schedule typical for each of the pigeons. Differences in behavior among the components were evident not only in the relative changes in response rate that took place in the presence of the mirror, but also in the frequencies of mirror responding during each component. Those differences and their correlations to other dependent measures are detailed in the general discussion.

Second, a multiple schedule involves the alternation of components in some order which may introduce order effects. The order of component alternation in Experiment 2 was determined randomly by a computer program each day, so order effects, if present, were obscured and distributed across each phase. When the mirror was introduced, there may have been differential effects for the component which came first in that session compared to those that came thereafter, but no analysis of component order effects has been conducted.

Another potential limitation, as noted previously, was the loss of observational data on some days. Data for the initial baseline for Pigeon 4464 were lost due to experimenter error, reducing the comparisons available with the remaining data to the differences which occurred between the B phase and the second A phase. Observational data were also lost on somewhat rare occasions that the camera ran out of battery during a session. On those days, data for the components that occurred later in the session were lost. That problem was not revealed until the observational data were analyzed near the end of the experiment, at which time it was too late to take additional videos. Data loss for certain components occurred a total of three times, twice with Pigeon 1022 (sessions one and eight represented on Figure 6) and once with Pigeon 4464 (session two represented on Figure 6.)

General Discussion

Zajonc (1972) defined a compresence effect as a change in the behavior of an individual that occurs as a result of the mere presence of a conspecific. The current experiments simulated the presence of a conspecific during B phases by introducing a mirror into to the operant chamber. Responding on the VI schedule was attenuated as a function of the mirror's presence and recovered when the mirror was removed for all three pigeons in Experiment 1. Responding controlled by the VR and DRL schedules was attenuated as a function of the mirror for two pigeons and potentiated for one pigeon in Experiment 2. No systematic change in FI response rates occurred in the presence or absence of the mirror for each of the three pigeons in Experiment 2, but changes in average FI PRP and temporal distribution of responses occurred following the introduction of the mirror for all three pigeons. Quantitative analyses of the temporal distribution of FI responding have not been conducted, but qualitative changes were revealed in the cumulative records of FI responding shown in Table 2.

Although the behavior changes that occurred in the presence of the mirror can be labelled as compresence effects, it is not clear if those changes occurred as a function of the mere presence of the reflection (audience effect) or the stimulus properties of the reflection and/or behavior of the reflection (co-action.) Because the visual-stimulus properties and behavior of the reflection mirror those of the pigeon, those variables remain uncontrolled. As suggested in the literature review, to claim that an audience effect has occurred, it is not sufficient to demonstrate that changes occur in the presence of social stimuli when other, potentially confounding, variables are part of the complex profile of stimuli present in a social context. As a case in point, an observational analysis of the data revealed that each pigeon interacted with the mirror by pecking their reflections, and, of course, each time the pigeon pecked the mirror the reflection would appear to be pecking back. That dynamic relation between pigeon and reflection behavior may produce a self-potentiating cycle of mirror pecking that competes with the target response (keypecking) and is specific to the use of a mirror. Alternatively, if a live organism were used, the conspecific might engage in counter attacks which could (1) result in the injury of one or both pigeons and (2) punish aggressive responding such that it no longer occurs (Azrin, Hutchinson, & Hake, 1966). The current experiments included no controls for dynamic social interactions such as those described above, thus it remains unclear if the compresence effects were a function of the mere presence of social stimuli or of the behavior and stimulus properties of the reflection. The purposes of the current experiments were not to distinguish between audience and co-action effects, but rather to investigate compresence effects in the context of different schedules of reinforcement. However, future experiments geared towards generating such a distinction might include an analysis of the relative changes in behavior that occur across conditions involving (1) the absence of social stimuli, (2) the presence of static social stimuli

(such as a still photograph of a conspecific), and (3) the presence of dynamic social stimuli (such as a reflection or live conspecific). If the mere presence of a social stimulus is sufficient to generate compresence effects, behavior would change in the second and third condition relative to the first. If not, only the third condition would produce a compresence effect.

The location of the response key relative to the mirror may be a variable that contributed to the relative levels of suppression that occurred as a function of the mirror's presence in the two experiments. The key in Experiment 1 was 13 cm away from the mirror's edge and the key in Experiment 2 was 7 cm away from the mirror, perhaps making changeovers between the response panel and the mirror quicker and more frequent in the second experiment relative to the first. A matching analysis of equal and concurrently available VI schedules that were separated by a partition of varying lengths revealed that changeovers occurred less frequently when the partition was longer in length (Baum, 1982). This suggests the distance between response options may be a relevant variable, but no such analysis could be conducted for the current experiments due to the limitations of the measurement system used to collect observational data. Future experimenters may consider the usefulness of automating the measurement of mirror responding, which would reduce the limitations of observational data collection and improve the accuracy of those measures.

Some other variables which may be relevant to an interpretation of the present results include generalized matching of responding on concurrent response options, species-typical behavior, restriction of social interaction, schedule-induced responding, and resistance to change. When two or more response options are concurrently available a matching occurs between the responses allocated to each option and the relative reinforcement rates available on each option (Herrnstein, 1970). The current experiments involved two concurrent response options in the B

phases, the key and mirror, and the distribution of responses between those options likely contributed to the compresence effects observed therein. In addition, pigeons are known to sometimes engage in unconditioned pecking of conspecifics (Reynolds, Catania, & Skinner, 1963). That species-specific response was not restricted in the current experiments and may have competed with the target response. Mirror responses can be considered examples of adjunctive behavior, which is a term describing behavior that is produced by environmental controls such as schedules of reinforcement but is neither explicitly nor adventitiously reinforced by the experimenter (Falk, 1966a). The frequency of schedule-induced adjunctive behavior tends to be a function of relative reinforcement rates which varied according to the components comprising the multiple schedule in Experiment 2. In addition, because those components yielded relatively different reinforcement rates behavior in each component may be relatively more or less resistance to change as a function of the relative reinforcement rates (Kuroda, Cook, & Lattal, 2018).   These variables are discussed in the subsections that follow.

The Matching Law. Herrnstein (1970) stated that "For concurrent schedules (i.e., simultaneous choice procedures), there is matching between the relative frequencies of responding and reinforcement" (p.243). That is, when concurrent sources of reinforcement are available, the amount of responding allocated to one source matches the relative frequency of reinforcement on that source compared to another. In the current experiments mirror responding was concurrently available to key pecking during B phases. Pecks at the mirror occur throughout each B phase despite the lack of programmed reinforcers available for that response. This suggests that, although there is no food reinforcement available for mirror responding, there may be a natural reinforcer associated with social interaction maintaining those responses. A literature search produced no results for matching analyses of nonhuman-social behavior nor matching

analyses of nonhuman-operant behavior maintained by social reinforcers. However, matching analyses of human-social behavior have been conducted and may be useful in an interpretation of the current experiments. For example, Beardsley and McDowell (1992) conducted an analysis of college student social behavior in an experiment where time spent looking at the experimenter was reinforced with verbal praise according to concurrent VI schedules with different interval values. Time spent looking at the experimenter was found to follow the predictions made by the matching law much in the same way animal behavior has been shown to in the laboratory. That is, allocation of responding matched the relative frequencies of reinforcement available on the concurrent options. In addition, McDowell and Caron (2013) conducted a matching analysis of the verbal behavior of adolescent boys identified to be at risk for delinquency and found that their verbal responses were accurately described by the matching law. To assess the role matching might play in compresence effects with pigeons, a direct analysis of the reinforcing properties of social stimuli is a necessary first step. A basic experiment that involves the presentation of social stimuli as a consequence for a pigeon's key pecking responses might be a reasonable first approximation to such an analysis, but some evidence of social stimuli functioning as reinforcers is already available. For example, Cherek, Thompson, and Heistad (1973) maintained key pecking on an FR schedule of reinforcement that, when completed, resulted in an opportunity to attack another pigeon. In addition, Lattal and Metzger (1994) and Elcoro, da Silva, and Lattal (2008) demonstrated that opportunities to engage in aggressive displays can function as reinforcers for Siamese fighting fish. Because pigeons often engage in unconditioned aggression in the presence of a conspecific (Reynolds, Catania, & Skinner, 1963), those experiments may be of particular relevance to an interpretation of the current experiments. If keypecking can be maintained by access to social stimuli or opportunities to peck a

conspecific, the Matching Law would predict that responding be allocated in part to the key and in part to the mirror in the current experiments.

Another variable in the context of matching and social reinforcement is the restriction placed on social interaction between two animals in a social context. Many of the previous experiments investigating co-action and audience effects that showed social potentiation also restricted the organism from engaging in physical-contact with the conspecific (Hake & Laws, 1967; Hake et al., 1969; Hake et al., 1983; Evans & Marler, 1991). The partition may have prevented topographies of social interaction that might have otherwise functioned as reinforcers and competed against the behavior compresence effects were measured against in those experiments. The mirror pecking responses in the current experiments were unrestricted, and, that specific topography of social interaction may compete with the target response (keypecking) relatively more than the topographies of social interaction allowed in those previous experiments (e.g. observing responses and co-action.) Some of those experiments used different species such as rats, which may not be as likely to engage in unconditioned aggression as pigeons, but the animals were separated in those experiments nonetheless. A direct comparison of compresence effects when physical-social interaction is restricted and unrestricted has yet to be conducted. Some future directions for this line of research might include (1) an analysis of compresence effects when physical contact is allowed in one condition and restricted in another and (2) a replication of the current experiment using rats instead of pigeons to investigate the role of species-specific behavior in compresence effects.

Schedule-Induced Responding. Another interpretation of the attenuation of operant responding that occurred in the current experiments is that mirror responding may be a form of adjunctive behavior that interrupts the operant response. Adjunctive behavior has been described

by Falk (1966*a*) as responding that is produced by environmental controls such as schedules of

reinforcement but is neither explicitly nor adventitiously reinforced by the experimenter.

Schedule-induced polydipsia, or the excessive consumption of water, and aggression are two

examples of adjunctive behavior (Falk, 1966*b*), the levels of which tend to be a function of the

relative rates of reinforcement. For example, Azrin, Hutchinson, and Hake (1966) measured

aggressive responses in alternating conditions of (1) nonreinforcement and (2) a multiple

schedule with a signaled reinforcement component and a signaled extinction component. They

found that periods of nonreinforcement (1) induced relatively fewer aggressive responses than

periods of alternating reinforcement and extinction (2), suggesting that the relative change is an

important variable and the discriminability of such a change may moderate the levels of induced

responding. In addition, Falk (1966*a*) found that polydipsia increased during longer fixed-

interval (FI) schedules relative to shorter FIs, and Cohen and Looney (1973) found that FR

schedules arranged in a multiple schedule induce aggression at different levels depending on the

response requirements in those components. That is, the pigeons pecked their reflections in a

mirror at higher rates during components with high response requirements relative to those that

required fewer responses for reinforcer delivery to occur.

In Experiment 2 the components of the multiple schedule produced different

reinforcement rates for each pigeon. According to Azrin et al. (1966) and Falk (1966a; 1966b),

those components that are associated with relatively low reinforcement rates compared to the

others should induce more mirror pecking responses. Although Experiment 2 did not include a

direct analysis of schedule-induced responding using the conventional procedures associated

with that line of research, the frequency of mirror-pecking responses that occurred during each

component was inversely correlated with the baseline rates of reinforcement on those

components for all three pigeons. The VR component, unlike the FI and DRL components, did not involve a discriminable period of nonreinforcement, but may induce aggression as a result of intermittent reinforcement availability which "necessarily involve[s] periods of extinction" (Azrin et al., 1966, p. 203). A useful replication of Experiment 2 might be to analyze mirror pecking responses using multiple schedules of reinforcement that consist of components of the same type of schedule, but with different reinforcement rates (e.g. Multiple FI 30-s FI 60-s). One would predict that greater frequencies of mirror pecking occur in the components with relatively low reinforcement rates under those conditions.

Resistance to Change. Resistance to change is the metric describing the relative change in behavior which occurs as a function of changing the conditions of reinforcement. Reinforcers that are relatively frequent, immediate, and high magnitude tend to produce patterns of behavior with greater resistance to change relative to their alternatives (Nevin, 1974). Reinforcer frequency varied across components in Experiment 2 and likely contributed to the relative behavior changes seen therein. Resistance to change is measured as the relative change that occurs between baseline response rates and those occurring during alternate conditions that might involve presession access to food, response independent food deliveries during the session, extinction (Kuroda et al., 2018), or the introduction of an alternative source of reinforcement. Nevin, Tota, Toquato, and Shull (1990) investigated the detrimental effects of satiation and extinction on resistance to change in procedures where alternative reinforcement was either contingent on a response or delivered independently of behavior. Both paradigms produced relative decreases in resistance to change compared to control conditions in which there was no alternative food source. If social interactions with the mirror indeed function as unprogrammed, natural reinforcers, then the mirror can be conceptualized as a source of alternative reinforcement

and it follows that the magnitude of compresence effects seen in the current experiments would be correlated with the rate of reinforcement available for the keypecking response.

Responding in Experiment 2 was maintained using a multiple schedule with components that produced differential rates of reinforcement. Introduction of the mirror in the B phase led to attenuation of VR responding for Pigeons 1022 and 4464, who had relatively low VR reinforcement rates compared to Pigeon 4079. Pigeon 4079's VR response rate and reinforcement rate were high during the initial baseline and showed relative insensitivity to the mirror's presence compared to the other two pigeons.

Pigeon 1022 regularly earned fewer reinforcers per minute on the VR component relative to the FI and DRL components during the initial baseline. Consistent with the previous literature on resistance to change, that pigeon's VR responding was attenuated at relatively high levels in the presence of the mirror relative to FI and DRL responding, which remained at or near baseline levels when the mirror was introduced. Pigeon 4464, however, tended to earn fewer reinforcers per minute on the DRL component compared to the VR component during the initial baseline. Again, the resistance to change literature would lead one to predict that DRL responding would be attenuated more than VR responding, but instead VR responding was more attenuated than DRL when the mirror was introduced. This discrepancy may, in large part, be due to a floor effect on Pigeon 4464's DRL response rates, which were characteristically low as is typical of a DRL schedule. Nonetheless, there was not an orderly relation between the reinforcement rates of each component of Experiment 2's multiple schedule and the levels of response rate attenuation that occurred on those schedules. Further experimentation may be necessary to clarify the role that resistance to change might play in the presence and magnitude of compresence effects. For example, one might consider constructing an experiment using multiple schedules of

reinforcement that consist of components of the same type of schedule but varying reinforcement rates (e.g. Multiple VI 30-s VI 60-s) then testing resistance to change in the presence of an alternative source of reinforcement such as the mirror used in the current experiments.

Summary and Conclusions

The intrusion of a social stimulus into an ongoing stream of schedule-maintained behavior in Experiments 1 and 2 attenuated response rates on VI, VR, and DRL schedules, but not on FI schedules. Suppression of VI responding was immediate and sustained throughout each B phase. The suppression was acute on the VR schedules and chronic on DRL schedules, suggesting that, over time, the relation between response rate and reinforcement rate characteristic of ratio schedules may override or sustain the observed compresence effects depending on the direction of that relation. Reinforcement rate appears to be a key variable in mirror responding as well, for the number of mirror responses occurring in each component was inversely correlated with the baseline reinforcement rates for those components. Those responses often took the form of mirror pecking, a social interaction that competes with the key pecking responses and likely contributes to the attenuation of response rates. The FI components, however, allow alternative responses and pausing to occur during the discriminable period of nonreinforcement that occurs during the interval, so mirror responding during that time did not have a direct effect on FI reinforcement rate like it did in the other components. Response distribution within intervals changed as a function of the mirror's presence, and the scalloped pattern of responding that is characteristic of FI schedules was altered to look more evenly distributed throughout intervals. The change in FI response distribution is reflected in the acute reduction of average PRP durations that occurred following the introduction of the mirror for each of the three pigeons.

These experiments offer insight into the contextual nature of compresence effects. That is, the nature of those effects depends in large part on the schedules of reinforcement or, more generally, the surrounding environments that maintain the responding against which compresence effects are measured, as well as the stimulus properties of the conspecific organism and the species-typical behavior of the organism under study. Those variables should be accounted for or controlled in experiments that investigate the effects that the mere presence of social stimuli may have on behavior as well as experiments that investigate the effects that dynamic-social stimuli and the social interactions they allow might have on behavior.

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Table 1. Matrix showing the number of sessions dedicated to each phase for each pigeon in Experiment 2. The pigeon number is indicated on the leftmost column.

	Condition (Absence or Presence of Mirror)		
Pigeon	Absent (A)	Present (B)	Absent (A)
1022	16	16	15
4079	18	18	15
4464	15	25	15

Table 2. Matrix showing cumulative records of FI responding on the last day of the initial baseline (left column) and the first day of the B phase (right column) in Experiment 2. Pigeon number is indicated on the left of the records and phases are indicated above each record. Vertical resets of the response line indicate 500 responses. The duration of each record is shown in minutes in the bottom right corner of each panel.
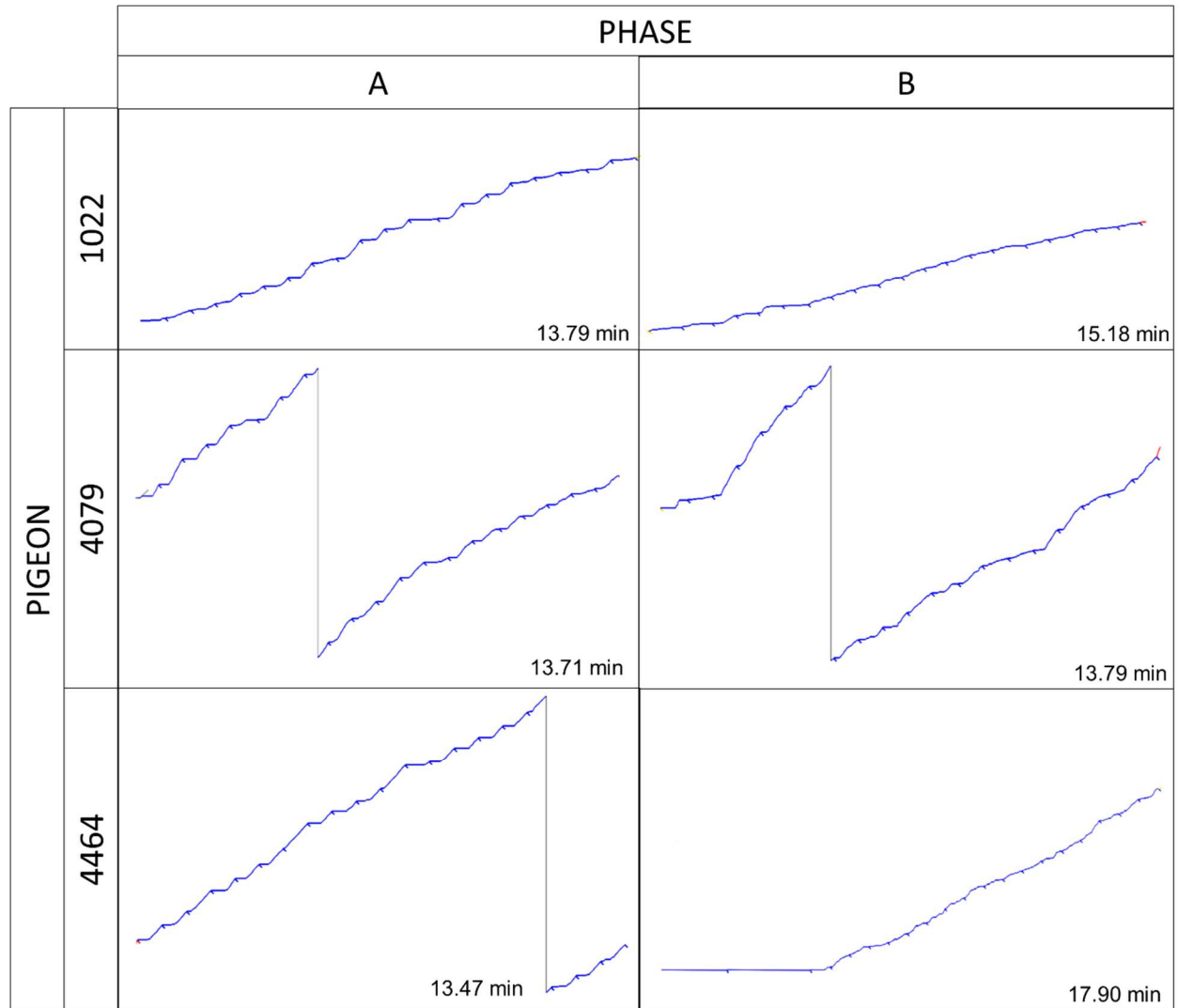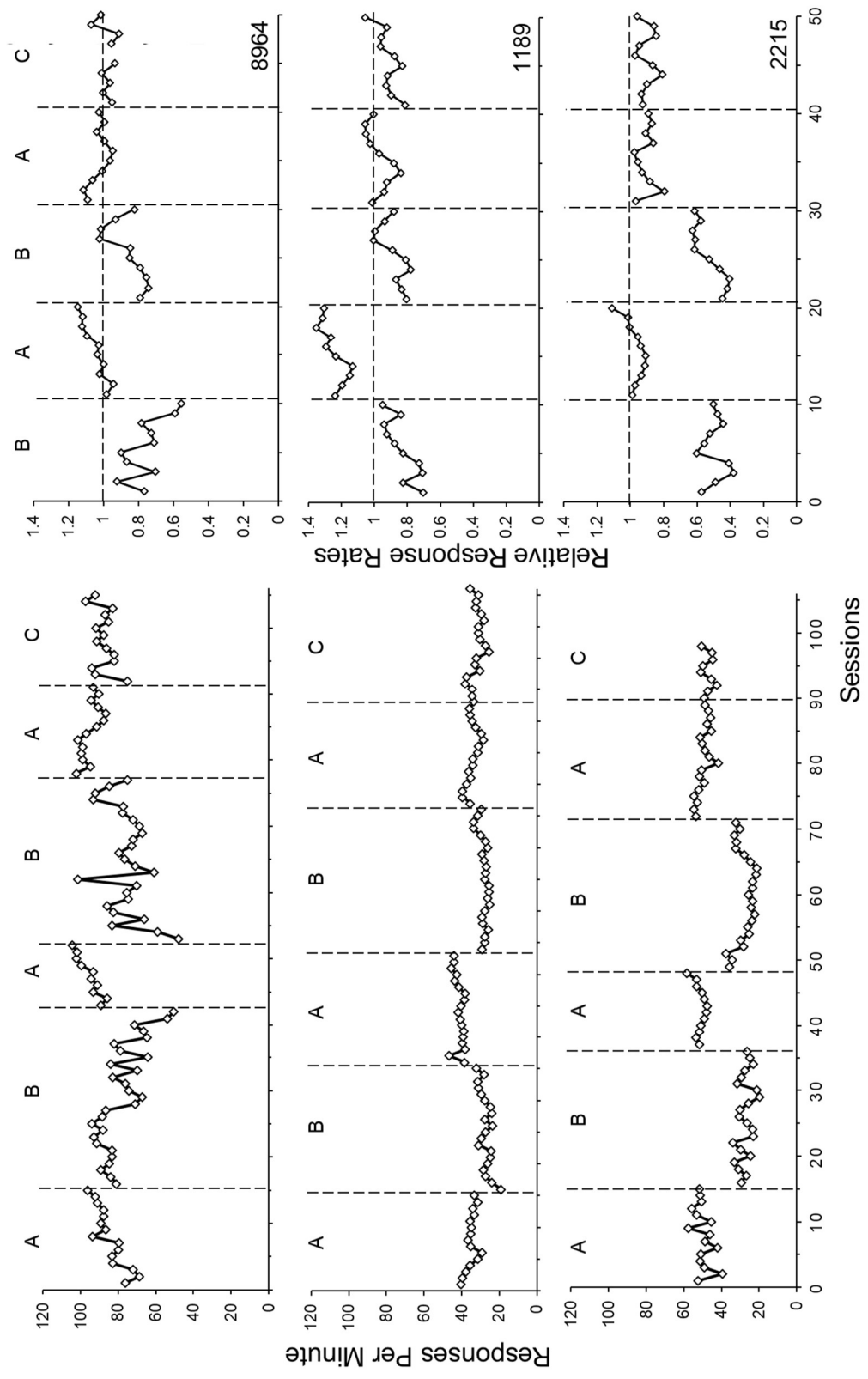
Figure 1. Responses per minute (left) and relative response rates (right) for Experiment 1. Pigeon 8964's response rates are on the top row, Pigeon 1189's response rates are on the middle row, and Pigeon 2215's response rates are on the bottom row. Vertical dotted lines represent phase changes, and each phase can be identified with the corresponding phase labels located at the top of the figure. Horizontal dotted lines on the relative response rate graphs represent the mean response rate for the last five sessions of the initial baseline.
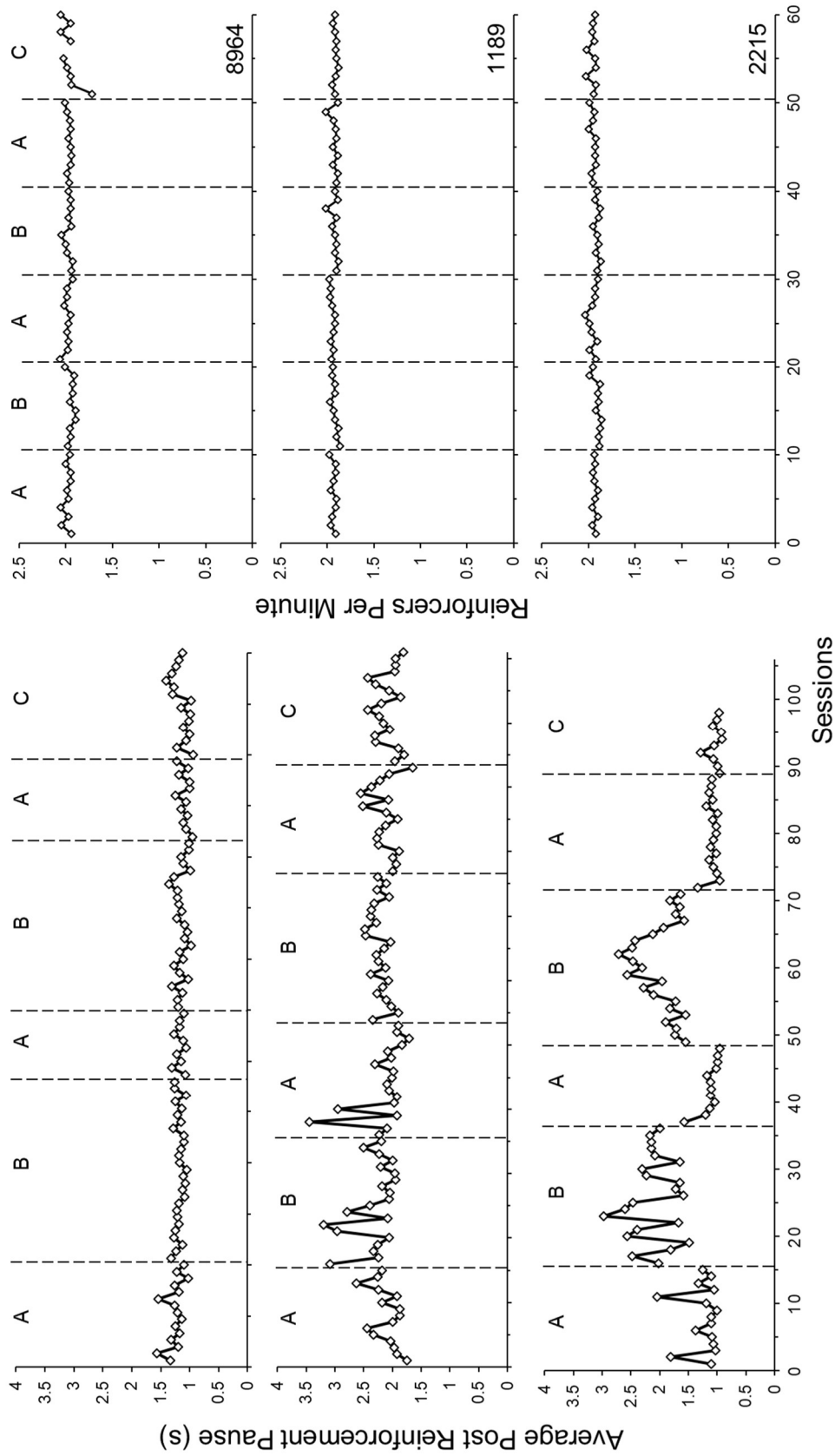
Figure 2. Average PRP for Experiment 1 (left column) and reinforcers per minute for Experiment 1 (right column). The rows are shown in the same manner as Figure 1. Reinforcement rate data are only shown for the last 10 sessions of each phase.
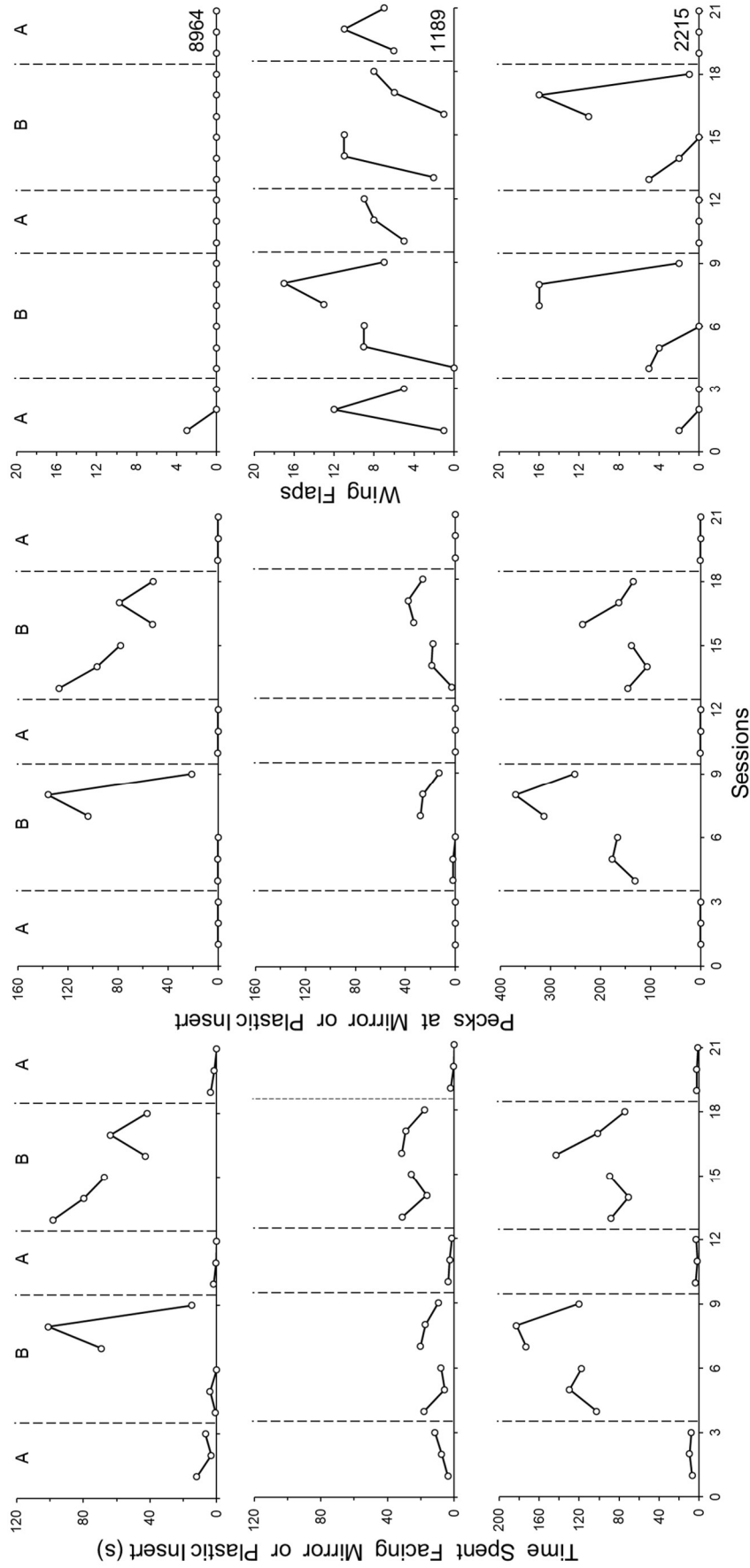
Figure 3. Observational data for Experiment 1. The rows are shown in the same manner as Figures 1 and 2. Time spent facing the mirror, in B phases, and plastic insert, in A phases, is shown on the left column, pecks at the mirror and plastic insert are shown on the middle column, and wing flaps are shown on the right column.
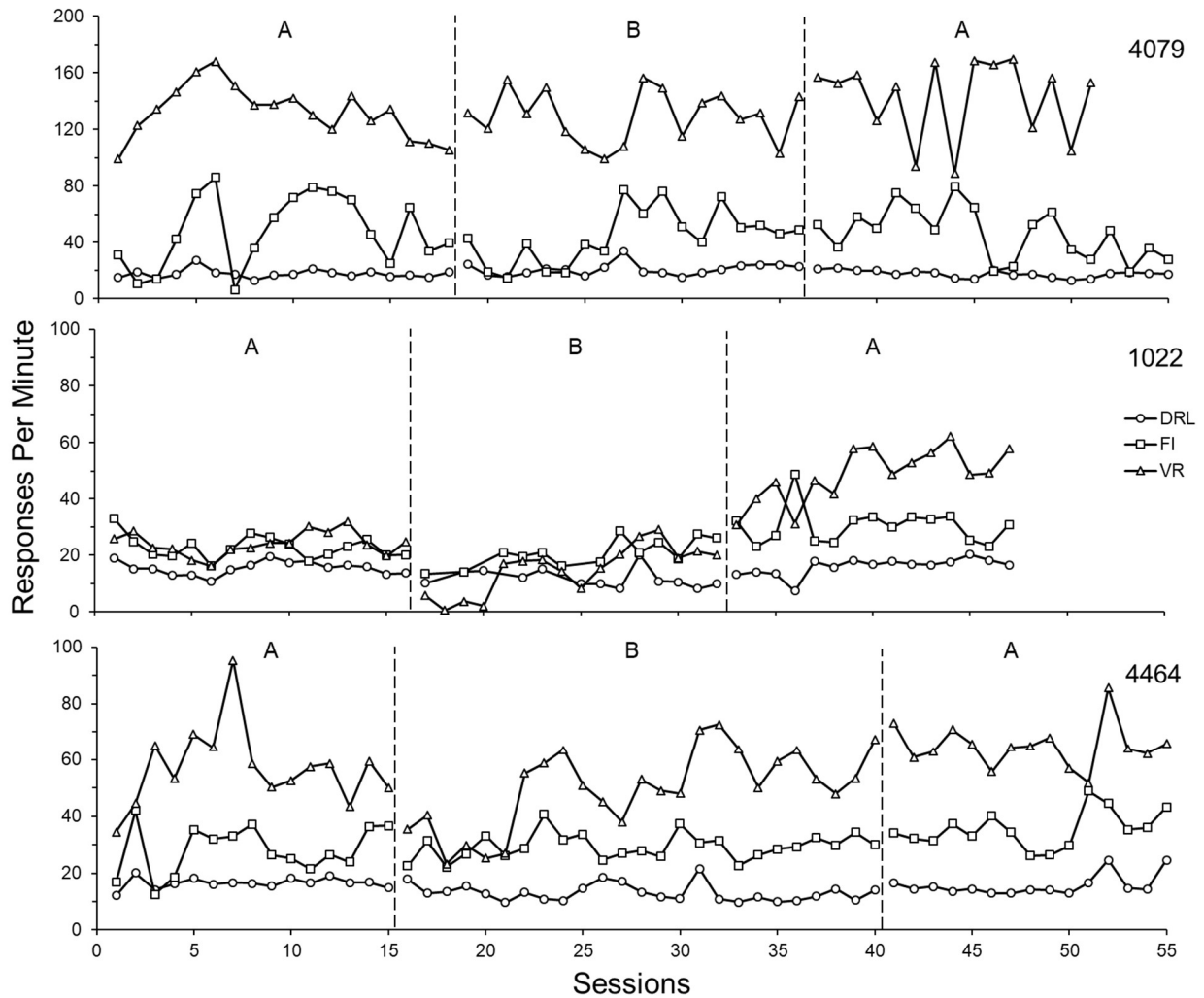
Figure 4. Responses per minute for Experiment 2. The top row corresponds Pigeon 4079, the

middle row corresponds to Pigeon 1022, and the bottom row corresponds to Pigeon 4464. Each

data path corresponds to a different component of the multiple schedule as follows: triangles for

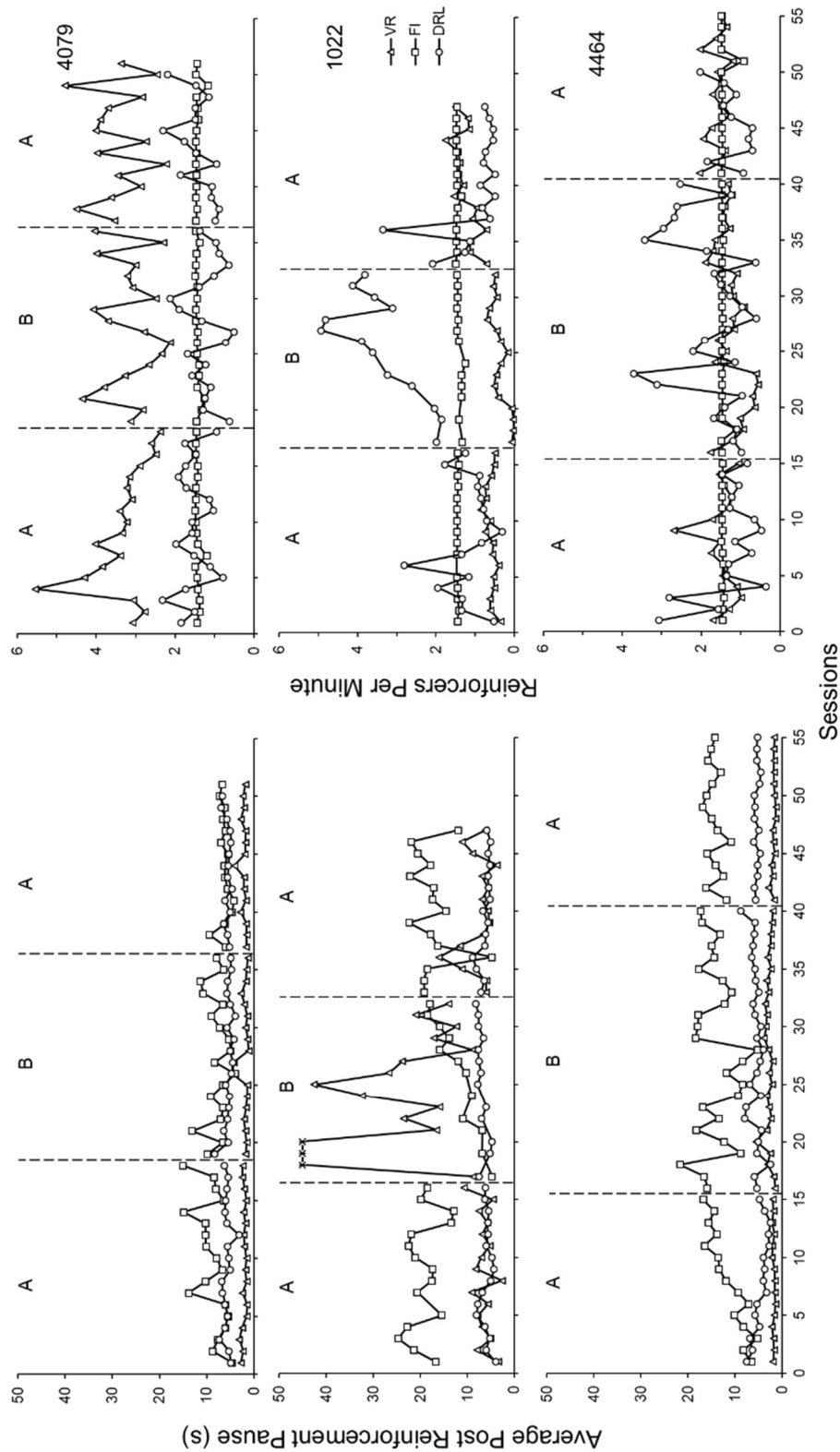VR, squares for FI, and circles for DRL. Note the change in the Y axis scaling for Pigeon 4079

Figure 5. Average PRP (left column) and reinforcers per minute (right column) for Experiment 2. The rows and data paths are arranged in the same manner as Figure 4. Note the three asterisks on Pigeon 1022's VR PRP data path. Those data points represent sessions where VR PRP was relatively long compared to those recorded during the other sessions. Instead of plotting those points with the others, the values for those data points are provided here in order from left to right: 107.74 s, 58.68 s, and 513.15 s.
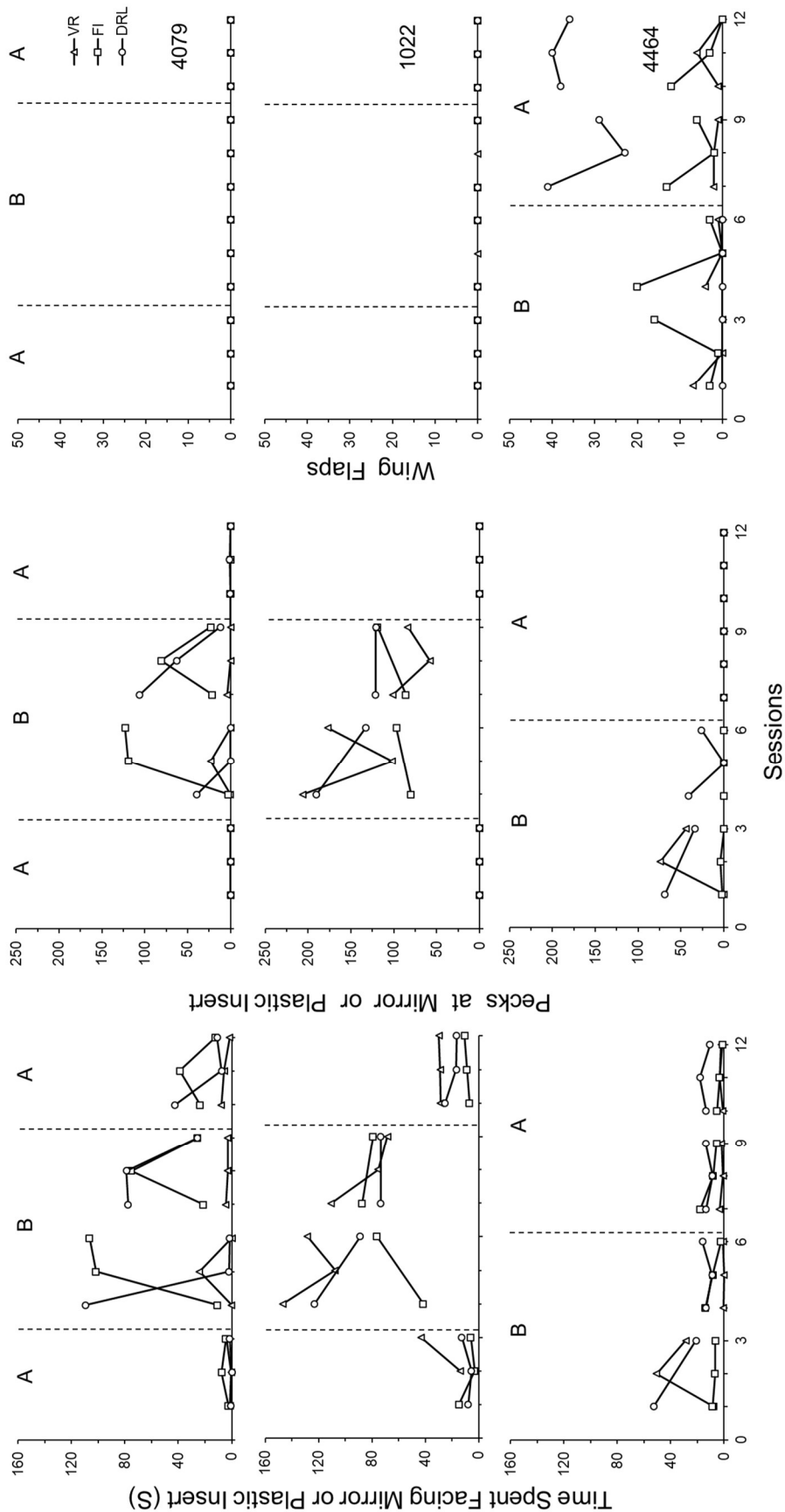
Figure 6. Observational data for Experiment 2. The rows and data paths are arranged in the same manner as Figures 4 and 5. Time spent facing the mirror, in B phases, and plastic insert, in A phases, is shown on the left column, pecks at the mirror and plastic insert are shown on the middle column, and wing flaps are shown on the right column. Data were lost for sessions one, two, and eight when the camera's battery died during those sessions. Data for the FI and DRL components on session six for Pigeon 1022 are not shown because that session was terminated according to the 60-min time criterion before that pigeon reached the other components.