THE EFFECTS OF REINFORCER MAGNITUDE IN THE PRECEDING AND UPCOMING RATIOS ON BETWEEN-RATIO PAUSING IN MULTIPLE FIXED-RATIO SCHEDULES.

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ABSTRACT

Experiment 1 examined the effects of reinforcer magnitude in the preceding and upcoming ratios on between-ratio pausing during a range of FR values in a multiple FR FR schedule of reinforcement. Two components which were associated with two different discriminative stimuli were used, where one component was associated with a small reinforcer (1-s) and the other component was associated with a large reinforcer (6-s). The longest between-ratio pauses were found when the upcoming reinforcer was small (S-S and L-S transition) than when the upcoming reinforcer was large (S-L and L-L transition). In addition, consistently longer between-ratio pauses occurred when the preceding reinforcer was large and the upcoming reinforcer was small (L-S transition). Experiment 2 examined the effects of the past reinforcer magnitude on the between-ratio pause when the discriminative stimuli to differentiate the preceding and upcoming reinforcer magnitude was removed, during a range of FR values on a multiple FR FR schedule of reinforcement. When the past reinforcer magnitude had been small and the upcoming reinforcer was small or large (S-S and S-L transition) consistently shorter between-ratio pauses occurred. In comparison, when the past reinforcer had been large and the upcoming reinforcer was small or large (L-L and L-S transition) consistently longer pause durations occurred across the two transitions. Overall and running response rates were analysed in Experiments 1 and 2 and it was found that overall and running response rates consistently decreased as the FR values were increased. Overall, these experiments showed that the preceding and upcoming reinforcer magnitudes have a direct effect on the length of the between-ratio pause where increasing the FR value was observed to consistently increase the length of the between-ratio pause, when also compared across the four transitions (Small-Small, Small-Large, Large-Large, and Large-Small).

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INTRODUCTION

A schedule of reinforcement describes the relation between an organism’s environment and the behaviour that will produce reinforcement (Cooper, Heron, & Heward, 2007). “A schedule of reinforcement is a rule that describes a contingency of reinforcement” (Cooper, Heron, & Heward, 2007, pg. 305).

Fixed Ratio Schedules

A fixed ratio (FR) schedule is an intermittent schedule of reinforcement that requires a fixed number of responses before a response produces a reinforcer (Cooper, Heron, & Heward, 2007). According to Ferster and Skinner (1957), within a FR schedule, every n^{th} response leads to the delivery of a reinforcing stimulus. For example, during an FR 10, every 10th response results in the delivery of reinforcement. During an FR schedule, the time to the delivery of reinforcement depends on how quickly the organism can complete the ratio requirement. In other words, if the subject responds rapidly, it will gain access to the reinforcer sooner rather than later (Cooper, Heron, & Heward, 2007; Ferster & Skinner, 1957). FR schedules typically produce high rates of responses, this is because the faster the organism responds, the more frequent the reinforcement (Cooper, Heron, & Heward, 2007). The size of the ratio requirement affects the rate of response during FR schedules. Smaller ratio requirements typically produce higher response rates than larger ratio requirements (Ferster & Skinner, 1957; Cooper, Heron, & Heward, 2007). Barofsky and Hurwitz (1968) provide an example where they found that the rats’ response rates were higher at an FR 40 than at an FR 10 and, for some rats, response rates were reported to increase when the FR value was increased to 80 but after this value, the rats’ response rates decreased when the FR values were increased further, e.g., to an FR 120 and an FR 160 (Barofsky & Hurwitz, 1968).

Hudson, Foster, and Temple (1999), investigated the performance of possums under FR schedules. They found that the possums overall response rates increased as the FR increased from an FR 1 upwards. Overall response rates were calculated by totalling the number of responses and dividing these by the total session time. Running response rates were also investigated where the running response rates were calculated as the total number of responses divided by the total session time minus the magazine operation and post-reinforcement pause time (Hudson et al., 1999). As the FR value increased the possums running response rates decreased (Hudson et al., 1999). Hudson et al. (1999) state that some of the decreases in running response rates, as the FR value is increased, could be a result of what is termed the within ratio pausing or ratio strain. When the response requirement was increased (FR value) within ratio pausing occurred which meant that response rates decreased (Hudson et al., 1999).

Killeen (1969) investigated the effects of reinforcement frequency and contingency as factors in fixed ratio behaviour. Pigeons were exposed to either a FR schedule or a yoked schedule. Killeen (1969) found that pigeons in the yoked schedule produced high rates of responses, high enough that the pigeons in the yoked schedule obtained all the reinforcers that the pigeons in the ratio schedule had set up. Overall, pigeons in both the ratio and yoked schedules produced an increase in their response rate, that is, as the FR value increased, initially from an FR 25 upwards, response rates also increased. The FR values used were FR 25, FR 50, FR 75 and FR 100 and as the FR values were increased, steady increases in response rates occurred. Response rates continued to increase even when the FR value was increased to an FR 100. Pigeons in the yoked schedule had slightly higher response rates throughout the range of FR values than the pigeons in the ratio schedule (Killeen, 1969).

Premack, Schaeffer, and Hundt (1964) examined the effects of FR and reinforcement time using reinforcement of drinking by running. Because of the methodology that Premack et al. (1964) used, they found a reversal effect in their results compared to the previous studies mentioned. It was found that when the rats were exposed to larger FR values, e.g., FR 200 and FR 300, the rats produced larger response bursts of licking, whereas when the rats were exposed to smaller FR values, e.g., FR 20, the rats produced fewer response bursts of licking. They argue that the effect of higher response rates during the larger FR values and lower response rates during the smaller FR values occurred because of the reinforcer that was used, which was access to a running wheel (Premack et al., 1964).

Crossman, Bonem, and Phelps (1987) compared the response patterns under FR, variable ratio (VR), and random ratio (RR) schedules. Pigeons were exposed to an FR schedule, followed by a VR schedule, and finally, followed by a RR schedule. The sequence of the schedules was rotated in a fixed order, this process was used to ensure that each schedule did not occur more than once every seventh session (Crossman et al., 1987). Crossman et al. (1987) reported that pigeons response rates increased when they were working on lower ratio values (e.g., FR 5, FR 10, and FR 40) compared to those under the larger values (e.g., FR 80) where the response rate levelled off or decreased. This pattern occurred during the fixed, variable, and random ratio schedules. In other words, there were no differences found in the response rates for the different ratio schedules, rather the significant effects occurred when the ratio values were gradually increased, showing a decreasing or levelling off response pattern (Crossman et al., 1987).

Overall, the existing studies suggest that response rates differ depending on both the FR values and the procedures used. Some studies have suggested that response rates increased when subjects were responding under lower FR values (e.g., FR 1 – 40) and then decreased when responding under higher FR values (e.g., FR 40 and upwards) (e.g., Barofsky & Hurwitz, 1968; Crossman et al., 1987; Hudson et al., 1999). Although, Killeen (1969) found different results from these as he reported that response rates continued to increase as the FR value was increased.

Post Reinforcement Pause

Skinner (1938) first described a pause in responding that occurred for rats responding on FR and FI schedules of reinforcement. When the rats pressed the lever for a certain period or number of times reinforcement would follow. After the delivery of reinforcement, Skinner

(1938) observed that the rats stopped responding for a short period of time, this behaviour typically occurred once the rat had ingested their pellet of food. Since then it has been found that during FR schedules, a brief pause in responding follows the delivery of reinforcement. This pause in responding has been termed the post-reinforcement pause (PRP). The size of the FR value is reported to have an effect on the PRP duration. Smaller FR values typically produce smaller PRPs, whereas larger FR values typically produce longer PRPs (Cooper, Heron, & Heward, 2007; Ferster & Skinner, 1957). The connotation of the PRP was used to refer to the pause after reinforcement suggesting that the pause was controlled by reinforcement (Schlinger, Derenne, & Baron, 2008). A neutral term, the between-ratio pause, or a more commonly used term the pre-ratio pause, is arguably the more functionally appropriate connotation to use, to refer to the pause after reinforcement (Griffiths & Thompson, 1973; Schlinger, Derenne, & Baron, 2008).

Research has identified some of the variables that affect the length of the pause durations under FR schedules of reinforcement (Schlinger, Derenne, & Baron, 2008). These have been identified as the size of the ratio (e.g., Felton & Lyon, 1966; Powell, 1968), the response effort (e.g., Wade-Galuska, Perone, & Wirth, 2005), the reinforcer magnitude (e.g., Perone & Courtney, 1992), the reinforcer probability (e.g., Crossman, 1968), and the deprivation level of the organism (Schlinger, Derenne, & Baron, 2008). Felton and Lyon (1966) provide an example on the effects of the size of the ratio on PRPs. Felton and Lyon (1966) investigated pigeons PRPs and response rates using FR values ranging from an FR 25 to 150. Felton and Lyon (1966) started with a continuous reinforcement schedule which was then gradually increased to an FR 50. When the pigeon’s response rates were stable, the FR value was gradually increased in successive steps to an FR 150. The results show that as the FR value increased, pauses in responding also increased. They found inconsistent results with response rates. As the FR values increased, Felton and Lyon (1966) stated that the pigeons response rates were neither consistent throughout the increase of the FR values nor were they found to be stable. Powell (1968) extended Felton and Lyon’s (1966) experiment and further investigated the effects of fixed ratio sizes and how they impact the PRPs. A distinct difference between Powell (1968) and Felton and Lyon’s (1966) experiment is that Powell (1968) used a range of increasing FR values and a decreasing range of FR values, e.g., FR 15, FR 20, FR 30, FR 40, FR 50, FR 60, FR 75, FR 90, FR 105, FR 120, FR 140, and FR 160. Once FR 160 was reached, the FR were then decreased to an FR 120, FR 90, FR 60, FR 40, FR 20, and FR 10 (Powell, 1968). The results showed that as the FR gradually increased, the pigeons pause duration consistently increased. As the FR values decreased the pause durations consistently decreased (Powell, 1968). Response rates were also investigated and for two out of three of the pigeons, as the FR values increased there was a general decrease in their response rates. The other pigeon’s response rate showed stability over the entire range of the FR values (Powell, 1968). Similarly, Topping, Johnson, and McGlynn (1973) examined the effects of delaying reinforcement and FR size on pre-ratio pausing. They used one of three FR schedules (FR 10, FR 75, or FR 150) for each pigeon. Delay to reinforcement ranged from 0-s to 180-s. Topping et al. (1973) reported that as the delay to reinforcement increased, the pigeons’ pre-ratio pause durations also consistently increased. Additionally, it was reported that as the FR value was increased, the pre-ratio pause consistently increased.

Mazur and Hyslop (1982) investigated within session post-reinforcement timeouts and compared the effects of these to those of no-timeout trials. Pigeons were exposed to either a FR 50, FR 100, or FR 150, where each experimental session consisted of half timeout trials and the other half were no-timeout trials. During the timeout trials, the response key would darken for 30-s and would then re-illuminate, whereas during the no-timeout trials, there were no pre-ratio timeouts (or darkening of the response key). Mazur and Hyslop (1982) report that, overall, shorter pre-ratio pauses were more evident during the timeout trials compared to the no-timeout trials. During all three FR values, the no-timeout trials showed the greatest pause durations. Therefore, it is evident that timeout from darkening the response key produced shorter pause durations which may suggest that the dissipation of satiation or fatigue may occur during the 30-s timeout period. The effect of the 30-sec timeout meant that shorter pause durations occurred in the ratio that was coming up (Mazur & Hyslop, 1982).

Belke (2011) took a different approach and investigated the post-reinforcement pauses with wheel running (revolutions) which varied within sessions by using a variable response requirement. Instead of using food as reinforcement, Belke (2011) provided the opportunity to run in a wheel as the reinforcer. Rats were initially exposed to an FR 30 schedule, where they had an opportunity to run for a fixed 60 revolutions as their reinforcer. After the FR 30 schedule, the rats were then exposed to a fixed variable schedule, ranging from 3-198, this provided rats the opportunity to run an average of 60 revolutions. And finally, the rats were exposed to a VR 30 where the rats were still provided the same opportunity to run 60 revolutions as their reinforcer. Belke (2011) reported that when the response requirements were changed from fixed to variable, the rats average PRPs reduced by 50%. In other words, when the response requirements were switched to a variable schedule, PRPs were reported to be shorter than when the rats were responding under the FR schedule.

Magnitude of Reinforcement

The effect of magnitude of reinforcement on FR schedules has also been widely studied. Magnitude of reinforcement can be defined as the amount (or volume) of reinforcement, for example the number of pellets provided, the concentration percentage of a reinforcing substance, or the duration that one can access reinforcement (Bonem & Crossman, 1988). Ferster and Skinner (1957) did not initially study the effects of magnitude of reinforcement but, coincidentally, they did report an incident where during one of their experiments, on an FR schedule, that the food magazine had partially blocked and they noticed an increase in the length of the subjects’ pauses in responding (or post-reinforcement pause). However, the first most systematic study of magnitude was by Powell (1969) (Schlinger, Derenne, & Baron, 2008). Powell (1969) investigated the effects of reinforcement magnitude on responding under FR schedules of reinforcement. Pigeons were exposed to a range of FR values, from an

FR 40 to an FR 70. The magnitude of reinforcement used was duration to reinforcement. The pigeons were provided with 2.5-s access and/or 4-s access to their reinforcer. Two key lights were associated with the different durations of reinforcement (white illuminated response key was associated with the 2.5-s access to reinforcement and the red illuminated response key was associated with the 4-s access to reinforcement). Powell (1969) reported an interesting inverse effect. The pause durations were consistently shorter when the pigeons were provided the 4-s access to reinforcement compared to those when the pigeons were provided access to the 2.5-s reinforcer. Powell (1969) also reported that magnitude of reinforcement and FR values had an interacting effect on the post-reinforcement pause, as it was observed that as the FR value gradually decreased, the post-reinforcement pause duration also gradually decreased (Powell, 1969).

Lowe, Davey, and Harzem (1974) obtained different results. Their pigeons were exposed to an FI 60-s, an FR 30, and a tandem FR 1 FI 60-s. The reinforcer magnitudes used were a range of concentrated condensed milk. The concentration percentages were 10%, 30%, 50%, and 70%. Overall, the results show that the length of the pause duration was a direct effect of the magnitude of reinforcement. In other words, the subject’s post-reinforcement pause durations increased as the percentage of condensed milk increased. Lowe, Davey, and Harzem (1974) suggested that this effect was due to the unconditioned inhibitory after effect of the previous reinforcer that was obtained.

Baron, Mikorski, and Schlund (1992) also examined the effects of reinforcement magnitude on pausing, but using progressive ratio schedules of reinforcement. Rats were exposed to a PR schedule which increased in a step size of five. Percentage of sweetened condensed milk was used as the reinforcer magnitude, where the percentage concentrations were 30%, 50%, or 70%. A timeout procedure was utilized where the timeout produced by a lever ranged from 0-30-s. Baron, Mikorski, and Schlund (1992) reported that pause duration and ratio size were directly related, in that as the ratio size increased the post-reinforcement pause was increased as well. On the other hand, the timeout procedure provided evidence that the timeouts reduced the duration of the post-reinforcement pauses. Similar to Powell (1969) as the magnitude of reinforcement was increased, the pause durations showed to be significantly shorter. A further finding was that overall response rates decreased as ratio size increased (Baron, Mikorski, & Schlund, 1992).

Schlinger, Blakely, and Kaczor (1990) also examined pausing but under variable-ratio schedules, they varied the reinforcer magnitude, variable ratio size, and the lowest ratio. Pigeons were exposed to a multiple two component VR VR schedule of reinforcement with 2-s access or 8-s access to reinforcement. Group 1 were exposed to VR schedules varying (ranging from a VR 20 to a VR 110) with the lowest ratio always 10. Group 2 were exposed to a VR 30, with the lowest ratio ranging from 1 to 10. They report that there was an inverse relationship between PRP and reinforcer magnitude. This is similar to previous investigations using pigeons and FR schedules (e.g., Powell, 1969). In Group 1, the different reinforcer magnitudes and increased VR size had a direct effect on the PRPs, especially in the 2-s access reinforcer component, where the larger PRPs occurred. In Group 2, reinforcer magnitude and the lowest ratio had the greatest effect on the PRPs. Overall, they report that the duration of PRPs was greatly influenced by not only the VR size and reinforcer magnitude but also by the size of the lowest ratio (Schlinger, Blakely, & Kaczor, 1990).

In summary, the previous studies suggest that increases in ratio size is consistently related to the length of the PRP. Based on what has been found is that smaller FR values produced smaller PRPs and larger FR values produced larger PRPs. In other words, as the FR increases, the pause durations also increases. Research has found that the increase in PRP when FR values are increased is because of the effect of the larger response effort that is required before reinforcement is delivered (Powell, 1968; Felton & Lyon, 1966; Topping, Johnson, & McGlynn, 1973). Magnitude of reinforcement was further studied to examine the effects of the PRP. Previous studies have suggested that the manipulation of reinforcer magnitude and FR schedules also has a direct effect on the length of the PRP. There are however, inconsistent results on whether magnitude of reinforcement (small vs. large) produced smaller or larger PRPs. For example, Lowe, Davey, & Harzem (1974) reported that longer pause durations was a direct effect of increasing the reinforcer magnitude (e.g., percentage of concentrated condensed milk). On the other hand, Powell (1969), Baron, Mikorski, and Schlund (1992) and Schlinger, Blakely, and Kaczor (1990) found that when the subjects were responding towards a small reinforcer their pause durations were reported to be longer than when they were responding towards a large reinforcer. The different methodologies used in these examples may have had contributed to these inconsistent results. It is suggested however, that the past reinforcer magnitude has a direct effect to the length of the PRP (Lowe, Davey, & Harzem, 1974).

Multiple Schedules of Reinforcement

Most studies so far have used single schedules in the studies of FR performance, but multiple schedules of reinforcement have been used, where these involve the presentation of two or more schedules with a different stimulus presented during each schedule (Ferster & Skinner, 1957; Cooper, Heron, & Heward, 2007). This provides the subjects an indication as to which schedule is currently in effect (Davis & Buskist, 2008). For example, a pigeon exposed to a mult FI 5 VR 20 may have the red light on when the FI 5 is in effect and a green light on when the VR 20 is in effect (Davis & Buskist, 2008). Within the multiple schedule the schedules (or components) may be alternated or presented randomly. Reinforcement may be delivered prior to a schedule change or during a component which may be in effect for a fixed time period (Ferster & Skinner, 1957; Cooper, Heron, & Heward, 2007). One advantage of using multiple schedules is that they provide the opportunity to observe independent performances under the successive components (Ferster & Skinner, 1957). For example, a hen could be exposed to a mult FR 10 FR 100 with a component change occurring after the delivery of each reinforcement. This would allow the examination of whether longer or shorter pauses occurred during the FR 10 or the FR 100.

Multiple schedules of reinforcement have been used with FR schedules to study whether pause duration is effected by the upcoming ratio or the preceding ratio (e.g., Crossman, 1968; Perone & Courtney, 1992; Wade-Galuska et al., 2005; Baron & Herpolsheimer, 1999; Galuska & Yadon, 2011; Harris et al., 2012). One hypothesis about the pause duration was that it is an aftereffect of the subjects having just completed the response requirement. In other words, the size of the previous ratio controls the pause duration (Baron & Herpolsheimer, 1999; Perone & Courtney, 1992). Another was that, pause duration may be controlled by the size of the upcoming ratio, because larger ratios mean that subjects have to make more responses before they can obtain their next reinforcer (Baron & Herpolsheimer, 1999; Perone & Courtney, 1992). Crossman (1968) provides an example. Crossman (1968) investigated the pause durations in multiple fixed-ratio schedules. The aim of this study was not to determine whether pause durations are the effect of the preceding or upcoming ratios but to determine whether pause durations were longer or shorter with small or large FR values. Two pigeons were exposed to a mult FR 10 FR 100 with 3-s access to food. Crossman (1968) found that pause durations under the FR 100, were significantly longer than those under the FR 10. Thus, larger FR values produced longer pauses in responding compared to smaller FR values (Crossman, 1968).

One way to investigate whether pause durations are the effect of the preceding or upcoming ratios is to use Mult FR FR schedule and to measure with a small and a large ratio presented in a quasi-random sequence (Baron & Herpolsheimer, 1999; Crossman, 1968; Perone & Courtney, 1992; Harris et al., 2012; Galuska & Yadon, 2011). The sequence is designed to allow the study of the four transitions: small to small, small to large, large to large, and large to small. Baron and Herpolsheimer (1999) provide an example. They exposed rats to an irregular sequence of FR values under a Mult FR FR schedule with the small and large components correlated with a different visual stimuli, to ensure that the preceding and upcoming ratios could have systematic effects. The response patterns in the FR, preceded and followed each transition type (small preceded by small, small preceded by large, large preceded large, and large preceded by small) were examined to find the effects of the preceding and upcoming ratios. The small and large components were presented in an irregular sequence to ensure that an equal number of transitions occurred within a session. Baron and Herpolsheimer (1999) report that when the upcoming ratio was small (e.g., small ratio to small ratio and large ratio to small ratio) pauses were quite small. On the other hand, when the upcoming ratio was large (e.g., small ratio to large ratio and large ratio to large ratio) pauses in responding were the longest. In regards to the preceding ratios, the large to small transition produced the longest pauses in responding, compared to the other three transitions (Baron & Herpolsheimer, 1999).

Ratio size is not the only variable to effect pause duration. Reinforcer magnitude has also been studied to see its effects on the post-reinforcement pause (e.g., Perone & Courtney, 1992; Baron & Herpolsheimer, 1999; Galuska & Yadon, 2011; Wade-Galuska et al., 2005; Everly et al., 2014). Magnitude has been manipulated as access to reinforcement (Harris et al., 2012; Baron & Herpolsheimer, 1999), duration (Perone & Courtney, 1992), volume or amount of reinforcement (Galuska & Yadon, 2011), and concentration of reinforcement (Belke, 2006). Perone and Courtney. (1992) provide an example. They utilized the four transitions (small to small, small to large, large to large, and large to small) to further investigate the effects of reinforcer magnitude by using either a small or a large FR value. Perone and Courtney (1992) reported that in the presence of a stimulus before the small reinforcer, pauses were large compared to those in the presence of a stimulus before a large reinforcer. On the other hand, after a large reinforcer, pauses were longer when the next reinforcer was to be small than it was to be large. Thus, Perone and Courtney (1992) found that pause durations depended on both the past and upcoming reinforcer magnitude. PRP was inversely related to the past and upcoming reinforcer magnitude (Perone & Courtney, 1992). Similarly, Galuska and Yadon (2011) examined the effects of prefeeding on fixed ratio schedules with different reinforcer magnitudes. Rats were exposed to a multiple fixed ratio schedule with identical FR values in both components. The FR values ranged from 30 to 100. The reinforcers were

1 pellet in one schedule and 3 pellets on the other schedule. An hour prior to the experimental sessions, the rats were prefed 12g of standard chow. Galuska and Yadon (2011) reported that when the rats were exposed to the large-small reinforcer transition, their median pause durations were longest, compared to the other transitions. Also, when the rats were prefed, the large-small reinforcer transition also produced the longest pause duration and a large increase in pause duration was reported in this transition compared to only a small increase in the other transitions. Williams et al. (2011) examined pausing on multiple fixed ratio schedules varying both reinforcer magnitude and the response requirement. Williams et al., (2011) used humans as their participants, and presented the task with two keys and a computer screen. Coins or points were used as the reinforcer, where the coins or points could be exchanged for money and the amount given was the reinforcer magnitude. Williams et al. (2011) reported that when the lean component (small FR) was followed by a rich component (large FR), pauses in responding were relatively longer than after the other transitions. These results are similar to those reported by Galuska and Yadon (2005) and Perone and Courtney (1992) with non-humans.

Harris et al. (2012) investigated the effects of signalled delays to reinforcement on pausing using multiple FR schedules. Hens were exposed to the multiple FR FR schedule with both the FR values the same and ranging from FR 1 to FR 40. A delay to reinforcement was added to one of the components. Hens were exposed to the four transitions across both components (delay-delay, delay-immediate, immediate-immediate, and immediate-delay) quasi-randomly. Harris et al. (2012) reported that during the component with the delay transition (delay-delay and immediate-delay), longer pauses were found, than in the component with no delay transition (delay-immediate and immediate-immediate). These results support the findings by Wade-Galuska et al. (2005); Perone and Courtney, (1992); Baron and Herpolsheimer, (1999); and Williams et al. (2011) in that, when an immediate to delay transition occurs (or large to small transition) longer pauses in responding occurred. Harris et al. (2012) also reports that when the upcoming reinforcer was delayed, longer pause durations occurred compared to when the upcoming reinforcer was immediate.

Everly et al. (2014) investigated the behavioural functions of stimuli signalling transitions across rich and lean schedules of reinforcement using mixed and multiple schedules. Everly et al. (2014) included an observing and an escape key as one of their components. A peck on the observing key deactivated and darkened the observing key where the food key was lit and provided the pigeon access to either a lean or rich stimulus. The lean or rich stimulus would remain active until the pigeon had completed the FR requirement. A peck on the escape key would remove the discriminative stimuli, i.e., instead of coloured keys differentiating the rich and lean stimulus, the illumination of a white key was used and the schedules would change from a multiple to a mixed schedule. Every et al. (2014) exposed pigeons to mixed or multiple FR schedules where they were provided 1-s access (lean component) or 6-7-s access (rich component) to reinforcement. A quasi-random sequence was used to ensure that each subject was exposed to the four transitions: lean-lean, lean-rich, rich-rich, and rich-lean. Everly et al. (2014) reported that the observing key was pecked at every opportunity during both the lean and rich stimulus. This meant that the observing key was not aversive enough to supress the pigeons' responding during the lean stimulus as predicted. During the escape procedure, when the pigeons had access to the escape key, the lean stimulus was reported to be aversive. This meant that whenever the lean stimulus was in effect, the pigeons would peck the escape key whereas the escape key was never activated when the rich stimulus was in effect. During the four transitions, PRP was longest when the rich stimulus was followed by the lean stimulus (rich to lean transition), compared to the lean to lean, lean to rich, and rich to rich transitions. The long pause durations were a function of both the increasing FR size and reinforcement. Wade-Galuska et al. (2005) reached similar conclusions. They exposed rats to a multiple FR 30 FR 30 with response force, for lever pressing, manipulated. The low force requirement was termed as favourable whereas the high force requirement was termed as unfavourable. Wade-Galuska et al. (2005) reported that when the rats were transitioning from favourable to unfavourable, pauses in responding were longest when compared to those in the other transitions. It was also reported that, in some cases, as the response force requirement increased pause durations increased.

Most researchers have found that, during the four transitions the largest pause duration were after the large to small transition. The aim of the present experiment was to replicate and extend Perone and Courtney's (1992) experiment by employing a multiple FR FR schedule of reinforcement and two different reinforcement durations. This enabled further investigation of PRP durations and the effects of the upcoming and preceding reinforcer magnitude. Using this procedure to study the assessment of behaviour in the two components (small reinforcer vs. large reinforcer) over a range of FR values with two different stimuli signalling which reinforcer magnitude was coming up. From Perone and Courtney (1992) it was reasonable to expect that in the presence of a stimulus that signals a small reinforcer, the past reinforcer will have a dramatic effect on pause durations when the past reinforcer were large. If the preceding reinforcer were large, then it was expected that larger pause durations would occur than if the preceding reinforcer was small. In comparison, if the upcoming reinforcer was large, then the preceding reinforcer would produce a smaller pause duration, whether the preceding reinforcers had were small or large. However, Perone and Courtney (1992) kept their FR constant throughout their experimental procedure, but past researchers (e.g., Baron & Herpolsheimer, 1999; Galuska & Yadon, 2011) have experimented on a range of FR values and have reported similar findings to Perone and Courtney (1992).

The present experiment examined two reinforcer duration magnitudes (small and large) and used a quasi-random sequence from the computer to produce the four transitions (small to small, small to large, large to large, and large to small). The multiple FR FR schedules enabled the investigation of the effects on PRP durations and response rates. Perone and Courtney (1992) only used FR values that were kept constant throughout their experiment. In this present experiment a range of FR vales were used to further examine the overall response rates under a range of FR values, in order to further investigate the bitonic nature that increasing FR values produce. A range of increasing FR values should produce a bitonic u-shaped function of the overall response rates. It was hypothesised that pause durations would depend on both the preceding and upcoming reinforcer magnitude. Additionally, it was also hypothesised that as the FR value gradually increases, the subjects’ response rates would show a gradual decrease, and their mean pause durations would show a gradual increase.

EXPERIMENT 1

This experiment aimed to explore changes in PRP durations and response rates when hens were exposed to a range of FR values in a two component multiple schedule of reinforcement. Magnitude of reinforcement was different between the two components: small (1-s) vs. large (6-s). The present experiment replicated and extended Perone and Courtney's (1992).

METHOD

Subjects

Six hens (*gallus gallus domesticus)* served as subjects. They were numbered 2.1 through to 2.6. Hens 2.1 and 2.2 were Brown Shavers, Hen 2.3 was a Barnevelder, Hen 2.4 and 2.5 were Buff Orpington, and Hen 2.6 was a White Orpington. Hens 2.1 and 2.2 were approximately three years old and Hens 2.3, 2.4, 2.5, and 2.6 were approximately two years old at the beginning of the experiment. The hens were housed individually in their home cages (450 mm long X 300 mm wide X 430 mm high) where they had free access to water, and grit and vitamins were provided on a weekly basis.

All hens had prior experimental experience with pecking at a computer screen to gain food reinforcers and Hens 2.3, 2.4, 2.5 and 2.6 had prior experimental experience with pecking at a response key to gain food as reinforcers. The hens were weighed every day prior to the experimental sessions (these were scheduled seven days per week) and were maintained at approximately 80% ± 5%, of their free feeding body weight, by post experimental feeding of commercial laying pellets.

The University of Waikato’s Animal Ethics Committee approved the use of animals for this experiment (Protocol number 915).

Apparatus

The experimental chamber (bottom panel of Figure 1) measured 600 mm long X 530 mm wide X 580 mm high. It was located in a room with several other experimental chambers. The inside of the experimental chamber was painted white, and the floor was covered by a black rubber mat. Within the chamber there was one circular response key, 30 mm in diameter, made from frosted transparent plastic which was positioned in the center of the chamber wall and situated 330 mm above the chamber floor, and surrounded by an aluminium plate, as illustrated in the top panel of Figure 1. The response key could be illuminated red or green, and a key peck required a force of at least 0.1 N, and resulted in an audible beep. Beneath the response key was an opening measuring 100 mm high X 70 mm wide, this provided access to wheat when the food hoper was raised. The hopper was part of an external magazine, which contained wheat. During the reinforcement period, the response key lights were extinguished and the keys were inoperable. The hopper opening was illuminated with a white light and the hopper was raised. An infrared sensor that detected the presence of a hens head was located across the opening and this was used to time access to reinforcement.

The experimental events were controlled by a Dell PC computer running the Med-PC-IV program that recorded the experimental events. After each session the summary data were manually recorded into a data book.

Figure 1: Photo of Experimental Chamber and Keys.

Procedure

Multiple Schedules. The response key could be illuminated red or green. Each colour was associated with an FR schedule and with one reinforcer magnitude (red associated with the small reinforcer and green associated with the large reinforcer). Each component terminated after a reinforcer had been obtained on that schedule. During the delivery of the reinforcer, the response key light was extinguished and the food magazine was lit and raised for a small (1 or 3-s) or a large duration (6-s). Immediately following the delivery of reinforcement, the response key was re-illuminated and the next component started.

There were four possible transitions that could occur within a session; small to small, small to large, large to large, or large to small. Each transition was programmed to occur 10 times per session. A pseudo-random sequence was used to select the next component and this ensured that a small or large reinforcer did not occur more than three consecutive times. The pseudo-random sequence was based on the Gellerman (1933) sequence and ensured that both the components (and the initial component in each session) were randomly selected and that each transition was scheduled to occur 10 times. Sessions ended with the key lights being extinguished when 40 reinforcers had been delivered or when 40 minutes had lapsed, whichever was the shortest.

A criterion was used to change a condition in which a hen had to complete 600 transitions in each multiple FR schedule. This criterion ensured that each hen had completed the same number of transitions. However, if a hen had been in an FR condition for an extended period of time (for example if a hen had been on an FR 64 for 35 or more sessions), the required number of transitions was reduced from 600 to 300.

Training. All hens had prior experience and did not require further training in the experimental chamber. The hens were placed in the experimental chamber where they responded on a multiple FR 4 FR 4 schedule of reinforcement. This meant that reinforcement became available after four responses, either when the response key was illuminated red or green. When the hen responded when the key was illuminated red, this gave them 3-s access to wheat (small reinforcer), and when the hens responded when the key was illuminated green, this gave them 6-s access to wheat (large reinforcer). The computer quasi randomly selected which sequence the small (red response key) and large (green response key) reinforcers appeared, this meant that, within a session each hen received 20 small and 20 large reinforcers within an experimental session. Each session ended when 40 reinforcers were delivered or when 40 minutes had lapsed.

The hens spent four sessions training on the multiple FR 4 FR 4 schedule of reinforcement and the FR values were then doubled to a multiple FR 8 FR 8, where the hens spent a further four days training. The multiple FR values were doubled until they increased to a multiple FR 32 in both components (for example, FR 4 FR 4, FR 8 FR 8, FR 16 FR 16, and FR 32 FR 32). During the multiple FR 32 schedule, all hens failed to respond at a stable rate during their four day training session. The hens were then placed on the multiple FR 32 FR 32 for a further three days training to stabilize their response rates. The multiple FR schedule was then reduced to a multiple FR 8 FR 8, for 7 days to help re-stabilize the hen's response rates and to ensure that the hens were still responding and receiving full 40 reinforcers.

Experimental Conditions. During Condition 1, each hen was placed on a multiple FR 1 FR 1 schedule of reinforcement where the key was lit red or green and where red associated with the small reinforcer (1-s access to wheat) and green was associated with a large reinforcer (6-s access to wheat).

During Conditions 2 (multiple FR 4 FR 4), 3 (multiple FR 8 FR 8), 4 (multiple FR 16 FR 16), and 5 (multiple FR 32 FR 32) each hen was required to complete at least 600 transitions (small to small, small to large, large to large and large to small) before they could proceed onto a new condition. During Conditions 6 (multiple FR 64 FR 64) and 7 (multiple FR 128 FR 128) the hens were required to completed 300 transitions before they could proceed onto a new condition. Table 1 provides a list of conditions and how many sessions were in effect during each condition.

Conditions 8, 9, and 10 involved replicating Condition 3 (multiple FR 8 FR 8), Condition 5 (multiple FR 32 FR 32), and Condition 4 (multiple FR 16 FR 16). As with Conditions 2-5, each hen was also required to complete 600 transitions before proceeding onto a new condition.

A condition change could occur if a hen had received zero reinforcements, for two consecutive sessions, during Conditions 6 or 7. The hen would then progress onto Condition 8 (smaller FR value), this ensured that the hen's behaviour had not extinguished.

Table 1: Number of sessions per Condition in Experiment 1.

	Condition	Hen 2.1	Hen 2.2	Hen 2.3	Hen 2.4	Hen 2.5	Hen 2.6
1	FR 1	7	7	7	7	7	7
2	FR 4	16	16	16	16	16	16
3	FR 8	15	15	15	15	15	15
4	FR 16	23	23	23	23	23	23
5	FR 32	19	19	21	28	38	36
6	FR 64	34	28	45	41	44	49
7	FR 128	3	27	120	88	12	0
8	FR 8	19	16	13	18	17	19
9	FR 32	21	22	10	24	33	24
10	FR 16	17	20	9	10	19	16

RESULTS

Not all hens completed Conditions 1 through to 7. Hen 2.1 and 2.5 did not complete Condition 7 (FR 128) and Hen 2.6 did not complete Conditions 6 or 7 (FR 64 and FR 128). This is because if a hen received zero reinforcements for two consecutive sessions then that condition would end and the hen would then progress onto a new condition with a lower FR value (e.g., Condition 8 or FR 8). This criterion was to ensure that the hen's behaviour would not extinguish. Also, during Conditions 9 and 10, Hens 2.3 and 2.4's transitions were reduced from 600 to 300 as there were no consistent difference in the replicated conditions.

Figure 2 shows the mean PRP from all the sessions completed in Conditions 1 to 7. The first column on the left shows the mean PRP from components when the hens were in a component with a small reinforcer after having received a small reinforcer (S-S). The second column from the left shows the mean PRP from the components when the hens were in a component with a large reinforcer after having received a small reinforcer (S-L). The third column from the left shows the mean PRP from components when the hens were in a component with a large reinforcer after having received a large reinforcer (L-L), and the last column shows the mean PRP from the components when the hens were in a component with a small reinforcer after having received a large reinforcer (L-S). The graphs in Figure 2 are on different scales for each hen, this is so the effects of the pause durations can be seen during the four transitions and over the range of FR values

In Figure 2 during the S-S transition the mean PRP were brief and showed a slight increase in PRP as the FR values increased for Hens 2.3, 2.4, 2.5, and 2.6. For Hen 2.5 a slightly lower PRPs occurred during the FR 128 condition, note this hen did not complete all the required transitions in this condition. Hen 2.1 had smaller PRPs during the FR 32 condition compared to the FR 16 condition. Hen 2.2 had larger PRPs during the FR 32 condition compared to the FR 64 and FR 128 conditions, but the PRPs were quite similar during these two conditions. During the S-

L transition smaller PRPs occurred across all hens' data and the PRPs were consistently smaller across Conditions 1 to 7. Only slight increases in PRP occurred as FR values increased across Conditions 1 to 7. Similarly, during the L-L transition small increases in PRP occurred across most hens' data, as FR values increased. A noticeable pattern can be seen in Figure 2, as the FR increased, PRP consistently increased across most hens' data. However, Hen 2.4 had slightly lower PRPs during conditions FR 64 and FR 128 compared to conditions FR 16 and FR 32. A consistent effect during the L-S transition was that the PRPs were longest and they increased in an ascending pattern when the FR was increased for all hens. Though, for Hen 2.1 slightly longer pauses occurred during the FR 32 condition compared to the FR 64 condition and for Hen 2.2 slightly longer pauses occurred during the FR 32 condition compared to the FR 64 condition.

Figure 3 shows a different presentation of the mean PRP data during the four transitions (S-S, S-L, L-L, and L-S). They are plotted against Conditions 1 to 7 (FR 1 to FR 128). Because of the large scales in Figure 2, it is hard to determine the effects that the FR values and reinforcer magnitude had on the mean PRP, but Figure 3 provides a clearer picture, especially during the smaller pause durations. The graphs in Figure 3 are on different scales for each hen, this is so the effects on the pause durations can be seen clearly.

The S-L transition produced, overall, smaller pauses than the other four transitions. Short pause durations occurred throughout Conditions 1 through to 7. Although, Hen 2.3 had longer pauses during Condition 6 (FR 64).

Shorter pauses also occurred during the L-L transition with Hens 2.4 and 2.6 having similar pause durations throughout Conditions 1 to 7 (FR 1 – FR 128). For Hens 2.1, 2.2, 2.3, and 2.5 similar pause durations occurred over FR1 to FR 16 and slightly longer pauses occurred in the remaining Conditions (FR 32, FR 64, and FR 128) with the larger FR values.

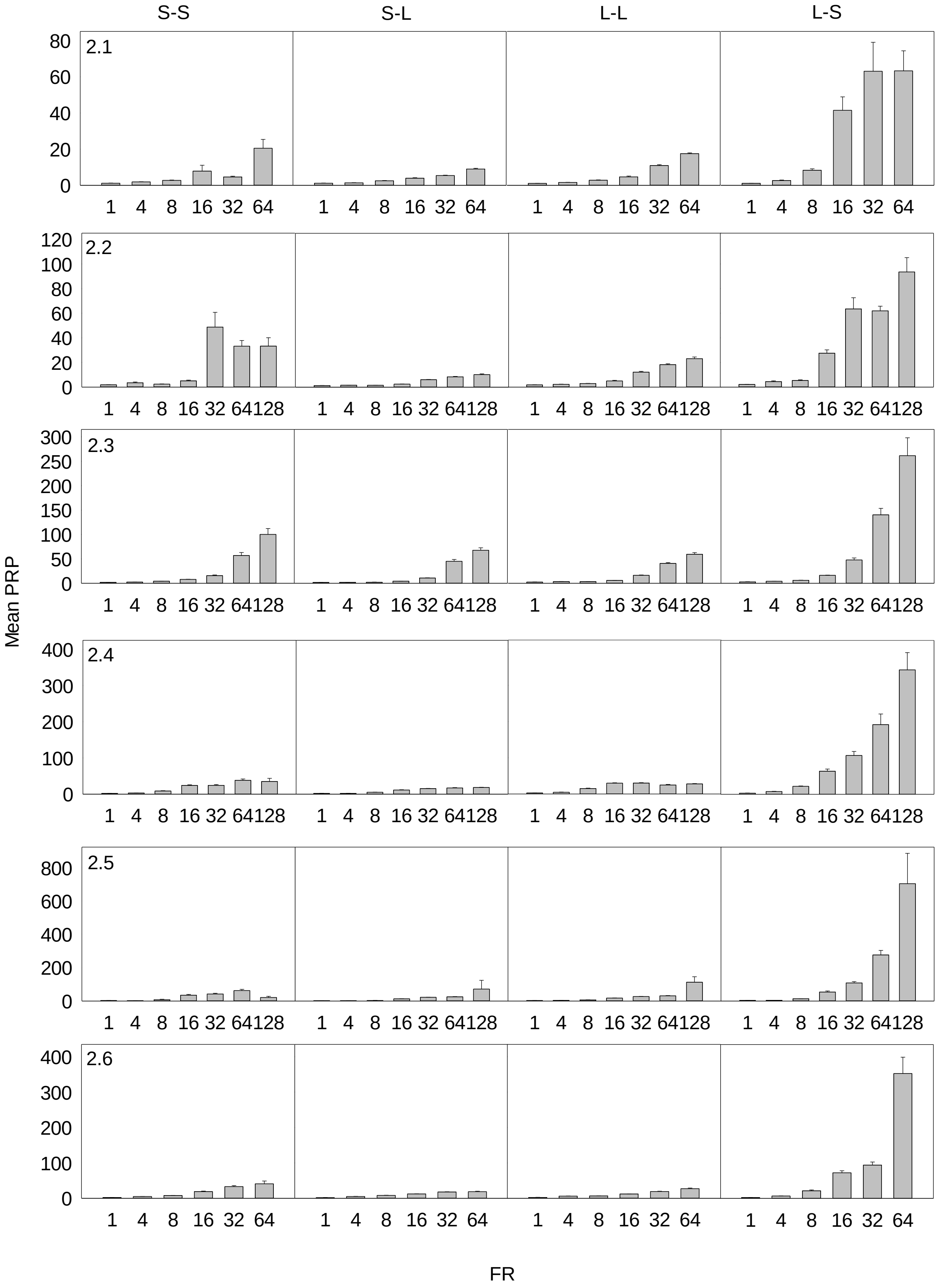

Figure 2: The mean PRP with Error Bars for all hens plotted across Conditions 1 to 7 for all transition types [Small-Small, Small-Large, Large-Large, and Large-Small] over all sessions completed.

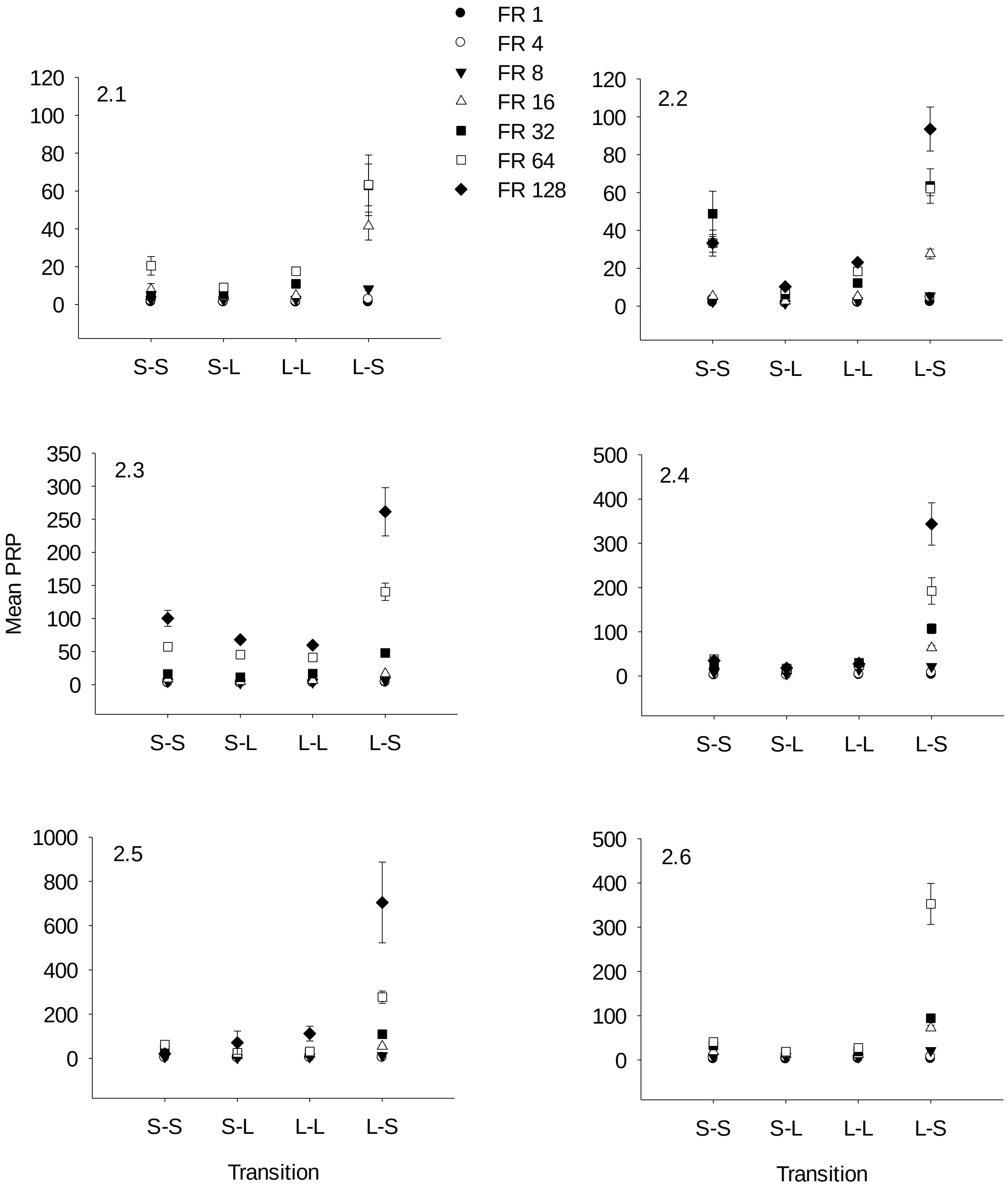

Figure 3: The mean PRP of Conditions 1 to 7 plotted for each hen across all transition types [Small-Small, Small-Large, Large-Large, Large-Small] over all sessions completed.

Similar results can be seen for the S-S transition where there were short pauses over Conditions 1 to 7 (FR 1 to FR 128) for Hens 2.4, 2.5, and 2.6. For Hens 2.1 and 2.3 similar and short pauses occurred during Conditions 1 to 5 (FR 1, FR 4, FR 8, FR 16, and FR 32) but during Condition 6 (FR 64) the pause durations were slightly longer than those at the smaller FR values. Hen 2.2 had smaller pause durations for the smaller FR values (FR 1, FR 4, FR 8, and FR 16) and longer pause durations during the larger FR values (FR 32, FR 64, and FR 128).

There was a consistent effect for the L-S transitions. Overall, longer pause durations were observed especially during the larger FR values (FR 32, FR 64, and FR 128) and slightly shorter pauses occurred during the smaller FR values (FR 1, FR 4, FR 8, and FR 16). In Figures 2 and 3, the largest effect on pause durations occurred during the Large-Small (L-S) transition and this effect was consistent for all hens.

Overall Response Rate

In Figure 4, the mean overall response rate from the last 5 sessions are plotted against FR on a logarithmic scale for Conditions 1 to 7, for each transition type. The rates were calculated as the total response time divided by total session time for each FR. Figure 4 shows that overall response rate was highest for all hens during Conditions 2 and 3 (FR 4 and FR 8). Overall response rate, on average, decreased for all hens during Conditions 4 through to 7 (FR 16, FR 32, FR 64, and FR 128). This pattern appeared to occur across Hens 2.3, 2.5, and 2.6. A peak in overall response rates occurred during Conditions 5 or 6 (FR 32 or FR 64) for Hens 2.1, 2.2, and 2.3. This peak in overall response rate occurred after FR 16 or FR 32, after which there was decrease in overall response rates. During FR 32 or FR 64, a slight increase in overall response rates occurred, as seen in Figure 4. Overall, over the smaller FR values overall response rates increased rapidly but then decreased as the FR values were gradually increased further. This effect can be seen in Figure 4, where the data are bitonic, that is, they form an inverted u-shape curve.

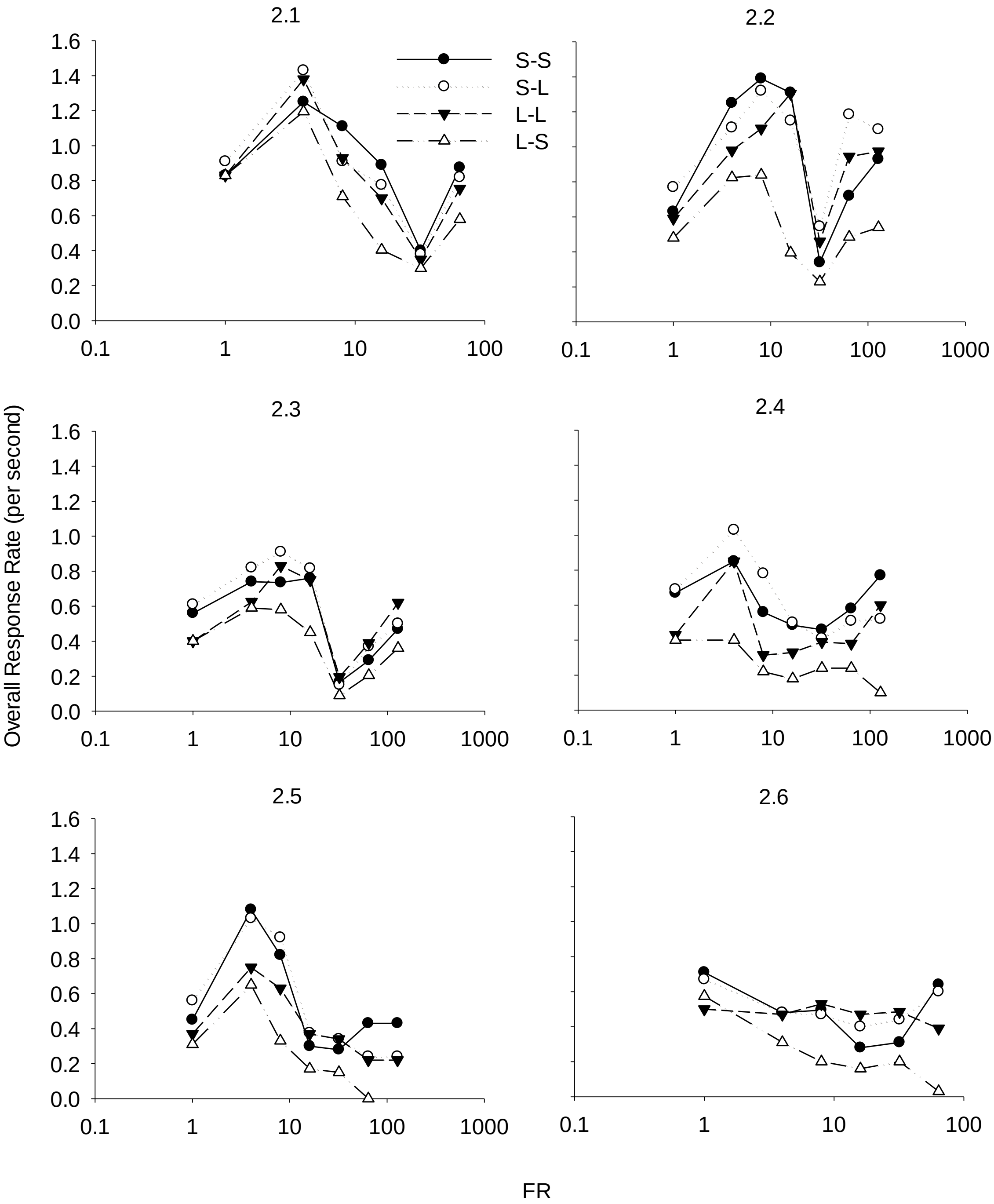

Figure 4: Overall response rates of Conditions 1-7 shown as responses per second plotted against common logarithmic FR value

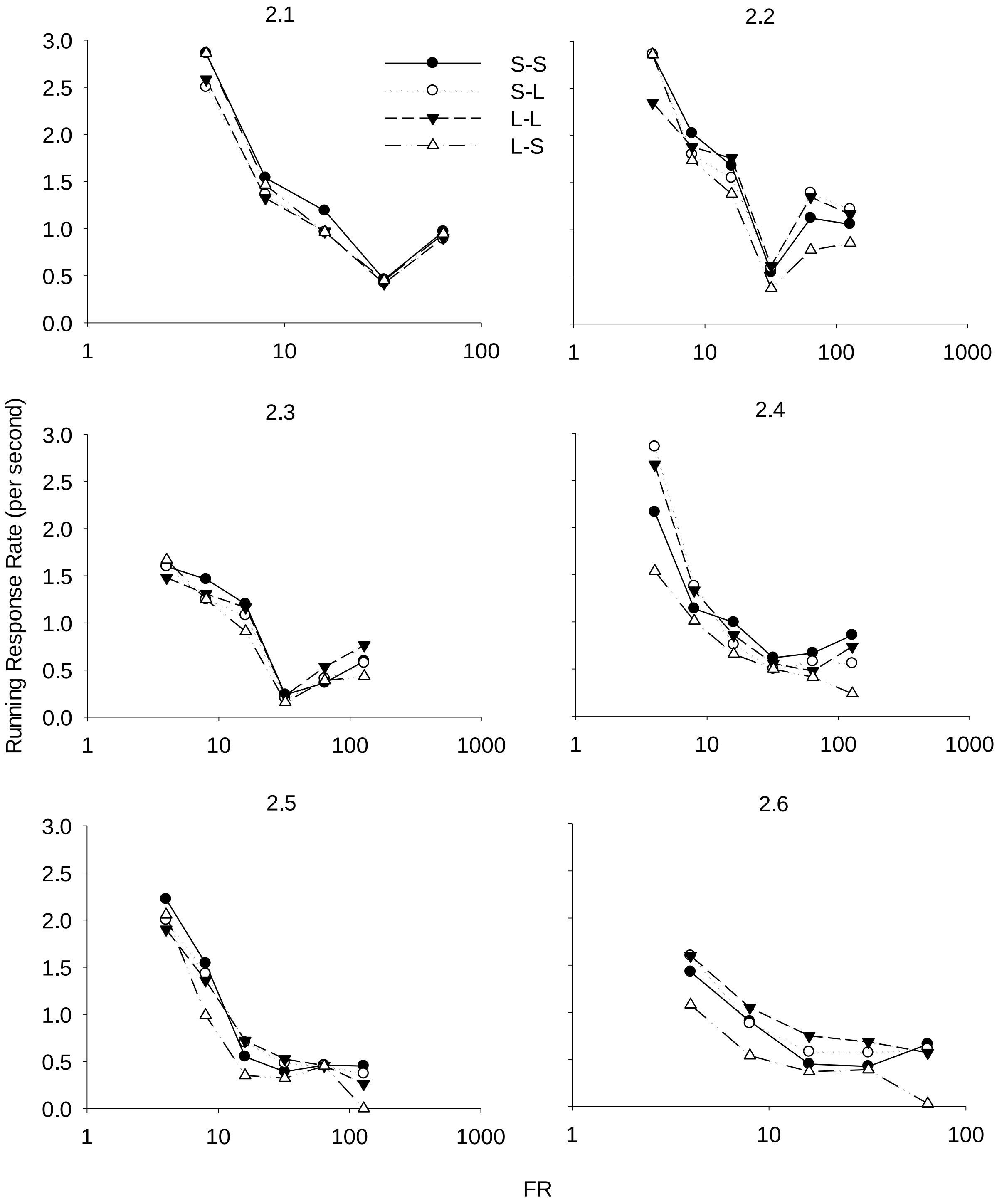

Figure 5: Running response rates of Conditions 1-7 are shown as responses per second (run time without PRP time) plotted against common logarithmic FR value.

Running Response Rate

The running response rates, shown in Figure 5, were calculated by using the key time minus PRP divided by total session time, using the last 5 session's data and are plotted against log FR of Conditions 1 to 7. The running response rates are the rate of responding from the first response to the last response of the FR value. Note that running response rates cannot be calculated for FR 1 as the run time and key time are the same for the running response rates. Overall, during Conditions 1 through to 7, as the FR schedules increased, running response rates consistently decreased for all hens. When a large reinforcer was followed by an upcoming small reinforcer (L-S transition) running response rates were noticeably slower, as shown in Figure 5, compared to the S-S, S-L, and L-L transitions. This pattern appeared to be consistent for all hens and throughout Conditions 1 to 7.

Reinforcement Rate

The reinforcement rate, as shown in Figure 6, were calculated by using the number of reinforcements delivered divided by key time, using the last 5 sessions data and they are plotted against FR of Conditions 1 to 7 on a log-log axes. A regression for each of the four transitions, for each hen line, was calculated using the least squares fit. The slopes are shown in Table 2. Figure 6 and Table 2 show that as the FR increased, the reinforcement rate decreased. The slopes of the fitted lines were steepest for Hens 2.1, 2.3, 2.4, 2.5, and 2.6 during the S-S and L-S transitions. In comparison, the slopes of the fitted lines were least steep during the S-L and L-L transitions for Hens 2.1, 2.4, 2.5, and 2.6. However, for Hen 2.2 the slopes of the fitted lines were steepest during the L-S transition compared to the S-S, S-L, and L-L transitions, where the slopes of the fitted lines were least steep. The slopes of the fitted lines for Hen 2.3 were steepest during the L-L transition compared to the S-L transition.

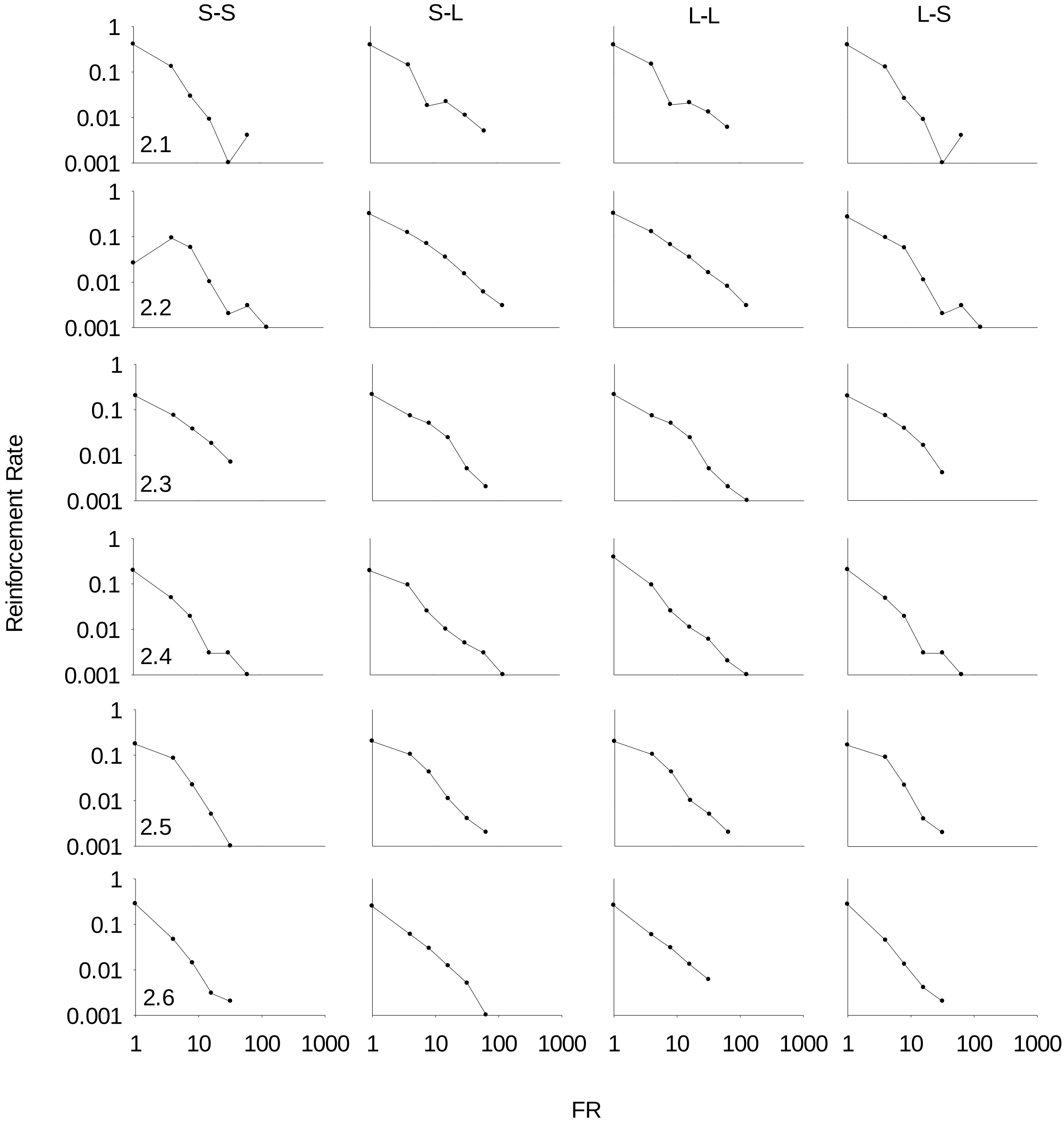

Figure 6: Common logarithms of reinforcement rate plotted against the common logarithm of the FR size for Conditions 1-7 for each hen during the four transitions [Small-Small, Small-Large, Large-Large, and Large-Small].

Table 2: The slopes of rate of reinforcement for each hen during the four transitions [S-S, S-L, L-L, and L-S].

	Hen					
Transition	2.1	2.2	2.3	2.4	2.5	2.6
S-S	-1.3879	-0.8673	-0.8625	-1.3098	-1.5076	-1.5079
S-L	0.6665	-0.9874	-0.7650	-1.1172	-1.1982	-1.2752
L-L	-1.0170	-0.9633	-0.7650	-1.2531	-1.1750	-1.0847
L-S	-1.3803	-1.2396	-0.8845	-1.3174	-1.3792	-1.4673

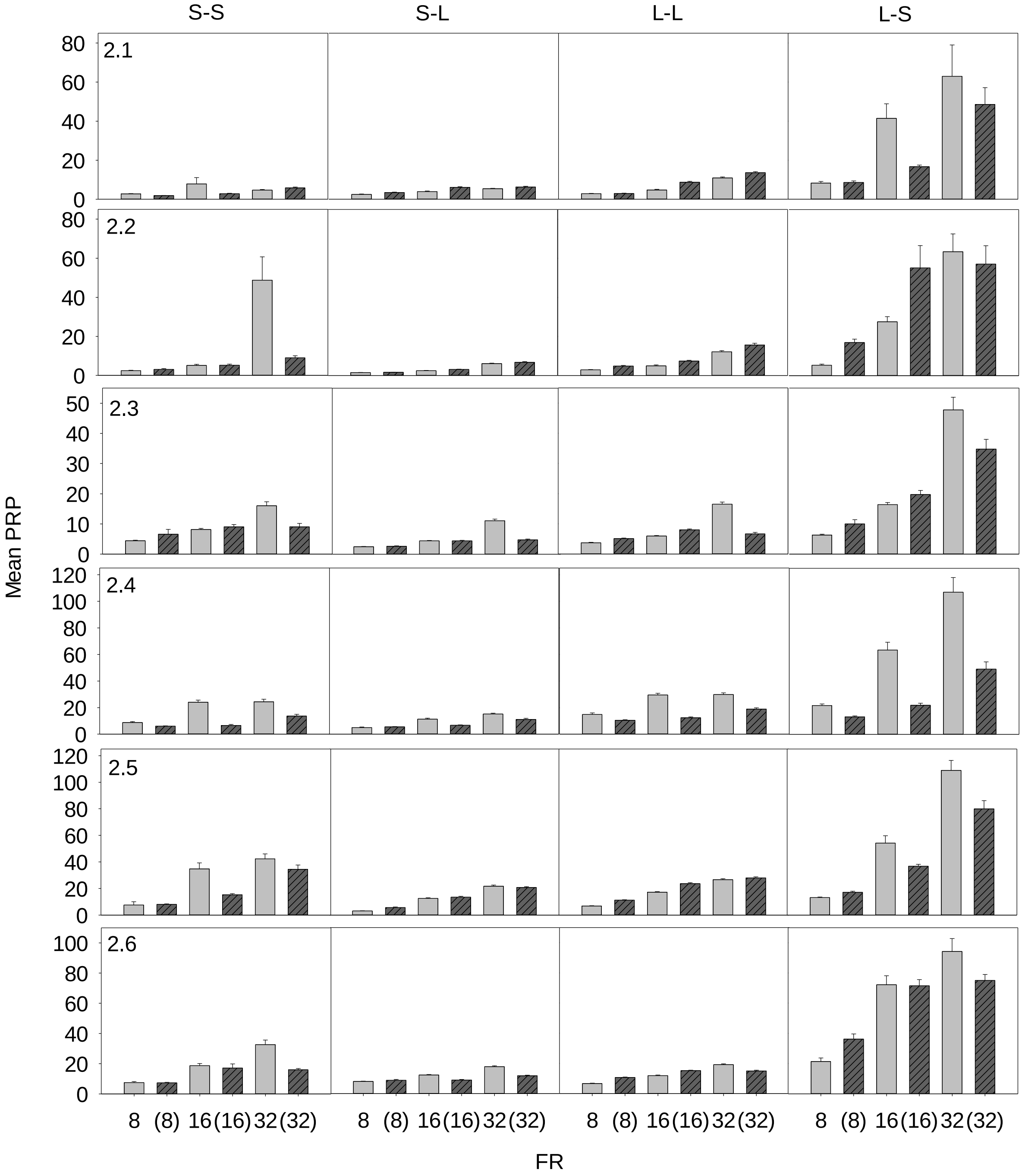

Figure 7: Replication of the mean PRP with error bars for all hens across Conditions 8-10 for all transitions types [Small-Small, Small-Large, Large-Large, and Large-Small] over all sessions completed.

Replication

Figure 7 shows the replication mean PRP for the total sessions completed in Conditions 8 to 10. The first column on the left shows the S-S transition, the second column on the left shows the S-L transition, the third column from the left shows the L-L transition, and the fourth column from the left shows the L-S transition. The scales for the graph in Figure 7 are different for some hens, this is so the effect of the pause durations can be seen during the four transitions and replicated FR conditions.

In Figure 7, the first bars for the FR 8, FR 16, and FR 32 are the data from the previous conditions that were completed earlier in the experiment (Conditions 3, 4, and 5). The second (patterned) bars are the data from conditions that were replicated (Conditions 8, 9, and 10). Figure 7 shows that the mean PRP of Conditions 8 to 10 were not consistently different from those of Conditions 3 to 5. During the S-S transition, for Hens 2.1, 2.2, 2.4, 2.5, and 2.6 the replicated FR conditions had smaller pause durations when compared Conditions 3 to 5. For Hen 2.3 their pause durations were slightly longer for those from the replicated conditions when compared to Conditions 3 to 5. During the S-L transition, Hens 2.2, 2.3, 2.4, 2.5, and 2.6 also had slightly smaller pause durations during Conditions 8 to 10 when compared to Conditions 3 to 5. For Hen 2.1 pauses were slightly longer for Conditions 8 to 10 when compared to Conditions 3 to 5. During the L-L transitions Hen 2.4 was the only hen to have smaller PRPs or slightly similar PRPs in Conditions 8 to 10 when compared to Conditions 3 to 5. An exception was Hen 2.6 who had smaller PRPs in the replicated FR 32 condition compared to the non-replicated FR 32 condition. During the L-S transitions Hens 2.1, 2.4, and 2.5’s pause durations were slightly smaller in the replicated conditions when compared to the non-replicated conditions. Hen 2.2 had slightly longer pause durations in the replicated FR 8 and FR 16 conditions and, smaller pause durations in the replicated FR 32 condition. Hen 2.3 had longer pause durations in Conditions 8 to 10 when compared to Conditions 3 to 5. Hen 2.6 had longer pause durations in the replicated FR 8 condition and slightly smaller pause durations in the replicated FR 16 and FR 32 conditions when compared to the non-replicated FR 16 and FR 32 condition.

DISCUSSION

The aim of the present experiment was to investigate the effects of the preceding and upcoming reinforcer magnitudes on PRP during a range of FR values on a multiple FR FR schedule of reinforcement. It was found that the preceding and upcoming reinforcer magnitudes had a direct effect on the between-ratio pause. It was further found that when a large reinforcer was followed by an upcoming small reinforcer, consistently larger pause durations occurred throughout the range of FR values, and the pauses consistently increased as the FR schedule was increased. In addition, during the S-S, S-L, and L-L transitions, consistent but small increases in pause durations occurred as the FR schedule was increased. Furthermore, when a stimulus signalled an upcoming small reinforcer, and where the past reinforcer was large (e.g., L-S transition), consistently larger pause durations occurred than when the past reinforcer was small (e.g., S-S transition). In comparison, when a stimulus signalled an upcoming large reinforcer (e.g., S-L and L-L transition), the past reinforcer magnitude produced consistently smaller pause durations even if the past reinforcer magnitude was small or large.

These results are similar to previous research that has investigated past and upcoming reinforcer magnitudes on multiple FR FR schedules of reinforcement (Perone & Courtney, 1992; Galuska & Yadon, 2011; Williams et al., 2011) and supports the suggestion that the past and upcoming reinforcer magnitude both have an effect on the between-ratio pause. The present findings showed that when the upcoming reinforcer was large, and the preceding reinforcer was small or large (S-L and L-L transition), small increases in pause durations occurred as the FR values were increased. In comparison, when the upcoming reinforcer was small, and the preceding reinforcer had been large (L-S transition), consistently longer pause durations occurred and consistently increased as the FR increased. In comparison to when the preceding reinforcer had been small (S-S transition), small pause durations occurred, but these were slightly longer than the PRPs in the S-L and L-L transitions. Thus, Harris et al.

(2012) found that the preceding component had only a weak effect on the pause duration and the pause durations were more influenced by the discriminative stimuli that signalled the upcoming reinforcer. The present findings found that the length of the pause durations were affected by both the preceding and upcoming reinforcer magnitudes. However, If the discriminative stimuli that signalled the upcoming component were removed then it would have to be assumed that only the preceding component would have an effect on the pause duration.

In the present experiment, the magnitude of reinforcement was held constant for the small and large reinforcers but the FR schedules were increased by doubling the FR value, in successive steps. Pause durations, as seen in Figure 2, increased as the FR was increased. The increase in the PRP was consistent across the four transitions and across all hens. The present findings support previous findings that when the FR values are increased, pause durations also increase. As previously mentioned, the increase of pause durations as the FR values is increased has been suggested to be because of the larger response effort required before the delivery of the next reinforcer (Powell, 1968; Felton & Lyon, 1966; Topping, Johnson, & McGlynn, 1973).

Hursh (1984) pointed out that when the “price” of a reinforcer increases, consumption decreases. One measure of consumption rate is reinforcer rate. Hursh (1984), using FR which is analogous to price, described the relation between price and consumption as a demand function. Two different demand patterns can occur, inelastic and elastic. During an inelastic demand, small decreases in consumption rate occur when there are increases in price. In comparison, during an elastic demand, large decreases in consumption rate occur when there are increases in price (Hursh, 1984). Demand curves that are steeper than -1.0 are inelastic and demand curves less steep than -1.0 are elastic, in comparison, slopes with -1 are termed unit of elasticity (Hursh, 1980). In the present experiment increases in FR values could be taken as increases in “price” and plots of the increase in FR, against the reinforcement rate, in a component, give the demand in that component. Figure 6 shows these demand curves for each of the four transitions during the range of FR values. The graphs in Figure 6 are roughly linear and could be described reasonably well by using straight lines. The slopes of the lines, which are of best fit, show that most of the functions are inelastic (slope steeper than -1) regardless of the transition type. The main pattern of Figure 6 shows that components with an upcoming small reinforcer show greater inelasticity (steeper slopes) despite the size of the previous reinforcer magnitude, compared to those with an upcoming large reinforcer. This means that the demand for a large reinforcer was greater than the demand for a small reinforcer. There was also some tendency for demand in components with large reinforcers to be more inelastic if the upcoming reinforcer magnitude had been large than if they had been small. Likewise, the demand of small reinforcers that were followed by an upcoming small reinforcer tended to be more elastic than if the upcoming reinforcer magnitude had been large. The present data suggests that the degree of elasticity seen, using FR schedules, is influenced by events in the preceding schedule, more so than in the upcoming schedule.

Overall response rates in this present experiment were affected by both the past and upcoming reinforcer magnitude. Overall response rates decreased when the past reinforcer had been large compared to when it had been small (Figure 4). Furthermore, when the past reinforcer had been small and the upcoming reinforcer was small or large (S-S and S-L transition) consistently higher overall response rates occurred for Hens 2.2, 2.3, 2.4 and 2.5. This effect was also consistent when the past reinforcer had been large and the upcoming reinforcer was going to be small or large (L-L and L-S transition) where lower overall response rates occurred. However, Hens 2.1 and 2.6’s overall response rates were affected when the upcoming reinforcer was large and the preceding reinforcer was small or large (S-L and L-L transitions), where higher overall response rates occurred compared to when the upcoming reinforcer was small and the preceding reinforcer was small or large (L-S and S-S transitions), where lower overall response rates occurred. Overall response rates increased at lower FR values and decreased at higher FR values, which produced a bitonic inverted u-shaped curve. A range of FR values were used, ranging from FR 1 to FR 128, which showed that overall response rates were highest during the FR 8 and FR 16 values and decreased at values FR 32 and upwards. This gave rise to the bitonic inverted u-shaped curve seen when the overall response rates were plotted. However, if such a wide range of FR values had not been investigated then this bitonic inverted u-shaped curve may not have been evident. The pattern that the overall response rates present also depend on the range of FR values that are used. If a smaller range of FR values had been used (e.g., FR 50 – FR 100), then only a decreasing function would have been seen. That is, if a small range of FR values had been used, then the graphs would have shown a consistent decreasing trend as the FR values were increased. Overall response rates appeared to be lowest when the past reinforcer were large and the upcoming reinforcer were small (L-S transition). It is noticeable that overall response rates were lowest during the L-S transition, when compared across all hens and across the range of FR schedules. The overall response rates have not been reported in most multiple FR FR studies (Perone & Courtney, 1992; Baron & Herpolsheimer, 1999; Harris et al., 2012; Galuska & Yadon, 2011; Wade-Galuska et al., 2005; Williams et al., 2011). However, previous studies on single fixed-ratio schedules have reported that a bitonic u-shaped function occurs when responding on a range of increasing FR schedules (Barofsky & Hurwitz, 1968; Hudson, et al., 1999), which supports the present findings.

Running response rates were examined and it was found that running response rates were affected by increases in the FR schedule. As the FR schedule was increased, running response rates were found to decrease. Harris et al. (2012) reported similar findings. Running response rates were also affected by reinforcer magnitude. When the upcoming reinforcer was large, higher response rates were produced for Hens 2.2, 2.4, and 2.6. With results similar to those of the present experiment, Perone and Courtney (1992) used a multiple FR 10 FR 100 schedule, that was kept constant throughout their experiment, and found that the running response rates were highest when the upcoming reinforcer was large than when it was going to be small. However, Perone and Courtney (1992) found consistent results with only one of their subjects. Harris et al. (2012)

used a range of FR values, from an FR 1 to FR 40, and they also found that during their Immediate components, running response rates were highest in comparison to those in the Delayed components, where they reported that running response rates were slowest. Galuska and Yadon (2011) used a range of FR values, ranging from an FR 30 to an FR 100, and found similar results to the present experiment, and to Perone and Courtney (1992). The running response rates were controlled by the upcoming reinforcer magnitude, where they reported that running response rates were largest when the upcoming reinforcer was going to be large. In the present study, inconsistent running response rates during the component in which the upcoming reinforcer was going to be small were higher for Hens 2.1, 2.3, and 2.5 than when the upcoming reinforcer was going to be large. No previous studies have reported such a finding. However, overall and running response rates were the lowest when the past reinforcer was large and the upcoming reinforcer was small (L-S transition). This effect is consistent across all hens and across all FR conditions (Conditions 1 to 7). This effect has also not been reported in previous studies (Perone & Courtney, 1992; Baron & Herpolsheimer, 1999; Harris et al., 2012; Galuska & Yadon, 2011; Wade-Galuska et al., 2005; Williams et al., 2011). However, previous results do support the findings that the L-S transition produced the largest pause durations. Future studies are required to determine whether overall and running response rates were lowest during the L-S transition and whether this is consistent across all subjects and across a range of FR schedules.

In the present experiment, replications were conducted for the FR 8, FR 16, and FR 32 conditions. When the data from the replications of the FR 8, FR 16, and FR 32 conditions were compared to the non-replicated FR 8, FR 16, and FR 32 conditions no consistent effects in the mean pause durations were found. However, the results, in the replicated FR conditions, did consistently replicate, in that the S-L and L-L transitions had the lowest pause durations, in comparison to the S-S and L-S transitions where they had the longest pause durations.

The means were used to analyse the PRP, overall and running response rates in the present experiment. However, Perone and Courtney

(1992), Baron and Herpolsheimer (1999), Wade-Galuska et al. (2005), Galuska and Yadon (2011), and Harris et al. (2012) described their data by using medians, interquartile ranges, cumulative frequency distributions, and cumulative records. Baron and Herpolsheimer (1999) stated that averaging data could affect the way the data are presented and that conclusions that are based on parts of an experiment (e.g., first five or last five sessions of an experiment) have been found to distort the extreme values which can affect the statistical properties of the data (Baron & Herpolsheimer, 1999). However, despite the present experiment using means across all sessions to analyse and report the present findings, similar results were concluded and similar patterns in PRP and running response rates were evident when compared across previous findings (Perone & Courtney, 1992; Baron & Herpolsheimer, 1999; Wade-Galuska et al., 2005; Galuska & Yadon, 2011; Harris et al., 2012). The analysis of pause durations, using means, yielded similar results to those who had used medians (Perone & Courtney, 1992; Baron & Herpolsheimer, 1999; Wade-Galuska et al., 2005; Galuska & Yadon, 2011; Harris et al., 2012), where it was consistently found that increases in FR values increased the length of the pause duration. In addition, similarities were also found during the L-S transitions which had consistently longer pause durations. This finding was also consistent when compared to the previous studies that had used medians to analyse their data. Thus, even though the present experiment used a different approach to analyse the data, the present findings that were concluded were consistent to previous researchers who had used medians, interquartile ranges, cumulative records, and cumulative frequency distributions to analyse their data (Perone & Courtney, 1992; Baron & Herpolsheimer, 1999; Wade-Galuska et al., 2005; Galuska & Yadon, 2011; Harris et al., 2012). Moreover, trends in PRP, overall and running response rates were still evident when means were used to analyse the present findings.

In summary, the present experiment found that the preceding and upcoming reinforcer magnitude had an effect on the pause durations. The post-reinforcement pause or the more appropriate connotation, the between-ratio pause was found to increase as the FR schedules were increased, where consistently larger pause durations occurred when the preceding reinforcer had been large and where the upcoming reinforcer was going to be small (L-S transition). A replication was conducted on FR 8, FR 16, and FR 32 and a consistent difference of smaller or larger between-ratio pauses occurred during the replication condition when compared to the earlier conditions of FR 8, FR 16, and FR 32.

To further investigate the effects of the preceding and upcoming reinforcer magnitudes on between-ratio pauses it is suggested that when the discriminative stimuli, that signals the preceding and upcoming reinforcer magnitude, is removed then only the past reinforcer magnitude should have an effect on the length of the pause duration. During the four transitions, it is suggested that the S-S and S-L transitions should have similar between-ratio pauses as with the L-L and L-S transitions. In the next experiment, the discriminative stimuli for the small and large reinforcer magnitudes were removed and replaced with a different discriminative stimuli that signalled both the past and upcoming reinforcer magnitudes.

EXPERIMENT 2

Experiment 1 replicated and extended Perone and Courtney's (1992) experiment where they examined the effects of pausing as the function of the past and upcoming magnitudes of reinforcement. Two discriminative stimuli were correlated with the two differing reinforcer magnitudes, and pausing was influenced by the past and upcoming reinforcer magnitudes. Pauses in general were shorter when subjects were provided access to the larger reinforcer magnitude than the smaller reinforcer magnitude but, pauses continued to be longer after the larger reinforcer magnitude than after the smaller reinforcer magnitude (Perone & Courtney, 1992).

Experiment 1 used a range of FR schedules (1-128) in a multiple FR FR schedule with two reinforcer magnitudes: small (1-s access to reinforcer) and large (6-s access to reinforcer). It was found that when a large reinforcer was followed by a small reinforcer (L-S) consistently larger pause durations were evident across all hens, compared to the other three transitions. It was also found that increased pause durations were a direct effect of increasing the FR schedule. Furthermore it was found that overall response rates were highest during the FR 16 or FR 32 conditions and decreased rapidly at FR conditions higher than an FR 32. Also, running response rates consistently decreased as FR schedules were increased across all hens.

The present findings are comparable to the findings that Perone and Courtney (1992) reported, that the L-S transition had consistently larger pause durations than the other three transitions. Comparable results were also found where the past and upcoming reinforcer magnitudes had a direct effect to the subjects PRP, where during the S-L and L-L transitions, smaller pause durations occurred compared to the S-S and L-S transitions where longer pause durations were found.

Furthermore, Perone and Courtney (1992) stated that if the discriminative stimuli, that signalled the preceding and upcoming reinforcer magnitude, were absent then only the past reinforcer magnitude should have an apparent influence on the subjects pause durations.

The aim of this present experiment was to further investigate the effects of the past reinforcer magnitude on the subjects' pause durations when the discriminative stimuli to differentiate the upcoming reinforcer magnitude was removed. In this experiment the Baseline Condition was the same procedure as in Experiment 1, but in Conditions 1-3 the original procedure was altered slightly. In Experiment 1, the two components were illuminated red or green to distinguish which reinforcer magnitude was coming up. In this present experiment, hens were exposed to multiple FR 32 FR 32, FR 4 FR 4, and FR 16 FR 16 schedule of reinforcement. The illumination of the green or red components were removed and replaced with the response key being illuminated both red and green together for both components. This procedure aimed to examine the changes in the hens' response patterns (i.e., pause durations, response rates) during the four transitions: S-S, S-L, L-L, and L-S. It was hypothesised that when the discriminative stimuli were removed then only the preceding reinforcer should have an effect on the subjects' PRPs, so similar PRPs should occur during the Small-Small and Small-Large transitions as with the Large-Large and Large-Small transitions.

METHOD

Subjects

The same subjects were used as in Experiment 1.

Apparatus

The apparatus was identical to the apparatus used in Experiment 1.

Procedure

In the Baseline Condition the hens were exposed to a mult FR 32 FR 32 schedule of reinforcement as in Experiment 1. Once the hens had successfully completed 600 transitions, the condition was changed. The difference to Experiment 1, was that the response key was illuminated red and green at the same time in both components (small and large), see Figure 8 for an example. Each hen was required to complete 600 transitions of the small to small, small to large, large to large, or large to small transitions.

In Condition 1 each hen was placed on a mult FR 32 FR 32 where they were required to complete 600 transitions before proceeding onto Condition 2 (same criterion as in Experiment 1).

During Condition 2 the hens were placed on a mult FR 4 FR 4 and during Condition 3 the hens were placed on a mult FR 16 FR 16. The criterion to transition onto a new Condition was the same as the one outlined in Experiment 1. Table 3 provides a list of conditions and how many sessions each condition was in effect.

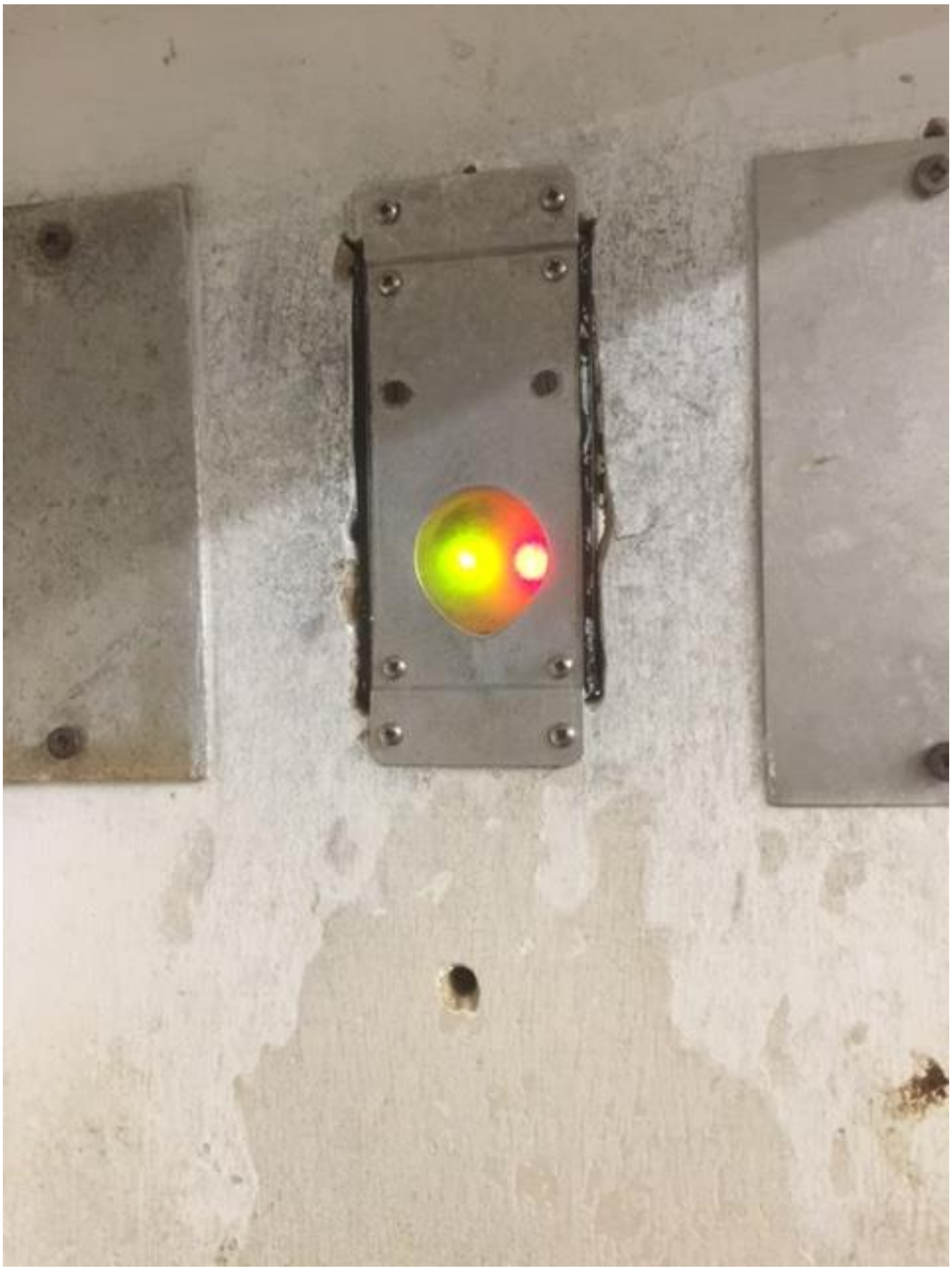

Figure 8: Photo of Response Key

Table 3: Number of Sessions per Condition in Experiment 2.

Condition		Hen 2.1	Hen 2.2	Hen 2.3	Hen 2.4	Hen 2.5	Hen 2.6
Baseline	FR 32	38	22			42	33
1	FR 32	24	24				22
2	FR 4	16	17				
3	FR 16	20	19				

RESULTS

Not all hens completed all the conditions. The data presented are from Hens 2.1, 2.2, 2.5, and 2.6. Hens 2.1 and 2.2 completed the Baseline Condition and Conditions 1, 2, and 3, Hen 2.5 completed the Baseline Condition, and Hen 2.6 completed the Baseline Condition and Condition 1.

Figure 9 shows the mean PRP from all the sessions completed in the Baseline Condition and Condition 1 (FR 32). When the Baseline and FR 32 Conditions are compared the S-S transition had similar PRPs in the Baseline and FR 32 Condition for Hens 2.1, 2.2, 2.5, and 2.6. When the PRPs of the Baseline and the FR 32 Conditions were compared during the S-L transition, Hen 2.1 had slightly longer PRPs in the Baseline Condition, whereas Hen 2.2 and 2.6 had slightly shorter PRPs in the Baseline Condition when compared to the FR 32 Condition. Hen 2.5 had similar PRPs in the Baseline Condition when compared to the FR 32 Condition. During the L-L and L-S transition, similar PRPs can be seen in the FR 32 Condition for Hens 2.1, 2.2, 2.5, and 2.6. When a comparison is made against the Baseline and FR 32 Conditions Hens 2.1, 2.2, 2.5, and 2.6 had slightly shorter PRPs in the Baseline Condition when compared to the FR 32 Condition. In comparison, consistently longer PRPs occurred for Hens 2.1, 2.2, 2.5, and 2.6 during the L-S transition in the Baseline Condition, where consistently shorter PRPs occurred across Hens 2.1, 2.2, 2.5, and 2.6 in the FR 32 Condition. Thus, having no discriminative stimuli resulted in both increases and decreases in PRP, but generally decreased the differences across transition types as expected.

Figure 10 shows the mean PRP from all the sessions completed in Conditions 1 to 3 and also show data from Conditions 2, 4, and 5 of Experiment 1. The left four columns represent the mean PRP of the four

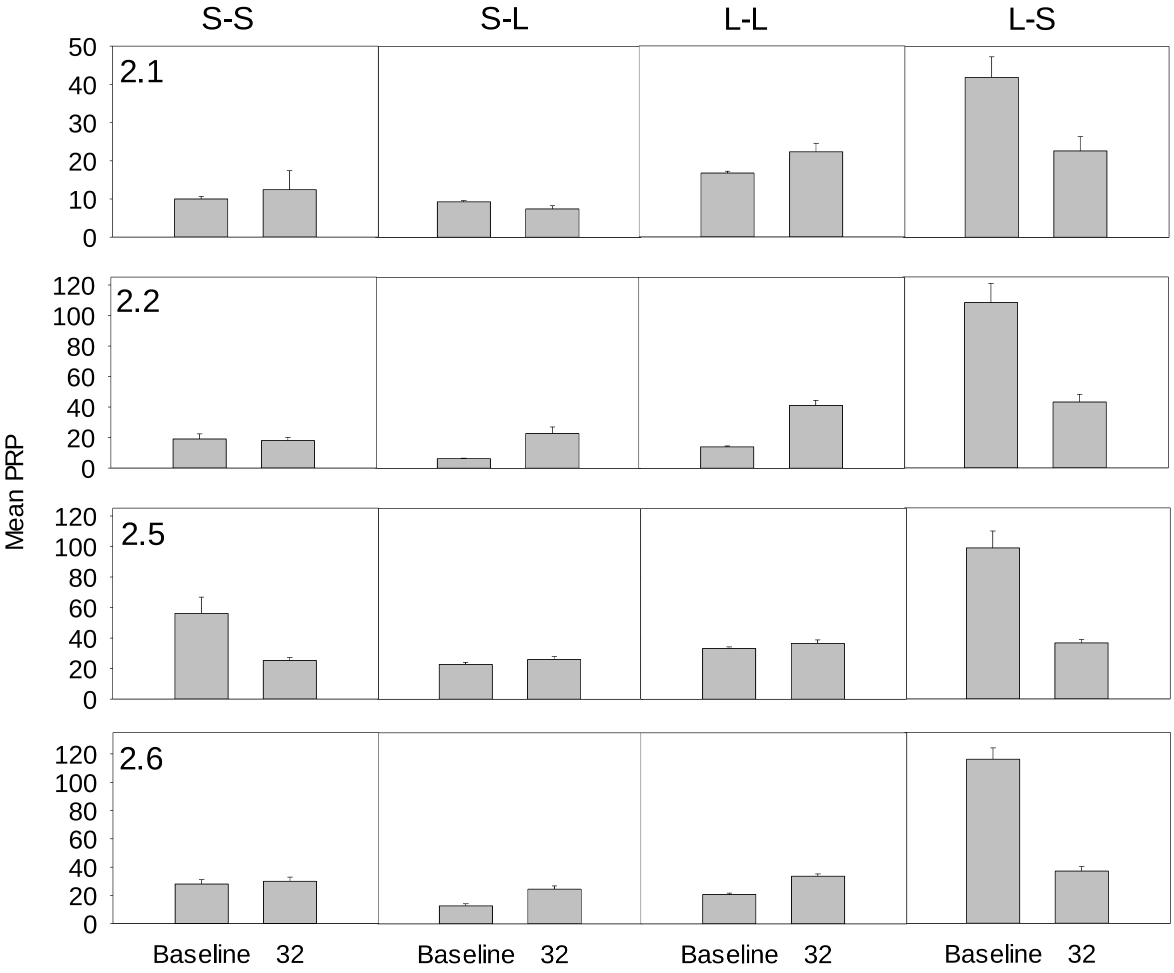

Figure 9: The mean PRP with error bars of the Baseline Condition and Condition 1 plotted for each hen across all transition types [Small-Small, Small-Large, Large-Large, and Large-Small] over all sessions completed.

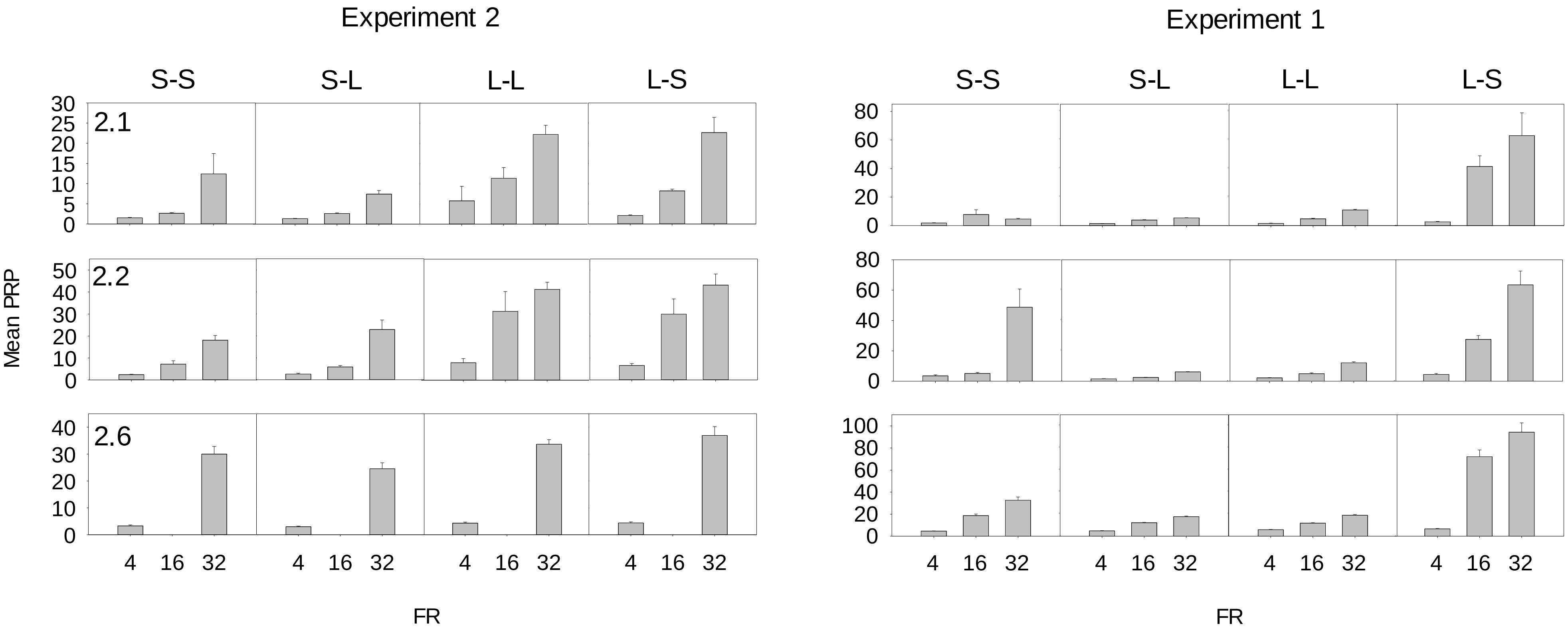

Figure 10: The mean PRP with error bars of Conditions 1-3 plotted for each hen and compared to Conditions 2, 4, and 5 of Experiment 1 during the four transitions [Small-Small, Small-Large, Large-Large, and Large-Small] over all sessions completed.

transitions (S-S, S-L, L-L, and L-S) completed in Conditions 1 to 3 whereas the four columns in the far right represent the four transition completed in Conditions 2, 4, and 5 in Experiment 1. Figure 10 shows that in Experiment 2, similar PRPs occurred during the FR 4, FR 16, and FR 32 Conditions of the S-S and S-L transitions. During the L-L and L-S transitions, in Experiment 2, similar PRPs occurred in the FR 4, FR 16, and FR 32 Conditions. In addition, the larger the FR value, the longer the PRP.

In comparison, in Figure 10, Experiment 1 shows that during the S-L and L-L transition, smaller PRPs occurred across all hens. During the S-S transitions slightly longer PRPs occurred across Conditions FR 4, FR 16, and FR 32 but, in the L-S transition consistently longer PRPs occurred across the FR 4, FR 16, and FR 32 Conditions, where this was consistent across all hens.

Overall Response Rate

The mean overall response rate from the last 5 sessions are plotted against log FR of Conditions 1 to 3, as shown in Figure 11. The rates were calculated as the total response time divided by total session time for each FR. Figure 11 shows that overall response rate was highest during Condition 2 (FR 4) for Hens 2.1 and 2.2. Overall response rate decreased at Conditions FR 16 and FR 32 for Hens 2.1 and 2.2. Hen 2.6 only completed the FR 32 Condition (Condition 1) so no noticeable increasing or decreasing trend can be reported. Overall response rates were highest during the smaller FR Conditions (FR 4 and FR 16 Conditions) and decreased at the FR 32 Condition for Hens 2.1 and 2.2. A small bitonic inverted u-shape curve can be seen in Figure 11 for Hen 2.2, in comparison to Hen 2.1 and 2.6 where no bitonic inverted u-shaped curve can be seen. In addition, Hen 2.2 had higher overall response rates during the S-S and S-L transition in comparison to the L-L and L-S transition where lower overall response rates occurred. Hen 2.1 had higher overall response rates in the FR 4 Condition, during the S-L, L-L, and L-S transition, but had lower overall response rates in the FR 16 and FR 32

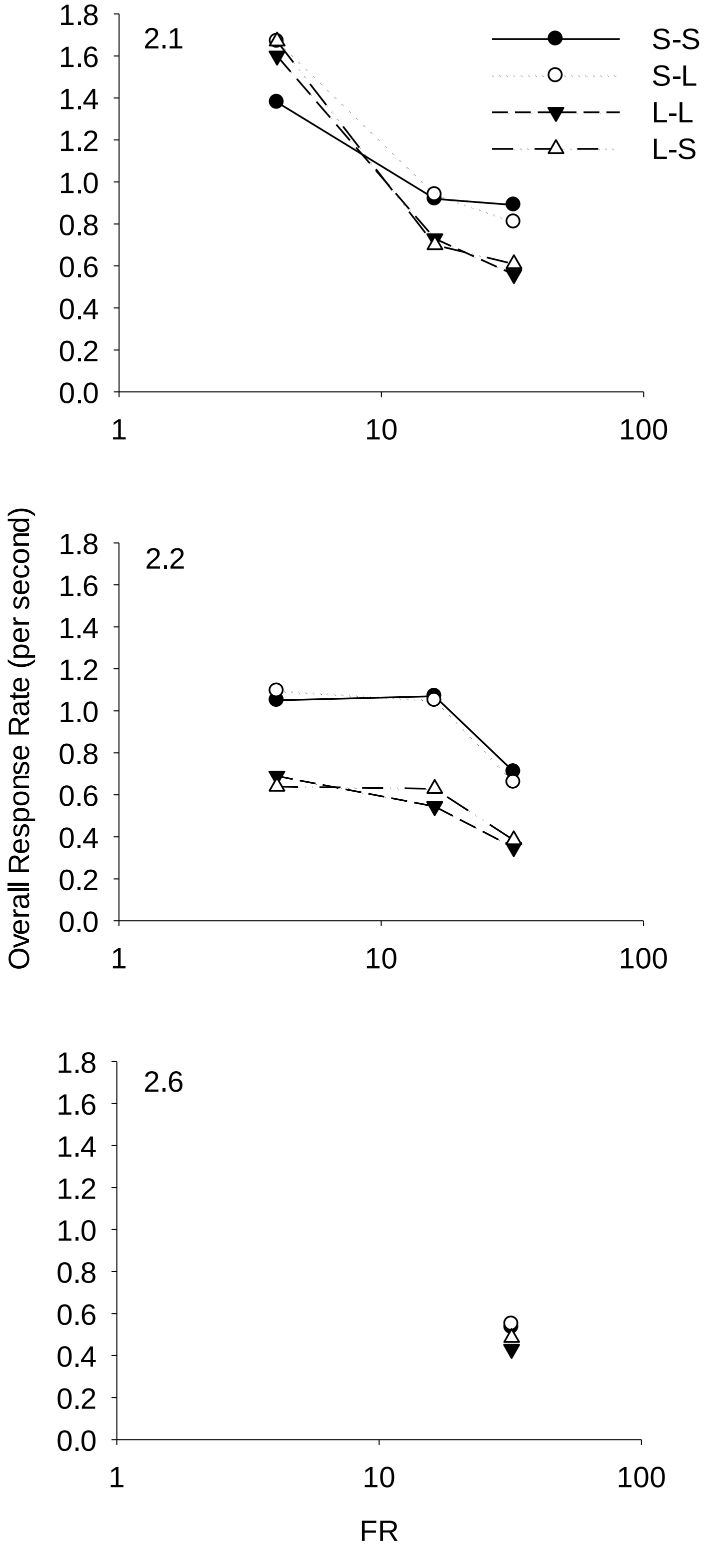

Figure 11: Overall response rates of Conditions 1-3 shown as responses per second plotted against common logarithmic FR value.

Condition, during the L-L and L-S transition. In comparison, lower overall response rates occurred in the FR 4 Condition during the S-S transition and higher overall response rates occurred in the FR 16 and FR 32 Conditions, during the S-S and S-L transitions. The S-S and S-L transitions had similar overall response rates, as with the L-L and L-S transitions, during the FR 4, FR 16, and FR 32 Conditions for Hen 2.2. Hen 2.1 had similar overall response rates during the S-S and S-L transitions, as with the L-L and L-S transitions, during the FR 16 and FR 32 Conditions. No similarities between the S-S and S-L transitions could be seen during the FR 4 Condition, as with the L-L and L-S transitions, for Hen 2.1.

Running Response Rates

The running response rates, shown in Figure 12, were calculated by using the key time minus PRP divided by total session time, using the last 5 session's data and are plotted against log FR of Conditions 1 to 3. As mentioned previously, running response rates are defined as the rate of responding from the first response to the last response on the FR value. In general, running response rates showed a consistent decrease as the FR values were increased across Hens 2.1 and 2.2. Hen 2.6 only completed the FR 32 Condition. Running response rates for Hen 2.2 were highest when the preceding reinforcer was small (S-S and S-L transition) compared to when the preceding reinforcer was large (L-L and L-S transition), where lower running response rates occurred. No consistent pattern of lower or higher running response rates occurred for Hen 2.1 during the four transitions for Conditions 1 to 3.

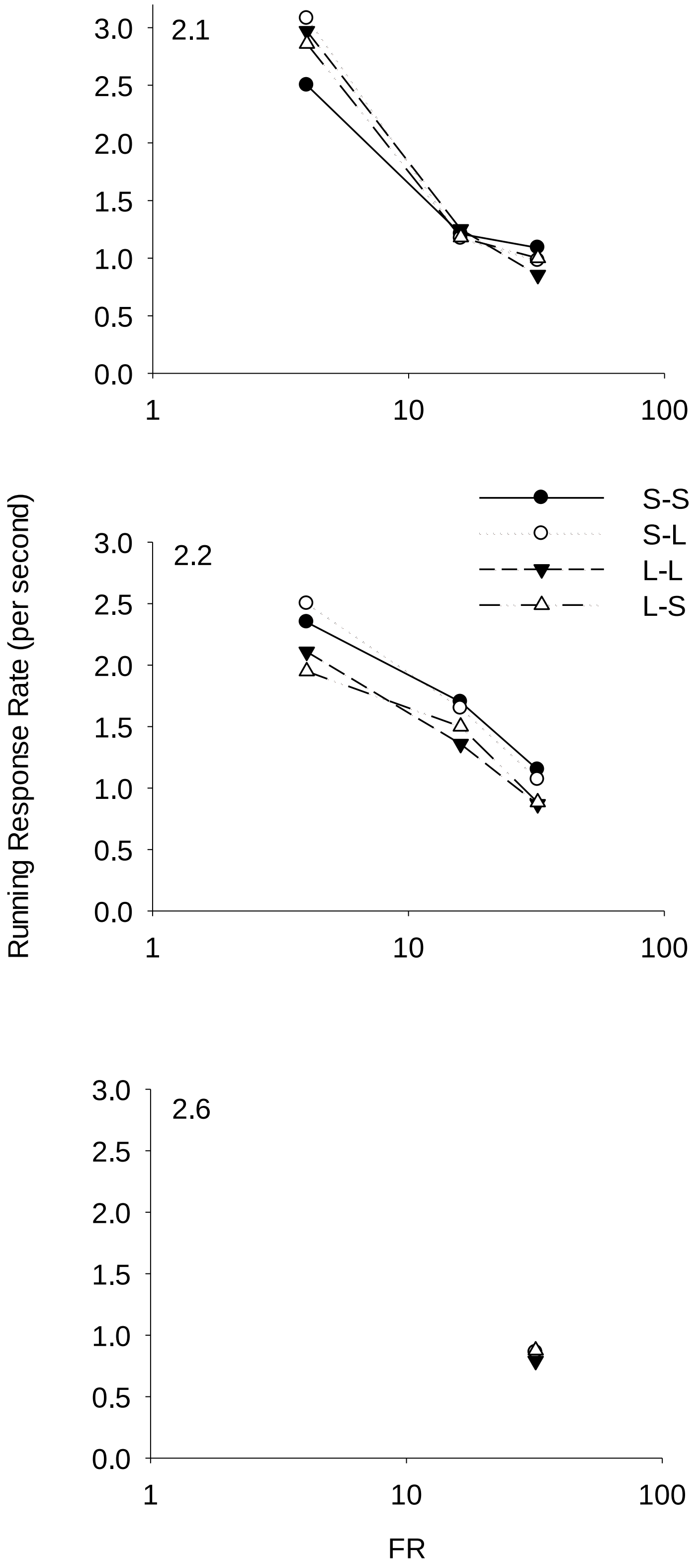

Figure 12: Running response rates of Conditions 1-3 shown as responses per second (run time minus PRP time) plotted against common logarithmic FR value.

DISCUSSION

The aim of the present experiment was to investigate the effects of the past reinforcer magnitude on PRP when the discriminative stimuli to differentiate the preceding and upcoming reinforcer magnitude was removed, during a range of FR values on a multiple FR FR schedule of reinforcement. Overall, when the discriminative stimuli that signalled the preceding and upcoming reinforcer magnitude was removed, it was found that the preceding reinforcer magnitude did have a direct effect on the between-ratio pause. Furthermore, when the preceding reinforcer was small and the upcoming reinforcer was small or large (Small-Small and Small-Large transition) pause durations were small and similar across the two transitions. In comparison, when the preceding reinforcer was large and the upcoming reinforcer was small or large (Large-Large and Large-Small transition) consistently longer pause durations were found, where they were also observed to be similar across the two transitions.

A Baseline Condition was conducted prior to the removal of the discriminative stimuli to observe the changes in pause durations and compared across the four transitions. In the Baseline Condition, small pause durations occurred during the S-L and L-L transitions, where slightly longer pause durations occurred during the S-S transition. Consistently longer pause durations occurred during the L-S transition and this effect was consistent across Hens 2.1, 2.2, 2.5, and 2.6. When the Baseline Conditions data were compared to those in Condition 1, there was a noticeable difference in pause durations when compared across the four transitions. This was a consistent pattern, over Conditions 2 and 3 as well. When the past reinforcer was small (S-S and S-L transition) similar and shorter pause durations occurred. In comparison, when the past reinforcer was large (L-L and L-S transition), consistently longer and similar pause durations occurred for both the L-L and L-S transitions.

Perone and Courtney (1992) investigated pause durations and the preceding and upcoming reinforcer magnitudes by using one discriminative stimuli for both the small and large reinforcer magnitudes. They found that pause durations did not differ as a function of the upcoming reinforcer magnitude but they did differ as a function of the past reinforcer magnitude (Perone & Courtney, 1992). Overall, Perone and Courtney (1992) found that longer pause durations were not the result of the upcoming reinforcer but were the direct result of the past reinforcer magnitude. The present findings support Perone and Courtney (1992) as the preceding reinforcer magnitude was directly related to the length of the between-ratio pause. In addition, the present results also show that when the past reinforcer was large, longer pauses occurred than when the past reinforcer was small. However, Perone and Courtney (1992) only did an analysis between the effects of the small and large reinforcer magnitudes and no analysis was reported on the effects of the four transitions. The present results did find a similarity between the between-ratio pauses during the S-S and S-L transitions and between the L-L and L-S transitions. In Experiment 1, when the upcoming reinforcer magnitude was small (S-S and L-S transition) longer pause durations occurred compared to when the upcoming reinforcer had been large (S-L and L-L transitions). It was further found that the L-S transition had consistently the longest between-ratio pauses across the range of FR values. In Experiment 2 however, similarities in between-ratio pauses occurred where there were shorter between-ratio pauses when the past reinforcer had been small (S-S and S-L transition) compared to when the past reinforcer had been large (L-L and L-S transition). This consistency occurred across the FR values that were used in Experiment 2. In summary, when there were two discriminative stimuli’s used to signal the preceding and upcoming reinforcer magnitudes, longer between-ratio pauses were found when the upcoming reinforcer was small (S-S and L-S transitions), than when the upcoming reinforcer was large (S-L and L-L transitions). In comparison, when the discriminative stimuli that signals the preceding and upcoming reinforcer magnitudes were removed, longer between-ratio pauses occurred when the past reinforcer was large (L-L and L-S transitions), compared to when the past reinforcer magnitude had been small (S-S and S-L transitions).

Overall response rates in Experiment 2 were directly affected by the past reinforcer magnitude. When the past reinforcer was small and the upcoming reinforcer was going to be small or large (S-S and S-L transitions) consistently higher overall response rates occurred for Hens 2.1 and 2.2. In comparison, when the past reinforcer was large and the upcoming reinforcer magnitude was going to be small or large (L-L and L-S transitions) consistently lower overall response rates occurred for Hens 2.1 and 2.2. The present results are consistent to the results found in Experiment 1 where it was found that the S-S and S-L transitions produced higher overall response rates compared to the L-L and L-S transitions for Hens 2.2, 2.3, 2.4, and 2.5. However, in Experiment 1, different overall response rates were found for Hen 2.1 where higher overall response rates occurred during the S-L and L-L transitions. In addition, the overall response rates in Experiment 2 were similar to those found in Experiment 1, in that higher overall response rates occurred during smaller FR values and decreased as the FR values increased. Perone and Courtney (1992) did not report the effects of the overall response rates so a comparison cannot be made. Future studies could examine whether the small reinforcer magnitude does produce higher overall response rates in comparison to the larger reinforcer magnitude and compare the effects across the four transitions.

Running response rates in Experiment 2 were similar to the running response rates in Experiment 1. As the FR values were increased, running response rates consistently decreased across the four transitions. When the past reinforcer was small and the upcoming reinforcer was small or large (S-S and S-L transition) consistently higher running response rates occurred for Hen 2.2. In comparison, when the past reinforcer was large and the upcoming reinforcer was going to be small or large (L-L and L-S transitions) consistently lower running response rates occurred for Hen 2.2. Hen 2.1 had no consistent higher or lower running response rates during the four transitions. Perone and Courtney (1992) reported similar results that were found with Hen 2.1, in that there were no consistent differences found in the running response rates when compared across the small and large reinforcer magnitudes.

In summary, the present experiment found that when the discriminative stimuli that signals the preceding and upcoming reinforcer magnitude is removed, the between-ratio pauses were found to be directly affected by the past reinforcer magnitude. In Experiment 1, between-ratio pauses were found to be related to both the preceding and upcoming reinforcer magnitude. In the present experiment, when the past reinforcer magnitude was small, consistent between-ratio pauses occurred across the FR Conditions, with shorter between-ratio pauses. In comparison, when the past reinforcer magnitude was large, consistent and longer pauses occurred during the L-L and L-S transitions. In comparison, Experiment 1 showed that longer pauses occurred when the upcoming reinforcer was small compared to when the upcoming reinforcer was large. Hen 2.2 had similarities in overall and running response rates during the four transitions. Higher overall and running response rates occurred during the S-S and S-L transitions compared to the L-L and L-S transitions where lower overall and running response rates occurred. Hen 2.1 had similarities in overall response rates where the S-S and S-L transitions had higher overall response rates compared to the L-L and L-S transitions where lower overall response rates occurred. However, the running response rates found no consistent differences between the four transitions. However, overall and running response rates did consistently decrease as the FR values were increased across conditions.

GENERAL DISCUSSION

The aim of this thesis was to investigate the effects of the preceding and upcoming reinforcer magnitudes on the between-ratio pause using two different discriminative stimuli to differentiate the small and large reinforcer magnitudes with hens working under a multiple FR FR schedule of reinforcement. In addition, this thesis also investigated the effects of the past reinforcer magnitude, on the between-ratio pauses, by removing the discriminative stimuli that differentiates the preceding and upcoming reinforcer magnitudes, and replacing it by using one discriminative stimuli for both the small and large reinforcer magnitudes, under a multiple FR FR schedule of reinforcement.

Experiment 1 found similar results to Perone and Courtney (1992), Galuska and Yadon (2011), and Williams et al. (2011) in that the preceding and upcoming reinforcer magnitude both had a direct effect on the length of the between-ratio pause. In addition, increases in FR values were also found to increase the duration of the between-ratio pause. As a result, present findings support those of previous studies (e.g., Perone & Courtney, 1992; Galuska & Yadon, 2011; Williams et al., 2011). Furthermore, it was found that when an upcoming reinforcer was small, and where the preceding reinforcer had been large (L-S transition), consistently longer between-ratio pauses occurred across the range of FR values when compared to the Small-Small, Small-Large, and Large-Large transitions. Previous findings have also found similar consistencies with the Large-Small transitions (Perone & Courtney, 1992; Galuska & Yadon, 2011; Williams et al., 2011; Harris et al., 2012).

Harris et al. (2012) found a weak effect when it came to the preceding component affecting the length of the between-ratio pause suggesting that it was the upcoming component that strongly affected the length of the between-ratio pause. Experiment 2 investigated the effects of the preceding reinforcer magnitude and found a consistent effect that when the past reinforcer had been small and the upcoming reinforcer was going to be small or large (S-S and S-L transition) similar and shorter between-ratio pauses occurred across the two transitions. In comparison, when the past reinforcer had been large and the upcoming reinforcer was going to be small or large (L-L and L-S transition) similar and longer between-ratio pauses occurred across the two transitions. These results were consistent with the findings of Perone and Courtney (1992).

The overall and running response rates from Experiment 1 were similar to those found in Experiment 2, in that they both decreased as the FR values increased. The bitonic u-shaped curve was found in the overall response rates of Experiment 1, as a result of the size and range of FR values that were studied. The main difference between the overall and running response rates of Experiments 1 and 2 was that in Experiment 1, consistently lower overall and running response rates occurred during the L-S transition, where this was consistent across all hens. In Experiment 2, the S-S and S-L transitions produced similar overall and running response rates, as with the L-L and L-S transitions. In Experiment 2, overall and running response rates were highest when the past reinforcer was small, and lowest when the past reinforcer had been large. This was consistent across conditions, and most hens. No previous studies have reported the effects on overall response rates and future research should examine whether similar effects are found. Running response rates were reported by Perone and Courtney (1992) however, they found no effects in the running response rates over the small and large reinforcer magnitudes unlike those found in Experiment 2.

Therefore, the present experiments have each added to knowledge in that discriminative stimuli that signal the preceding and upcoming reinforcer magnitudes do affect the length of the between-ratio pauses which further suggests that longer between-ratio pauses occurred when the upcoming reinforcer was going to be small compared to when the upcoming reinforcer was going to be large. In comparison, when the discriminative stimuli that signalled the upcoming reinforcer were removed, between-ratio pauses were affected by the past reinforcer magnitude, more so than the upcoming reinforcer magnitude. It was further found that when the past reinforcer was small, shorter between-ratio pauses occurred compared to when the past reinforcer had been large where longer between-ratio pauses occurred.

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