PREFERENCE IN ASYNCHRONOUS PRESENTATION OF STIMULI

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ABSTRACT

A self-control procedure that involved a later onset of a stimulus signalling a small reinforcer within the waiting time for a larger reinforcer was investigated to determine a point of shifting preference and a discounting function as the delay varied. The results from Experiment 1 to Experiment 3 showed exclusive impulsive choices regardless of the delay. In order to examine if the results were due to the procedure and the parameters, or the species used, Experiment 4 attempted to obtain shifts in preference using simultaneous onset of stimuli with the same species. The results demonstrated no changes in preference but an increase in proportion of self-control choices was shown. Due to the limited information from the replicated studies, the accounts for the results could not be concluded. The explanations derived from choice models seemed most plausible, but limitations of the choice models were discussed.

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All behaviour involves making choices. When the choice results in a desirable outcome in the long term, this is regarded as an act of self-control (Logue, 1988). One example of self-control is when a high school graduate chooses not to work right away for a less satisfying wage, but chooses to pursue further education to obtain a job with better pay rate later on. Impulsiveness is the opposite of self-control in which a short-term outcome with less reinforcing value is chosen (Logue, 1988). An impulsive act would be that the high school graduate chooses to work right away, foregoing the opportunity of securing a job with a better pay rate later on by not continuing further education. Thus, enhanced self-control may have a particular long-term advantage in everyday life.

In addition, self-control is of clinical importance because some disorders can be considered as a failure of self-control, such as drug abuse and pathological gambling (Logue, 1995; American Psychiatric Association, 2000). For example, drug abuse can be seen as an attempt to obtain immediate satisfaction while ignoring its harm to a person's health in a long term. Accordingly, self-control is important in both everyday life and clinical settings. Research on self-control should help us understand how these choices are made, and eventually lead us to develop techniques to enhance self-control to promote wellbeing in everyday life, as well as in clinical settings.

Similar to the choices in our everyday life, experimental investigations on self-control typically have subjects choose between two simultaneously presented schedules of reinforcement in order to receive either a larger reinforcer which is available later (LL; also known as larger delayed reinforcer) or a smaller reinforcer available sooner (SS; also known as smaller immediate reinforcer), where the delay to reinforcers and the magnitude (e.g., amount or duration) of reinforcers are manipulated. If a choice is made for the LL outcome over the SS outcome, this choice is defined as self-control, while the opposite choice is defined as impulsiveness (Rachlin & Green, 1972; Green, Fisher, Perlow, & Sherman, 1981; Logue, 1988).

Since the larger outcome will only be available after a delay (and another delay often applies to the smaller outcome), the relation between the choices and the delay to reinforcer has been extensively studied in a number of experiments. For example, Green, Fisher, Perlow and Sherman (1981) employed pigeons to repeatedly choose between an LL outcome and an SS outcome by a response on one of the two keys, representing the LL and SS keys, across different delays. Two periods were organised. The trial period lasted for 30 s, and was followed by 10 s outcome period. This ensured that the total trial duration was kept constant. The onset of the trial period was signalled by the activation of houselight. During the trial period, two keys were lit simultaneously. The time between the onset of keys and the end of trial period, called *T*, varied from 2 to 28 s. If the red key, the choice key, was pecked, pigeons would be offered 2 s access to food followed by 8 s blackout. In other words, a response made on the red key led to the SS outcome. If pigeons pecked the green key, the commitment key, a delay of 4 s to reinforcer was effective, and was followed by 6 s food reinforcer. Hence, a peck on the green key produced the LL outcome.

The results obtained by Green et al. (1981) showed a clear demonstration of shifting preference by all subjects as a function of delay to reinforcer. Specifically, when the *T* value was 2 s, all birds strongly preferred the SS outcome, while all of them changed their preference to the LL outcome when the *T* was 28 s.

This change in preference reported by Green et al. (1981) can be described and explained by a choice model, the temporal discounting framework. According to the discounting framework, the subjective value of a reward is discounted progressively as a function of delay (Green & Myerson, 2004). Subjective value represents the allocation of the choices for either LL or SS outcome across the delay. In Figure 0.1, the y-axis (the vertical axis) represents the subjective value, and the x-axis (the horizontal axis) refers to the time or the delay to reinforcer, while the heights of the bars represent the actual amounts of two future rewards. The two curves are termed discounting functions. They indicate the subjective values of the rewards across delay. If a choice is made at Time 1 that has a longer delay to reward, the value of LL outcome is discounted less than the value of SS outcome at Time 1. In other words, one would choose the LL outcome at this point. Time 2 is a point of shifting preference. Before this point where delay to the outcomes were shorter, one would prefer the SS outcome. Thus, according to the discounting framework, the actual amount of the LL outcome is discounted less progressively than that of the SS as the delay increases, and this results in the changes in preference.

This could explain the results from Green et al. (1981) where all pigeons shifted preference. According to Figure 0.1, when the *T* value was 28 s, the value of the LL outcome was discounted less than the value of the SS outcome. In this case, the LL outcome was strongly preferred. However, when the *T* value was 2 s, the subjective value of LL outcome was less than that of SS outcome, which resulted in stronger preference for the SS outcome across all the subjects.

Changes in preference have also been observed in experiments conducted with humans. For example, Green, Fristoe, and Myerson (1994) recruited adults to

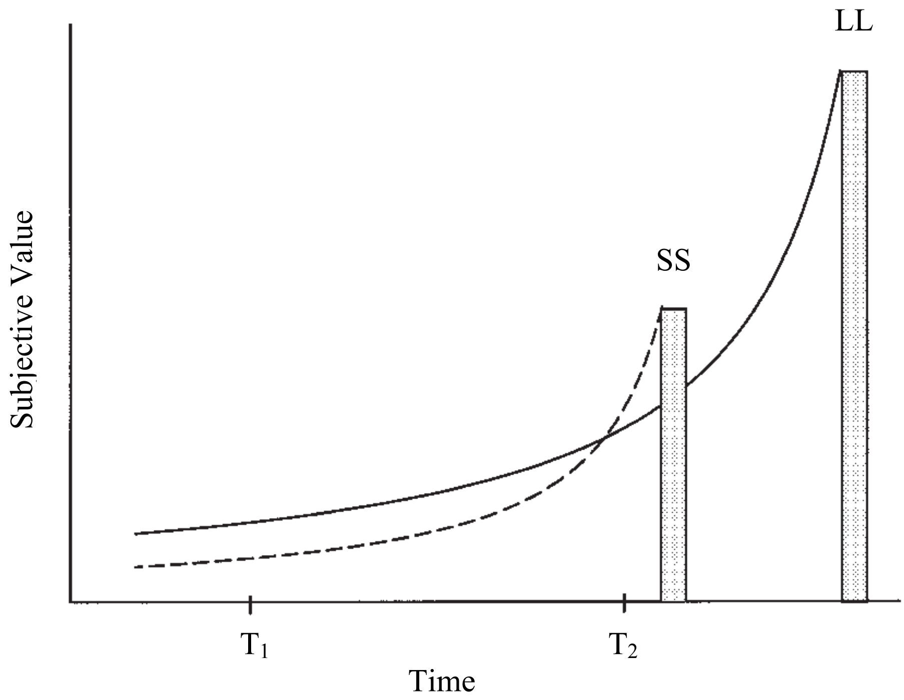

Figure 0.1. Choice between an LL reward and an SS reward as a function of time. The curves represent the discounting subjective values while the heights of the bar represent the actual amounts of the rewards. T_1 = Time 1; T_2 = Time 2 (Green & Myerson, 2004).

make a series of choices between two delayed hypothetical monetary rewards. The ratio of the SS reward to the LL reward was kept constant ($20 to $50; $100 to $250; $500 to $1,250) and delays to both rewards increased equally to keep the interval between the two rewards constant. The students had to make repeated choices as the delay increased. For example, a student might be asked to choose $20 in one week or $50 in three months and one week, and then he/she might be asked again to choose between $20 in three months and $50 in six months. The results obtained by Green, Fristoe and Myerson (1994) showed that while the time interval between two rewards was kept constant, the increment of delay to both rewards resulted in an increased number of students who preferred the LL reward to the SS reward. That is, the preference shifted as the delay increased, as described by the temporal discounting framework.

To describe the temporal discounting, mathematical functions have been developed. Generally, discounting occurs when an amount, A, is reduced by a discounting variable, π, to a subjective value, V. The V value is less than the amount and π is a fraction ($0 \leq \pi \leq 1$) (e.g., Rachlin, 2006). It is expressed as:

$$V = \pi A \text{ or } \frac{V}{A} = \pi \; . \tag{1}$$

However, the discounting variable, π, is dimensionless, and hence, cannot be applied directly.

In economics, the exponential discounting function was proposed, in which $\pi = e^{-KD}$. That is:

$$V = Ae^{-KD} \; , \tag{2}$$

where D is the delay to reward, e is a mathematical constant, and K is a parameter that determines the discounting rate (Samuelson, 1937). However, as the exponential discounting function is based on an early assumption that the discounting rates, *K*, for both of the LL and the SS rewards are the same, this discounting function should be rejected. For example, Rachlin and Jones (2008) argued that the exponential discounting function would suggest that when the values of two future rewards with different amounts and different delays are discounted temporally with the same rate, the two exponential discounting functions will never cross. This means changes in preference would never occur, and that the LL reward would always have a higher subjective value than the SS reward. In other words, human should never act impulsively. Indeed, the basic assumption of this economic conceptualisation is that human behave "rationally", and hence, it would not be surprising that the exponential discounting functions do not predict changes in preference per se (Mazur, 2006; Green & Myerson, 2004). Accordingly, the exponential discounting framework cannot sufficiently describe the evidence from everyday life that humans frequently act impulsively, or the laboratory results from the above outlined experiments.

Nevertheless, Green and Myerson (1993) suggested that the assumption that discounting rates for both the LL reward and the SS reward are the same is incorrect. Thus, if the discounting rates for the two rewards are different, the two exponential discounting functions do cross. Kagel, Green and Caraco (1986) argued that if this exponential discounting function can provide an accurate description, the discounting as a function of delay is really due to the risk involved when waiting for the reward. That is, it is always a possible that the subject will not receive the reward at the end of the waiting, and hence, making the discounting of LL reward value less steep than that of SS reward (i.e., the *K* value is smaller for the LL reward than that of the SS reward).

Behavioural economists argue that the discounting function is a hyperbola (Rachlin, 2006; Green & Myerson, 2004). That is:

$$\pi = \frac{1}{1+\delta} \,, \tag{3}$$

where δ ($\delta \geq 0$) controls the discounting degree. However, δ is also dimensionless. In order to account for the effects of delay to reward, the dimensions of delay and discounting rate are added to the variable, δ. That is, $\delta = KD$. In this case, the discounting function would be (Mazur, 1987):

$$V = \frac{A}{1+KD} \,. \tag{4}$$

According to Equation 4, even if the discounting rates, K, for the LL reward and the SS reward are the same, the discounting functions will cross. In other words, the hyperbolic discounting function should be able to describe shifts in preference as seen above. If the hyperbolic discounting function can provide an accurate description of discounting data, according to Green and Myerson (2004), "choices between different times are really choices between different rates of reward" (p. 772).

A generalised version of the hyperbolic discounting function has been suggested to include a power parameter (Rachlin, 2006):

$$V = \frac{A}{1+KD^{S}} \,. \tag{5}$$

In this hyperbola-like function, the added parameter, s, represents the sensitivity towards to the delay. This suggestion stemmed from the power law (Stevens, 1957), which states that the relation between a psychological response and its physical dimension or stimulus is a power function. In this case, the psychological response, sensitivity, exponentiates its physical dimension, delay.

Another hyperbola-like discounting function based on Equation 4 was suggested by Green, Fry, and Myerson (1994):

$$V = \frac{A}{(1 + KD)^{S}} \; . \qquad (6)$$

In this equation, the parameter, *s*, is the power function of the entire denominator. Owing to the inclusion of sensitivity, this equation also fits the power law. Rachlin (2006) pointed out that in some cases, sensitivity exponent is a unity ($s = 1$). In this case, both Equation 5 and Equation 6 reduce to Equation 4. He also suggested that the sensitivity exponent for delay would usually be close to 1.

To determine which discounting function can provide the best description, different discounting curves are mapped out for the estimated subjective values calculated from these discounting functions across different delays. These discounting curves are then compared to the actual data collected (Green & Myerson, 2004). The best fit will provide the largest proportion of variance accounted for, R^2. Rachlin, Raineri, and Cross (1991) compared exponential discounting function (Equation 2) to the simple hyperbolic function (Equation 4) with humans as participants. An amount of hypothetical money of $1000 delayed from 1 month to 50 years was displayed to the participants while an immediate amount of hypothetical monetary reward (from $1 to $1000) was displayed one by one, next to the delayed reward, as the delays increased. Participants were to choose between the immediate reward and the delayed reward across its delays. Their results are shown in Figure 0.2, which clearly demonstrated that the simple hyperbolic function (Equation 4) provided a much better fit than the exponential function (Equation 2). Specifically, the hyperbola accounted for 99.5% of the variance.

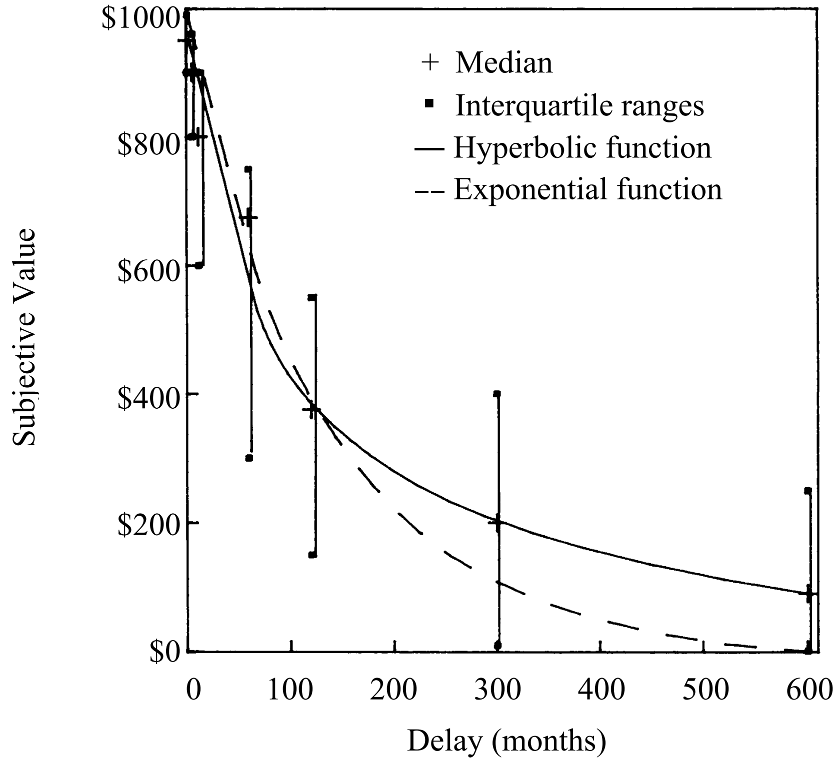

Figure 0.2. Subjective value of a hypothetical delayed $1000 reward decreases as delay increases. From Rachlin, Raineri, and Cross (1991).

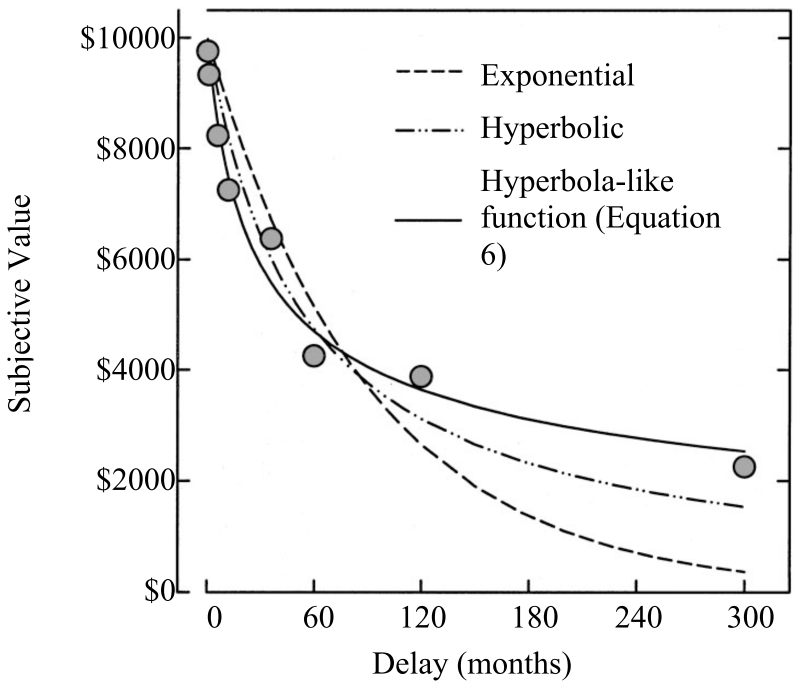

Figure 0.3. Subjective value of a hypothetical delayed $10000 reward decreases as delay increases. From Green and Myerson (2004).

Similarly, Green, Fry, and Myerson (1994) recruited human participants, including children, young adults and older adults. The participants were required to make a series of choices between a fixed-amount hypothetical monetary reward (e.g., \$1000 and \$10000) offered after a varying delay (e.g., 1 week to 25 years) and an immediate hypothetical monetary reward varying from 0.1% to 100% of the delayed reward (e.g., \$1 to \$1000). Their results showed that, for young adults, Equation 6 accounted for 99.7% and 97.7% of the variances for \$1000 and \$10000 delayed rewards respectively. For older adults, Equation 6 accounted for 99.5% and 99.9% of the variances for \$1000 and \$10000 delayed rewards correspondingly. For children, Equation 6 accounted for 94.5% and 99.5% of the variances for \$100 and \$1,000 delayed rewards respectively. Green and Myerson (2004) later re-analysed Green, Fry and Myerson's (1994) results of young adults discounting \$10000 across different delays. They found that the exponential function (Equation 2) provided the poorest fit, it accounted for only 81.5% of the variance. The simple hyperbolic function (Equation 4) accounted for 93.7% of the variance, hence, provided better fit. Nevertheless, Equation 6, the hyperbola-like function, accounted for 97.7% of variance (see Figure 0.3, for a graphical comparison), suggesting that Equation 6 is superior in fitting the discount data than exponential and simple hyperbola.

Rachlin (2006) argued that Equation 5, another hyperbola-like function, can also fit the delay discounting data well. In fact, Rachlin (2006) pointed out it is not possible to choose between the two hyperbola-like functions (Equation 5 and Equation 6) based on variance accounted for, R^2. Rachlin (2006) re-analysed Raineri's (as cited in Rachlin, 2006) data, where he found that variances accounted for from both equations were very high, and were very close to each other. On average, both equations accounted for 99.5% of variance of the delay discount data obtained by Raineri (as cited in Rachlin, 2006). Accordingly, it is possible to conclude that the two hyperbola-like functions, both Equation 5 and Equation 6, can provide much better description of the temporal discounting data than exponential discounting function and the simple hyperbolic function.

To date, most of the self-control studies use a procedure that starts the delays to the LL outcome and the SS at the same time. This is organised by presenting two or more reinforcement schedules simultaneously to an organism. For example, Rachlin and Green (1972) used a chained procedure where two white keys were lit simultaneously in the initial link, and the pigeons had to distribute an FR 25 requirement over two keys, a commitment key and a choice key. The final response determined the choice between the two keys. If the choice key was chosen, another set of two keys with different colours were presented simultaneously again in the terminal link for the pigeons to make one more choice.

Another extensively employed procedure in the self-control studies is the discrete trial procedure. In this procedure, an organism is required to make a choice between two simultaneously presented discriminative stimuli, followed by a reinforcer associated with the chosen stimulus after some delay. This procedure was used by Green et al. (1981) as outlined above, in which the subjects needed to make a response on either of the simultaneously lit side keys to receive the associated reinforcer.

Mischel (1974) used a unique procedure to investigate self-control in children where only a single operative stimulus was used. Children in this study were to choose between a pretzel (i.e., the LL reward) and animal crackers (i.e., the SS reward). In order to receive the pretzel, children needed to sit quietly for 15 min. The trial could be terminated by ringing a bell at any time during the waiting, and only animal crackers were offered afterwards. Even though only a single operative stimulus was employed in this study, the delay to the SS outcome and the LL outcome started at the same time.

In the temporal discounting literature, variations of the discrete trial procedure were developed. For example, Mazur (1987) introduced an adjusting-delay procedure, in which the delay to reinforcer was continuously adjusted based on the results of subject's preceding trial. If the subject chose the SS outcome in one block of trials, the delay to LL outcome in the following block would decrease. Likewise, if the subject chose the LL outcome in one block of trials, the delay to LL outcome in the next block of trials would increase. The purpose of this procedure was to find the indifference points where the subject chose two outcomes equally often. Recently, Richards, Mitchell, de Wit, and Seiden (1997) developed an adjusting-amount procedure for use with rats. In their procedure, the rats were to choose between an SS outcome, a smaller amount of water, and an LL outcome, a larger amount of water. If the SS outcome was chosen, the amount of the SS outcome would decrease, and if the LL outcome was chosen, the amount of the SS outcome would increase. Richards et al. (1997) then varied delay to LL outcome to find out the indifference points at these delays. Although in these two studies some variations were made to the discrete trial procedure in order to adjust the procedure to accommodate the research interest, these two variations still have two stimuli simultaneously presented to the subjects.

All of the above experimental procedures used in self-control studies attempted to describe a scenario where an organism tries to choose between two options that are offered at the same time. Regrettably, this will often fail to match the real world choice scenarios. Consider that a pathological gambler has committed not to gamble again, but at a later time, this gambler comes across a gambling facility. Now the question is raised as to whether or not this gambler would start gambling again.

To address the above scenario, Ishii and Sakagami (2002) developed a procedure with pigeons as their subjects, where the SS alternative appeared during the waiting for the LL outcome. They attempted to investigate if the pigeons' choice distributions were affected by the point when the SS alternative appeared during the waiting. They also aimed to investigate the differences in pigeons' performance maintained by three schedules, a fixed interval (FI) 10 s, a fixed time (FT) 10 s, and a differential reinforcement of other behaviour (DRO) 10 s schedules.

Their procedure is presented in Figure 0.4. Before the start of a trial, the central key was lit white. A single peck on the central key would start the trial and darken the central key. At the beginning of the trial, one of the side keys was lit green, called the LL key. The LL key was associated with one of the three schedules and the following LL outcome, 6 s access to food. If FI 10 s schedule was in effect, a peck on the LL key after 10 s had elapsed would be followed by the LL outcome. If the FT 10 s was operative, no responses were required and the LL outcome would be automatically available after 10 s delay. If the DRO 10 s was in effect, the LL outcome would only be available after 10 s without a response. If a response was made during the DRO 10 s, the 10 s delay would restart. The other side key was lit red after a predetermined delay from the start of the trial, called the SS key. The SS key was associated with the immediate 1.5 s

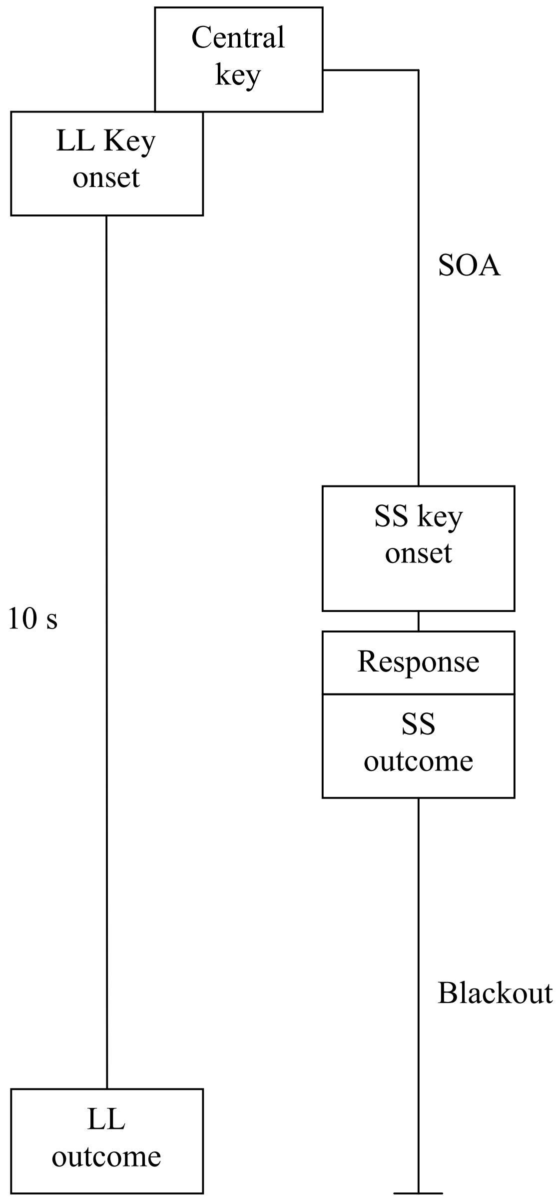

Figure 0.4. The experimental procedure used in Ishii and Sakagami (2002). Whether a response was required preceding the receipt of the LL outcome was dependent on the condition.

access to food (i.e., the SS outcome). The interval between the start of the trial (or the onset of the LL key) and the onset of the SS key was termed schedule of asynchrony (SOA) (Ishii & Sakagami, 2002). The SOA varied from 0 to 9 s. Hence, the onset of SS key was always before the LL outcome being available. Once the SS key was available, a single response on it would terminate the LL key, and the SS outcome would be offered immediately.

The results of Ishii and Sakagami (2002) showed that the number of impulsive choices was higher in the DRO 10 s condition than the FI and FT 10 s conditions. They argued that the contingency associated with the DRO 10 s, which was to reset the 10 s delay if a response was made, was a punishment. This resulted in a decreased number of self-control choices being made. However, the FI and FT 10 s conditions produced similar number of self-control choices being made under these two conditions.

More importantly, consistent with the self-control and temporal discounting literature, Ishii and Sakagami (2002) showed that pigeons shifted preference from choosing the SS outcome when the SOA value was 0 s to the LL outcome when the SOA value was 9 s in the FI and FT conditions. This was explained in terms of the shortened delay to LL outcome. That is, as the SOA value increased, the delay to LL outcome decreased.

As argued above, most of the self-control studies cover only one scenario where two options were offered at the same time, while Ishii and Sakagami (2002) presented an alternative scenario in their study where one alternative, the SS option, was offered during the waiting for LL outcome. More importantly, Ishii and Sakagami (2002) also found shifts in preference comparable to the self-control studies using simultaneous onset of stimuli. Thus, it is also reasonable to expect that the temporal discounting functions will provide an accurate description of their results. In fact, Ishii and Sakagami (2002) argued that their results should be readily described by the discounting functions. Unfortunately, their results were not quantitatively analysed by using any of the previously outlined discounting functions. Without sufficient raw data presented in their study, re-analysing their results using discounting functions is not possible. Thus, whether or not their results could actually be described by the discounting functions is still unresolved. Nevertheless, if the temporal discounting functions can provide accurate descriptions of the results in this procedure, it is also possible that the framework can predict the future choice distributions in similar choice scenarios where the SS alternative appeared during the waiting, and thus, may help to prevent making an impulsive choice in these scenarios.

Thus, the present study aims to replicate part of Ishii and Sakagami (2002), using only the FI condition where FI 10 s schedules was associated with the LL outcome and the FR 1 schedule was associated with the SS outcome. It is anticipated that the subjects will demonstrate shifts in preference from SS outcome to LL outcome as SOA value increases. More importantly, if changes in preference are found in the present study, the temporal discounting framework can be used to describe the results. Although it was not carried out by Ishii and Sakagami (2002), they did suggest this possibility. Thus, this study not only serves to validate the procedure itself, but also serves to investigate if the temporal discounting functions can indeed provide accurate descriptions of the results generated in this procedure. This will also enable the comparison across the three discounting functions, the exponential function (Equation 2), the simple hyperbolic function (Equation 4) and the hyperbola-like functions (Equation 5 and

Equation 6). If an accurate description can be provided by any of these three discounting functions, it is possible that this function can also be used to predict the future choice distribution of that organism in a similar choice scenario, and hence, may be served to help to prevent the impulsive choices being made in the future where the SS alternative is encountered during the waiting for the LL outcome.

EXPERIMENT 1

METHOD

Subjects

Six Brown Shaver hens (numbered 91 to 96) served as subjects in this experiment. Three of these hens (subjects 91, 93 and 95) were one year old, and the other three hens were 2 years old (subjects 92, 94 and 96) at the start of this experiment. The hens were kept at approximately 80% of their free-feeding body weights. In addition to the wheat which was provided as reinforcers in the experiment, supplementary feed of commercial layer pellets was also provided if necessary. When experimental sessions were not conducted, 50 cc of supplementary feed was provided to the hens. The hens were individually housed in home cages, measuring 440 mm (height) × 310 mm (width) × 445 mm (length), with water freely accessible as well as grit and vitamins provided weekly. All six hens had previously participated in experiments.

Apparatus

The experimental chamber was constructed of particleboards with internal dimensions of 510 mm (height) × 414 mm (width) × 522 mm (length). The chamber had three circular Perspex response keys with 30 mm in diameter. They were located on one end of chamber, called the response wall. The response keys could be lit green, red or white. These keys were 65 mm apart from each other, and 370 mm above the removable grid floor measuring 345 mm (width) × 395 mm (length), which was located on top of a metal tray. Two side keys could be lit either red or green, and were operative by 28 V multi-chip light-emitting diodes (LED), while the central key could be lit white by 28 V single-chip LED.

A response made on the lit key with at least 0.8 N would produce a tone sound of 0.05 s, indicating an effective key peck. An overhead houselight located in the centre of the top of the chamber was lit by six 3.8 V white LEDs. A fan situated on the wall opposite to the response wall was continuously operative, providing some masking noise throughout each session.

A food magazine was located behind an aperture, measuring 70 mm × 100 mm, on the response wall. The aperture was 120 mm above the floor of the experiment chamber. While the magazine was raised to provide access to wheat, it was lit with 28 V white single chip based LED and a sensor was also operative to record eating time. The key lights and houselight were extinguished when the magazine was raised.

The experiment was run on a personal computer with an Intel® Pentium® II processor located away from the experiment chamber in the same room. MED PC © IV software controlled experimental events and recorded data. A log book was also used to manually record session data for each hen.

Procedure

An experimental session started after a hen was put in the chamber. The experimental events were controlled by the MED PC © software. An experimental session was completed when either 40 free choice trials had been completed or 40 min had elapsed.

The colours used in the experiment were predetermined with left key lit green and right key lit red. The left green key was associated with an FI 10 s schedule and 6 s access to food, and thus, the LL outcome. The subjects were required to make a response on this key after 10 s had elapsed in order to receive the food. Thus, the left green key was the LL key. The right red key was associated with an FR 1 schedule and 2 s access to food, and hence, the SS outcome. That is, the subjects were required to make a single response on this key to receive the SS outcome. This key was known as the SS key.

Each experimental session consisted of 40 free choice trials. A free choice trial began with the LL key lit first. During the FI 10 s requirement associated with the LL key, the SS key was lit based on the schedule onset asynchrony (SOA) value. Only one SOA value was used in an experimental session. The hens were required to peck either the LL key after 10 s has elapsed, or the SS key. If the FR 1 requirement on the SS key was met, both keys were extinguished, and the SS outcome was made available. If the FI 10 s requirement on the LL key was met, both keys were extinguished, and the LL outcome was made available. The sequence of experimental events was presented in Figure 1.1.

The current procedure varied slightly from Ishii and Sagakami's (2002) procedure. First, Ishii and Sakagami (2002) used a central key to start a trial. The use of a central key seemed superfluous since the start of a trial was also the onset of LL key, so the onset of LL key should signal the start of a trial. The other feature excluded from the current study was the random but even distribution of two colours and their associated contingencies. This pseudo-random distribution of two colours was to eliminate the effect of possible position bias. However, if the position bias existed, it should be described by the temporal discounting function for the LL outcome that the discounting rate, *K*, may be lower in one subject than the others, without the pseudo-random presentation of the two colours. For example, if a hen favours the left side, which would make her choose the LL key more often, then the discounting rate for the LL outcome will

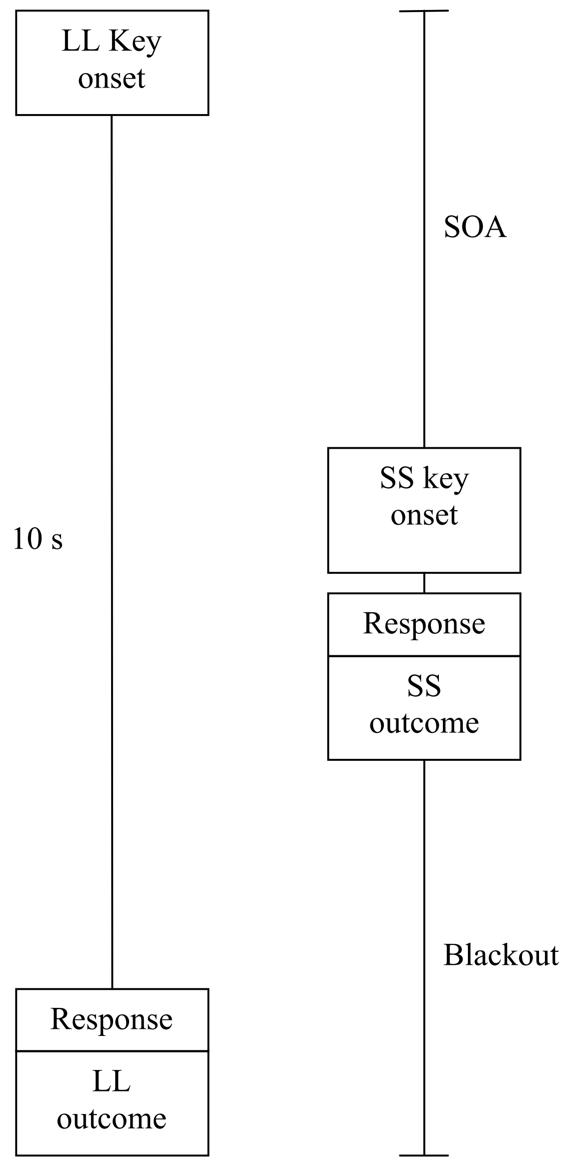

Figure 1.1. The sequence of the experimental events in a free choice trial.

be lower for her than for the other subjects. Since the discounting rate, *K*, would be able to account for the potential position bias, it seemed unnecessary to include the pseudo-random distribution of the two colours and their associated contingencies. Finally, the present study used 2 s access to reinforcer instead of 1.5 s used by Ishii and Sakagami (2002). The 2 s access to reinforcer as the SS outcome was usually used in the previous self-control experiments with hens as subjects (e.g., McEwan, 1989; McBriar, 1999).

Preceding the 40 free choice trials, there were eight forced choice trials. A forced choice trial consisted with the onset of either of the LL key or the SS key. Thus, half of the forced choice trials involved LL key onset only, and the other half consisted of SS key onset only. The onset of SS key was according to the SOA value used in the following free choice trials. The eight forced choice trials were distributed equally on both side keys randomly, with each side key and its associated contingencies used for four times.

For all trials, after making a choice, the magazine was raised and the reinforcer was offered. All lights stayed extinguished except for the magazine light, signalling the availability of reinforcer. If the SS key was chosen, a blackout period was implemented after 2 s consumption of reinforcer. The blackout period varied in order to keep the total trial duration constant at 16 s. If the LL key was chosen, no blackout period was operative after the consumption of LL outcome. An inter-trial interval of 10 s was implemented between the two trials, across all the trial including forced choice and free choice trials.

The SOA value was kept constant during both forced choice trials and free choice trials in each experimental session. Each SOA value was an integer ranging from 0 to 9 s. If the 0 s SOA was used, both keys were lit at the same time. If the 9 s SOA was used, the SS key was only lit after 9 s had passed since the start of trial. Thus, the onset of SS key was always before the completion of the requirement on the LL key. There were two series of the SOA values used in the sessions. If the ascending series was in effect, the SOA value started from 0 s, and then it was increased by 1 s per session until the SOA value reached 9 s. If the descending series was used, the SOA value started from 9 s, and then it was decreased by 1 s per session until it reached 0 s. Two series were alternated. This resulted in each hen experiencing both ascending and descending series of SOA values.

After each ascending and descending series, the proportion of choices made for the LL outcome out of the total choices was plotted for each SOA value. Visual inspection was used to check the stability. The performance of a subject was judged stable when the ascending and descending series produced similar data. If the stability criterion was not met, the ascending and descending series continued to alternate until the stability criterion was met.

RESULTS

The behaviour of all subjects was judged stable when they completed both ascending and descending series. Table 1 shows the order of the series that each subject completed. The data from the ascending and descending series from each hen were used to calculate the proportion of the LL outcome chosen for each SOA value. The results were presented in Figure 1.2, showing the proportions of the LL choices for all SOA values in both series for all subjects. Inspection of Figure 1.2 showed that all subjects tended to choose the SS outcome exclusively regardless of the SOA values.

Some exceptions were noted. During the ascending series, all the subjects, except for subject 91, chose the LL outcome occasionally. For example, the proportion of the LL choice for subject 96 reached 0.35 when the SOA was 1 s. Other subjects, including 92, 93, 94 and 95, all showed occasional choices made for LL outcome during the beginning of ascending series. However, all subjects exclusively chose the SS outcome later when SOA value increased. For the descending series, all subjects tended to exclusively choose the SS outcome, and the proportions of the LL outcome chosen were 0.0 throughout the series except

Table 1
The order of the series completed by each subject in Experiment 1

Hen					
91	92	93	94	95	96
a, d	a, d[1]	a, d[2]	a, d	a, d	a, d

Note. a and *d* indicate the ascending series and the descending series respectively. The descending series of all of the subjects stopped at 1 s SOA, except for subject 93.
[1] The results of 5 s SOA was not used as the hen completed that session was subject 93 by mistake.
[2] This series stopped at 2 s SOA.

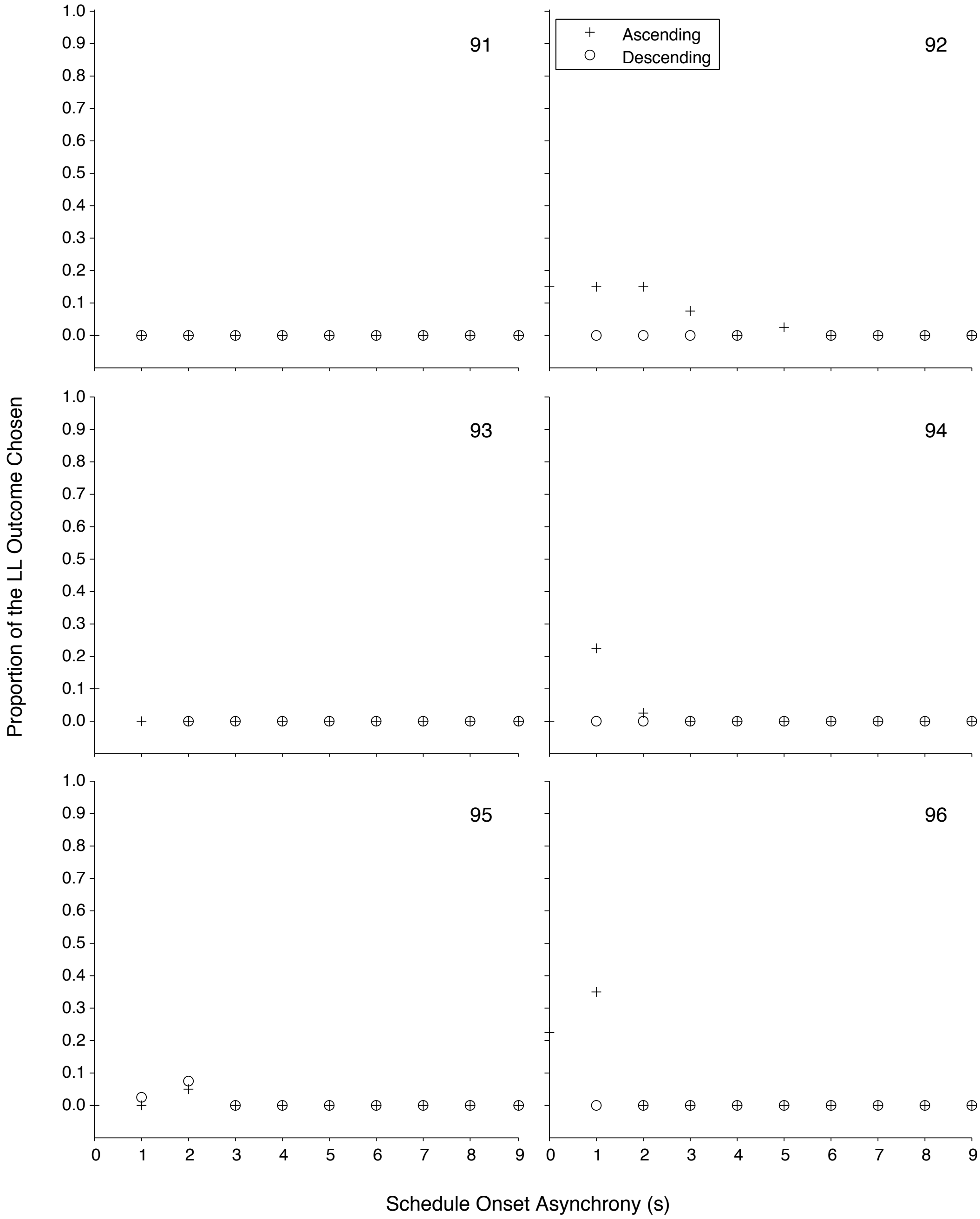

Figure 1.2. Proportion of the LL outcome chosen as a function of the schedule onset asynchrony for each hen in Experiment 1. The cross (+) represents the ascending series, and the circle (○) represents the descending series.

for subject 95. However, subject 95 only showed some LL choices at the end of descending series when SOA values were small. Overall, the results showed exclusive SS choices for subjects, regardless of the changing SOA.

DISCUSSION

The current study aimed to replicate the FI condition in Ishii and Sakagami (2002). Based on the findings obtained by Ishii and Sakagami (2002), it was expected that changes in preference would be observed as a function of changing SOA. However, the results of the present experiment showed that all subjects almost exclusively chose the SS outcome at all SOA values during both ascending and descending series.

As mentioned, the current procedure did not follow the exact procedure used by Ishii and Sakagami (2002). Some features were excluded or altered. It is possible that the current results were due to these variations. As outlined, the variations included excluding the pseudo-random presentation of two stimuli and the central key to initiate a trial, as well as lengthening the SS reinforcer duration from 1.5 s to 2 s. Amongst all the variations, it is mostly likely to be a result of removing pseudo-random presentation of stimuli. This arrangement was used by Ishii and Sakagami (2002) to eliminate the effect of possible position bias. As this feature was excluded, it is possible that the current findings of exclusive preference for SS outcome were a consequence of a possible position bias. In the current experiment, the left key was only lit green and was associated with the FI schedule and the LL outcome, while the right key was only lit red and was associated with the FR schedule and the SS outcome. If the subjects did prefer the right key extremely, it is possible that the subjects would continue to respond on the right key regardless of the contingencies on the left key. If this was the case, it would explain the exclusive SS choices on the left key.

To establish a position bias, the behaviour of a subject on the two alternatives needed be compared, such as the time the subject spent or the responses the subject made on the two alternatives. The contingencies on the two alternatives need to be the same. For example, free operant access to both alternatives would be an ideal way to test a position bias. Unfortunately, the position bias cannot be established in this case, given that the current procedure employed two different schedules of reinforcement on two keys, and hence, the contingencies on the two alternatives were not equal. However, this does not exclude the possibility of a potential position bias in favour of the right side.

The exact cause of the position bias is currently unknown. One possible source may be heredity. Baum (1974) argued that if the organism's musculature and/or nervous systems were developed with some asymmetry, the asymmetry might contribute to the position bias. One example is the handedness in humans (Baum, 1974). However, it is very unlikely that all six subjects have inherent favour towards the right side.

Another possibility was suggested by Kangas and Branch (2008) that the bias may be a product of past reinforcement history. That is, if the past experiment, in which the subjects served, involved two equal schedules with unequal reinforcer magnitudes, the subjects would develop a position bias, favouring the side key that was associated with the reinforcer with larger magnitude. The acquisition of position bias in this case can occur rapidly. For example, Cumming and Berryman (1961) found that all of their subjects developed a position bias very quickly in their matching to sample experiment. However, it does not seem plausible as the experiment the hens served previously only involved a central key. Thus, it is not likely that the previous experiment would produce a position bias.

It is also possible that the position bias was a result of different response strengths required on two keys (Baum, 1974). That is, if the left key required a more forceful response, the subjects may prefer the right key as it was easier to operate. A post-experiment test on the forces required on the two side keys showed that the left key required 0.83 N while the right key required 0.78 N. However, the difference in the forces required on the two keys was very small. Even if a position bias was due to the unequal forces required on two keys, the bias should not be that extreme.

Although the position bias was not established given the nature of the present procedure, nor did the source of this bias, it is still possible to control the effect of possible position bias if there was one. It is made possible by including the pseudo-random presentation of the two stimuli as used by Ishii and Sakagami (2002). If the position bias was indeed responsible for the exclusive SS choices, the pseudo-random presentation of the two stimuli should result in the subjects sampling the LL outcome when the FI 10 s schedule is presented on the right side.

EXPERIMENT 2

Experiment 1 attempted to use a procedure that is parallel to a real life choice scenario, where an organism may encounter an alternative that has less reinforcing value while waiting for a larger reinforcer. In Experiment 1, this was arranged with the left side key lit green with FI 10 s schedule and 6 s access to reinforcer. The right side key was lit red, and was only associated with FR 1 schedule and 2 s access to reinforcer. The subjects had to make a choice between the two alternatives, but the onsets of two alternatives were not arranged simultaneously, except when the SOA value was 0 s.

The results of Experiment 1 showed that the hens chose the SS outcome exclusively. The obtained results may be a consequence of excluding pseudo-random presentation of the two alternatives. In this case, the effect of a possible position bias was not eliminated. Thus, Experiment 2 will organise pseudo-random distribution of the LL and SS keys between two side keys throughout the forced choice trials and the following free choice trials. Should the position bias be responsible for the results obtained in Experiment 1, the hens would also choose the LL reinforcer in the Experiment 2 when the LL key is presented on the right side.

METHOD

Subjects

Same as Experiment 1.

Apparatus

Same as Experiment 1.

Procedure

Same as Experiment 1 except that both side keys could be lit either red or green. The green colour and the red colour as well as their associated contingencies were randomly and evenly distributed between the two side keys. This arrangement was in effect throughout the forced choice and free choice trials.

RESULTS

The behaviour of each subject was judged stable after completing both ascending and descending series. The order of the series that each of the subjects completed is presented in Table 2. The data from the two series were used to calculate the proportion of the LL outcome chosen for each SOA value for each hen. The proportions of the LL outcome chosen for each SOA value for all subjects were presented in Figure 2.1.

Figure 2.1 shows that the subjects chose the SS outcome exclusively in the current experiment. For example, subjects 92, 93 and 96 did not make any LL choice in both series. Some exceptions can also be noted that subjects 91, 94, and 95 made occasional LL choices in some sessions. However, the proportion of the LL choices from these three subjects did not deviate from 0.0 remarkably.

Table 2
The order of the series completed by each subject in Experiment 2

Hen					
91	92	93	94	95	96
d, a	d, a	d, a	d, a	d, a	d, a

Note. a and *d* indicate the ascending series and the descending series respectively. The 0 s SOA value was not used in both ascending and the descending series due to a programme error.

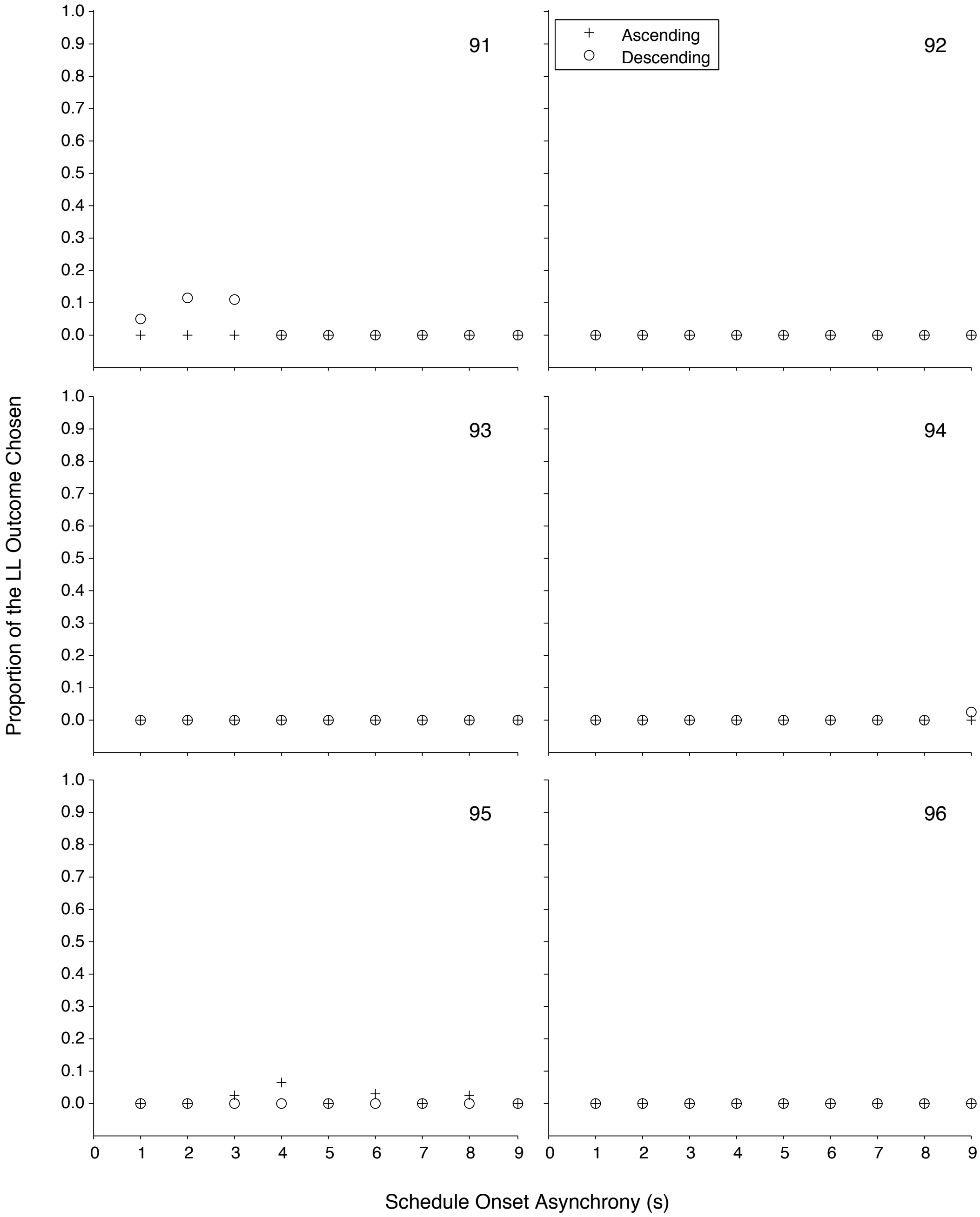

Figure 2.1. Proportion of the LL outcome chosen as a function of the schedule onset asynchrony for each hen in Experiment 2. The cross (+) represents the ascending series, and the circle (○) represents the descending series.

DISCUSSION

In response to the possible position bias held by the subjects, Experiment 2 organised a procedure that used pseudo-random presentation of red and green keys on two sides with their correspondent contingencies as did by Ishii and Sakagami (2002). However, the results of Experiment 2 showed that the distribution of choices did not differ from the findings in Experiment 1. Thus, no position bias was found, and hence, it could not be responsible for the results in Experiment 1.

However, this does not exclude the possibility of other biases, such as a colour bias. The colour associated with the FI 10 s schedule was green and the colour associated with the FR 1 schedule was red throughout both experiments. If the subjects favour the red colour over the green colour for some reason, they are likely to respond on the SS key more often. However, due to the current procedural arrangement, this bias cannot be established either. Similar to position bias, the exact cause of the colour bias is unknown but it is likely to be heredity (Baum, 1974), or past reinforcement history with a colour (Kangas & Branch, 2008). Nevertheless, it is possible to arrange two different colours to eliminate the possible bias in favour of the green colour.

Moreover, as the current experimental procedure was still not exactly the same as the procedure used by Ishii and Sakagami (2002), other variations to their procedure may be responsible for the current results. Ishii and Sakagami (2002) employed a central key in their procedure. The subjects had to make a response on it to initiate a trial. It is unclear how the exclusion of the central key would be a source of the current results. As the onset of the LL key was also the start of a trial, it was assumed that the onset of the LL key should signal the start of a trial by default. However, it is noted that where a forced choice trial only involved the presentation of the SS key, there was no signal indicating the start of that trial. Thus, the contingencies the subjects experienced in the forced choice trials may not be the same as the contingencies experienced in the free choice trials. Accordingly, it seems appropriate to organise a central key so that the subjects are required to make a response to initiate a trial.

The other variation was using 2 s reinforcer duration as the SS outcome instead of 1.5 s reinforcer duration used by Ishii and Sakagami (2002). This variation should not have produced the current results. According to the discounting framework, a discounting function of the LL outcome should exist regardless of the different sizes of the SS outcome. Moreover, as mentioned, 2 s reinforcer duration is often used as the SS outcome in self-control experiments with hens as subjects (e.g., McEwan, 1989; McBriar, 1999). Other studies using pigeons as subjects also used 2 s reinforcer duration as the SS outcome, such as Green et al. (1981). Thus, it does not seem necessary to shorten the 2 s reinforcer duration.

The results in Experiment 1 and Experiment 2 showed that the subjects chose the SS outcome regardless of the changing SOA values. For most of the subjects, the number of the trials in which they encountered the LL outcome was about four out of a total of 48 trials per session. Thus, it seemed necessary to organise several days of forced choice trials to "remind" them of the LL outcome associated with the LL key.

Overall, the current results continued to show that the subjects exclusively chose the SS outcome, irrespective of the different SOA values. It was suggested that the possible colour bias might be a source of the current results. The possible colour bias should be eliminated by replacing the red and green colours. Also, since the current procedure varied from Ishii and Sakagami (2002), it seemed that the variations might be responsible for the current results. Hence, the Experiment 3 will employ a central key to initiate a trial. Although the reinforcer duration used in the current experiment differed from that used in Ishii and Sakagami (2002), it should not have caused the exclusive preference for the SS outcome. Finally, in order to make the subjects experience the LL outcome more often, a number of sessions involving only forced choice trials will be organised in Experiment 3.

EXPERIMENT 3

The previous two experiments both resulted in subjects choosing SS outcome exclusively across different SOA values, which did not replicate the results obtained by Ishii and Sakagami (2002). Several possible problems that contributing to these results were suggested, including possible colour bias, as well as excluding a central key to initiate a trial.

In response to the possible colour bias, the present experiment will use yellow and blue keys to replace the previous green and red keys. Although hypothetically, different colours may be preferred at the same time, it seemed highly unlikely that the subjects will prefer both the previous green colour and the new colours. A central key will also be introduced in the current experiment so that the hens will have to make a response on this key to start a trial as arranged by Ishii and Sakagami (2002). Finally, six days of forced choice trial sessions were organised to ensure the subjects experienced the LL outcome.

METHOD

Subjects

Same as Experiment 2.

Apparatus

Same as Experiment 2, except that both side keys could be either lit blue or yellow, instead of red or green. The yellow key was associated with the FI 10 schedule and the LL outcome. Thus, the yellow key was the new LL key. The blue key was associated with the FR 1 schedule and the SS outcome, and hence, it was the SS key. The central key that was previously installed (see Method in Experiment 1) was operative in this experiment.

Procedure

Before the commencement of Experiment 3, six days of forced choice trials training sessions were conducted. One session consisted of 20 trials. Each trial started with the central key lit white, requiring a single peck to initiate the trial. In each trial, either of the LL or SS key was lit. In half of the trials, only the SS key was presented, while in the other half of the trials, only the LL key was presented. The presentation of the either key was distributed randomly and evenly between both sides across all trials. In the trials where SS key was presented, each of the 10 SOA values was used. The order of the 10 SOA values was randomly determined.

The experiment sessions were run the same as Experiment 2, except that the central key was lit white before each trial, including forced choice trials. A peck on the central key was required to initiate the trial. Moreover, the blue and yellow keys were used instead of the red and green keys. The blue key and the yellow key were distributed randomly and evenly between both sides across the forced choice trials and the free choice trials, as organised in Experiment 2.

RESULTS

The performance of each subject was judged to be stable when two series had produced similar data. The order in which the ascending and descending series were completed is presented in Table 3. The data from the last ascending and descending series for each subject were used to calculate the following: the proportion of the LL choices made at each SOA value; the number of the LL responses and the corresponding response rate; the latency of the SS choice; the number of the LL responses between the onset of SS key and SS responses (called the switching responses); as well as the cumulative responses on the LL key per trial.

Figure 3.1 shows the proportion of the LL choices as a function of the changing SOA in the last two series. The SS outcome continued to be chosen almost every time in the present experiment across all subjects except subject 92. Specifically, in both series the proportion of the LL choices made by subject 96 was 0.0 regardless of the SOA values. For subjects 91, 93, 94 and 95, results also showed that these hens exclusively chose the SS outcome in both series with only few occasional sampling of the LL outcome. However, the results for subject 92 showed relatively higher proportions of LL choices than other subjects. Notably, in the descending series, the proportion reached 0.42 when 2 s SOA was used.

Table 3
The order of the series completed by each subject in Experiment 3

Hen					
91	92	93	94	95	96
d, a, d	d, a, d, a, d	d, a, d, a	d, a, d	d, a, d	d, a, d

Note. a and *d* indicate the ascending series and the descending series respectively.

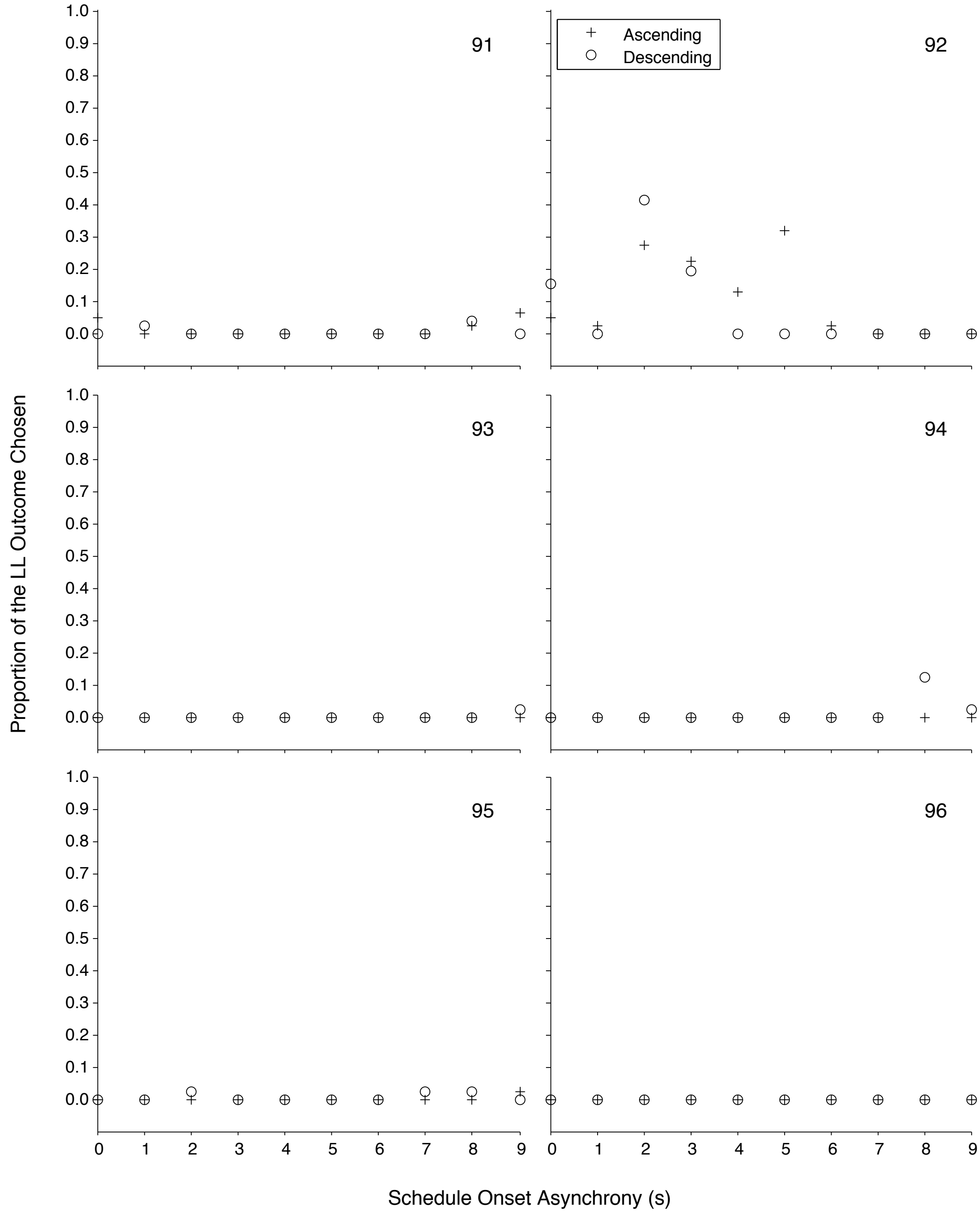

Figure 3.1. Proportion of the LL outcome chosen as a function of the schedule onset asynchrony for each hen in Experiment 3. The cross (+) represents the ascending series, and the circle (○) represents the descending series.

Moreover, the proportions of LL choices made by subject 92 seemed to be negatively correlated with the SOA values. That is, relatively higher proportions of LL choices were noted when the smaller SOA values were used. Nevertheless, this relation was not clear as much lower proportions can be seen when 0 and 1 s SOA values were in effect, compared to the proportions obtained when 2 and 3 s SOA values were used.

Figure 3.2 presents the response rate on the LL key for each SOA value in the last ascending and descending series. Figure 3.3 is the corresponding mean number of responses on the LL key for each SOA value in both series. Figure 3.2 showed that the response rates by all subjects generally increased as the SOA value increased. Likewise, Figure 3.3 showed that the session mean number of responses on LL key increased as the SOA increased. However, it is notable that the mean number of responses on the LL key was very small for all subjects apart from the results for subject 96 under the condition where the SOA values were smaller than 4 s. For example, the mean numbers of responses on the LL key by subject 94 remained very close to 0.0 when the SOA values were 0 to 4 s. This was also reflected in Figure 3.2 that the subjects 91 to 95 generated much lower response rates compared to subject 96.

Figure 3.4 presents mean latency to respond on the SS key after its onset for each SOA value in the both series. It can be noticed that the latencies to make the SS response were mostly within 2 s. The exceptions were that the mean latencies were around 2.5 to 3.5 s when the SOA values were 2 and 3 s for subject 91. For subjects 93, 95 and 96, the latencies of the SS response were around 1 s at all SOA values. Across all subjects, the latencies were not related to the increment of the SOA value.

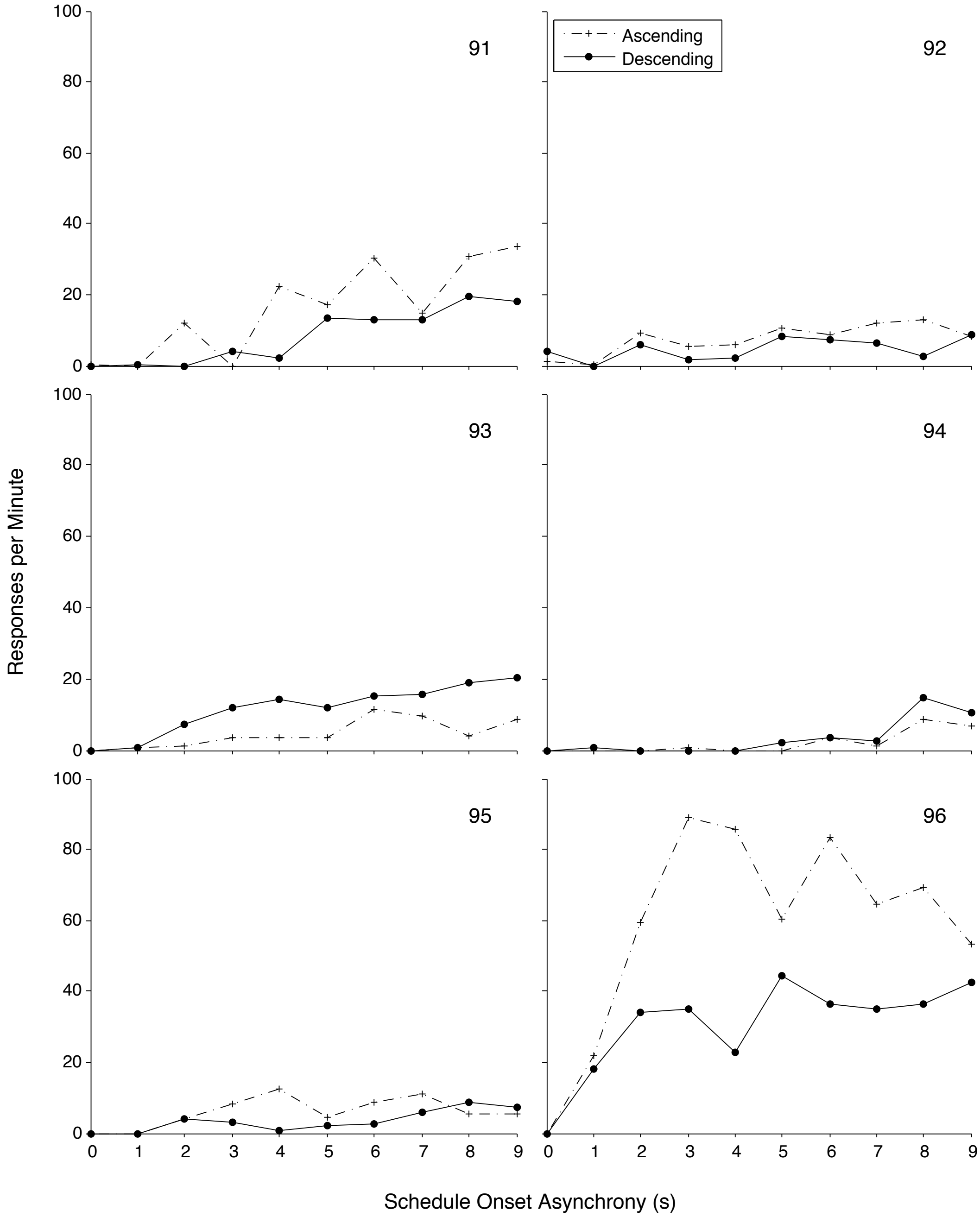

Figure 3.2. Responses rate on the LL key for each hen of the last two series of each SOA value in Experiment 3. The cross (+) represents the ascending series, and the filled circle (●) represents the descending series.

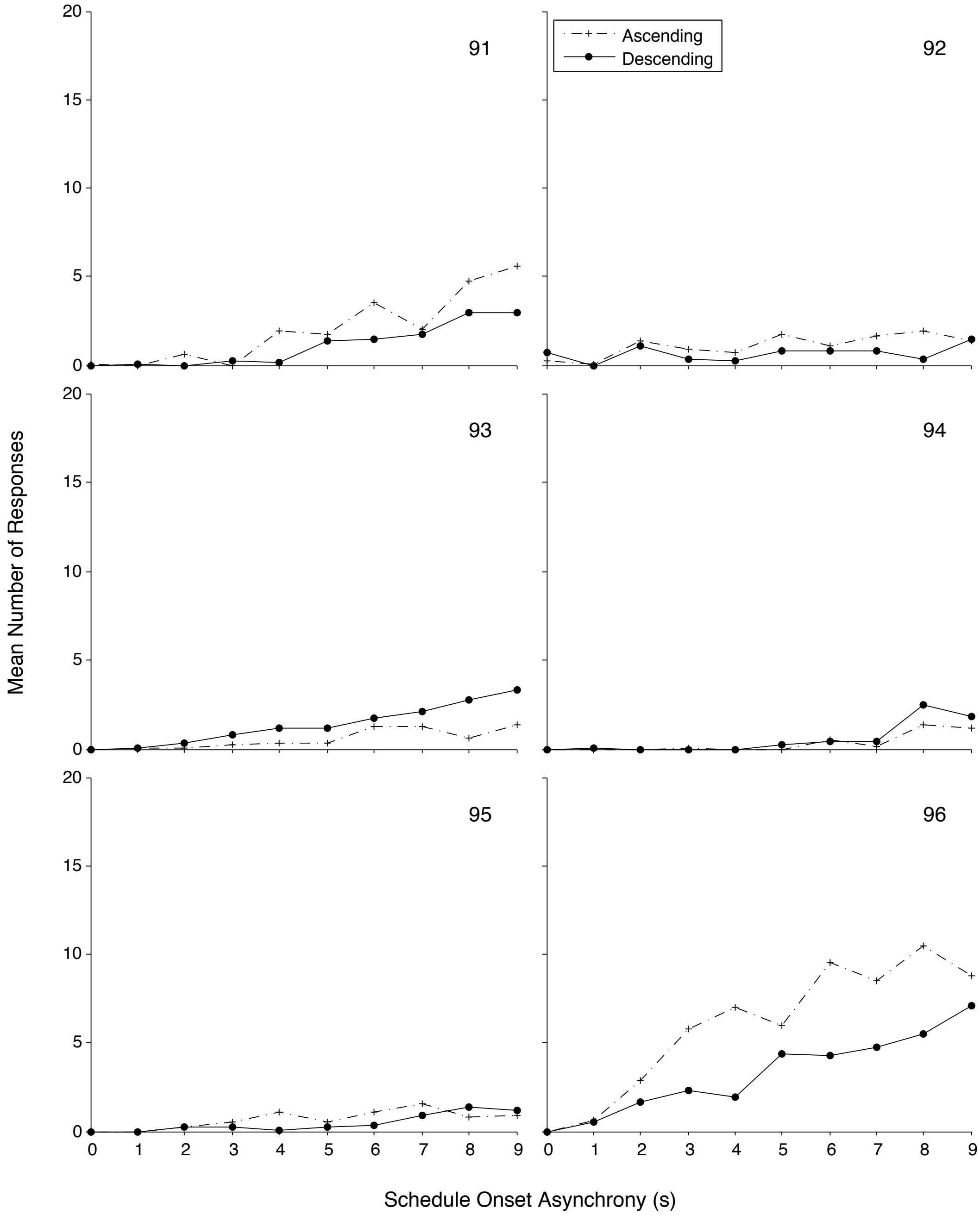

Figure 3.3. Mean number of responses on the LL key for each hen of the last two series of each SOA value in Experiment 3. The cross (+) represents the ascending series, and the filled circle (●) represents the descending series.

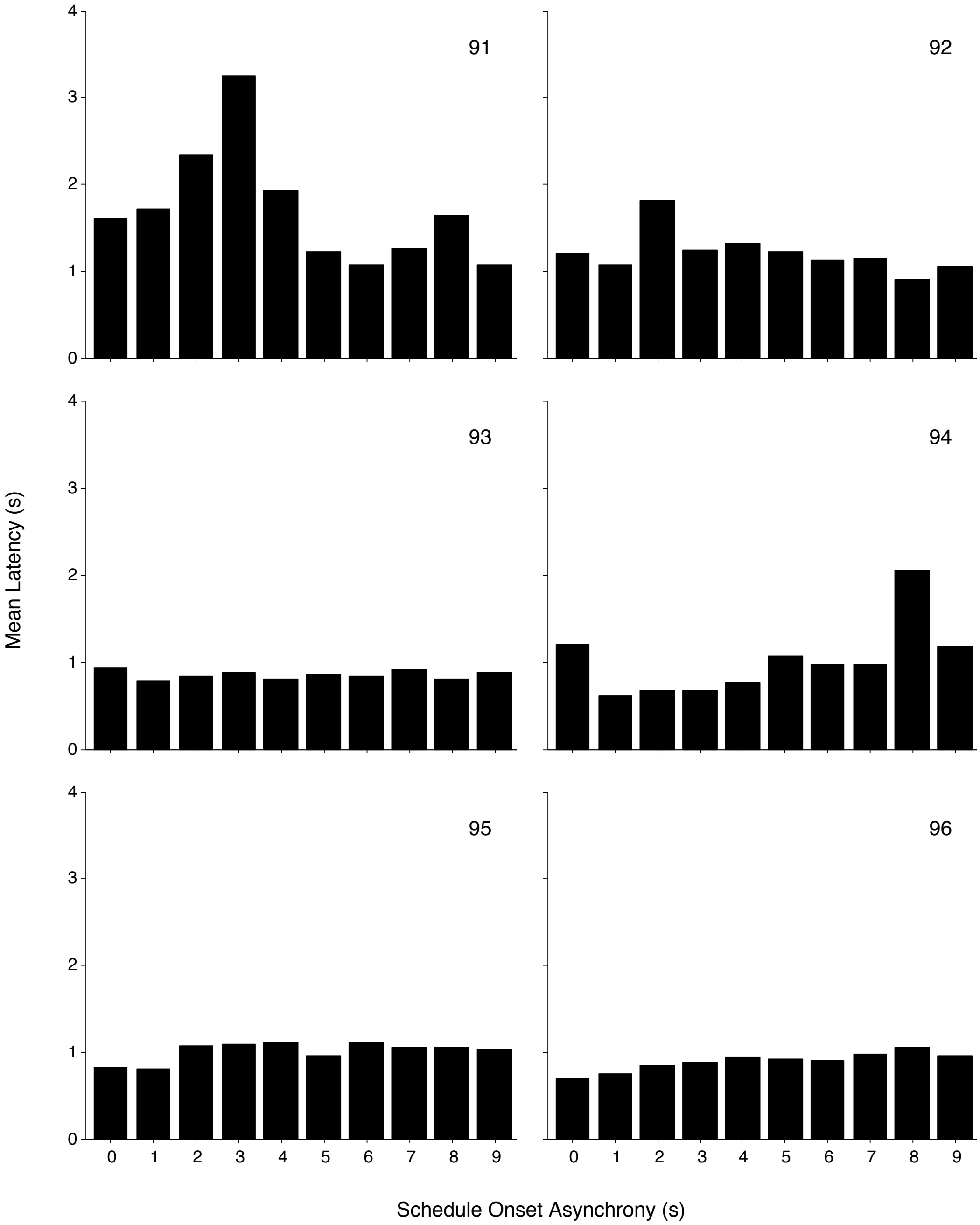

Figure 3.4. Mean latency to respond on the SS key after its onset for each hen of the last two series of each SOA value in Experiment 3.

Figure 3.5 presents the mean number of the switching responses. For each subject, the mean number of switching responses was small. There was an increasing mean number of switching responses as the SOA increased. Overall, all subjects tended respond on the SS key after its onset with rare occasions where they responded on the LL key first before the SS response.

Figure 3.6 and Figure 3.7 present cumulative responses on the LL key before the onset of SS key. The data in Figure 3.6 were taken from the 9 s SOA session in the last ascending series, while the data in Figure 3.7 were from the 9 s SOA session of the last descending series. Both figures showed that the subjects tended to either respond on the LL key before SS key onset in a constant and steady pattern, or not respond on the LL key at all. Although the sessions of the other SOA values were not analysed, significant differences were not expected as there were generally very low numbers of responses made on the LL key. Further analysis of the data taken from Experiment 1 and Experiment 2 also showed similar results.

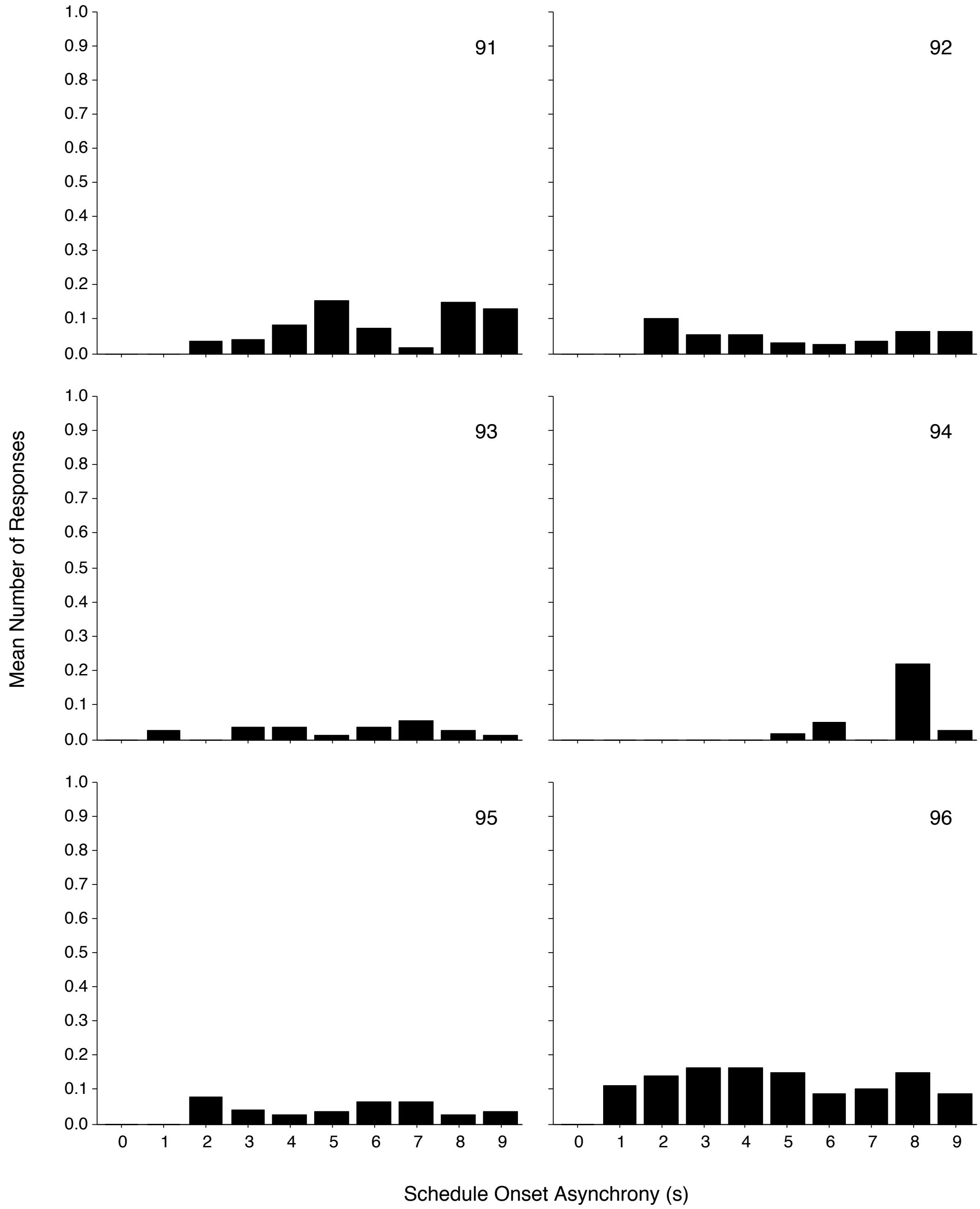

Figure 3.5. Mean number of responses made on the LL key between the onset of the SS key and the SS response on trial basis for each hen of the last two series of each SOA value in Experiment 3.

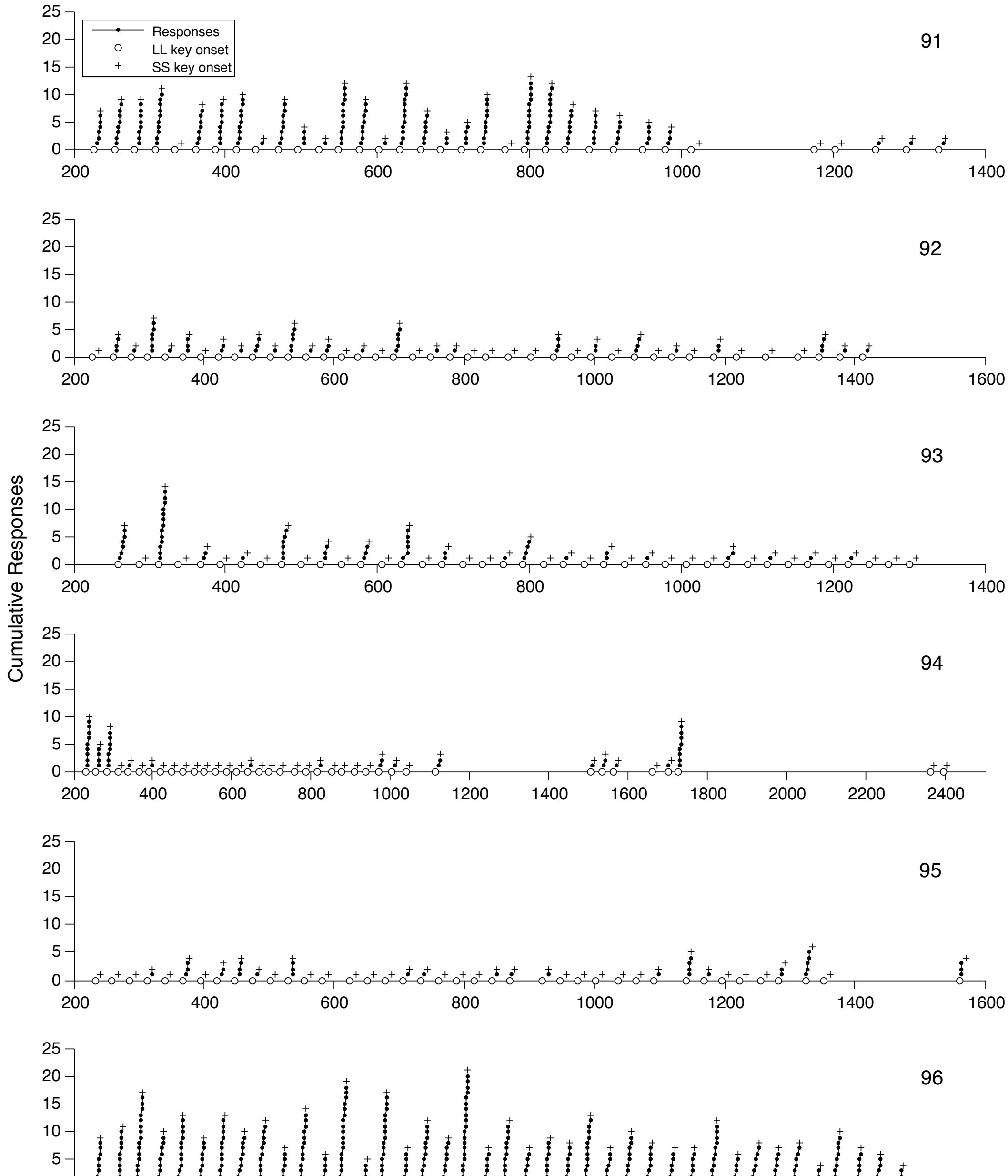

Figure 3.6. Cumulative responses on the LL key between the onset of the LL and the SS keys from the 9 s SOA session of the last ascending series for each subject in Experiment 3. The unfilled circle (○) represents the onset of the LL key, the linked filled circle (●) represents the cumulative number of responses made on the LL key, and the cross (+) represents the onset of the SS key.

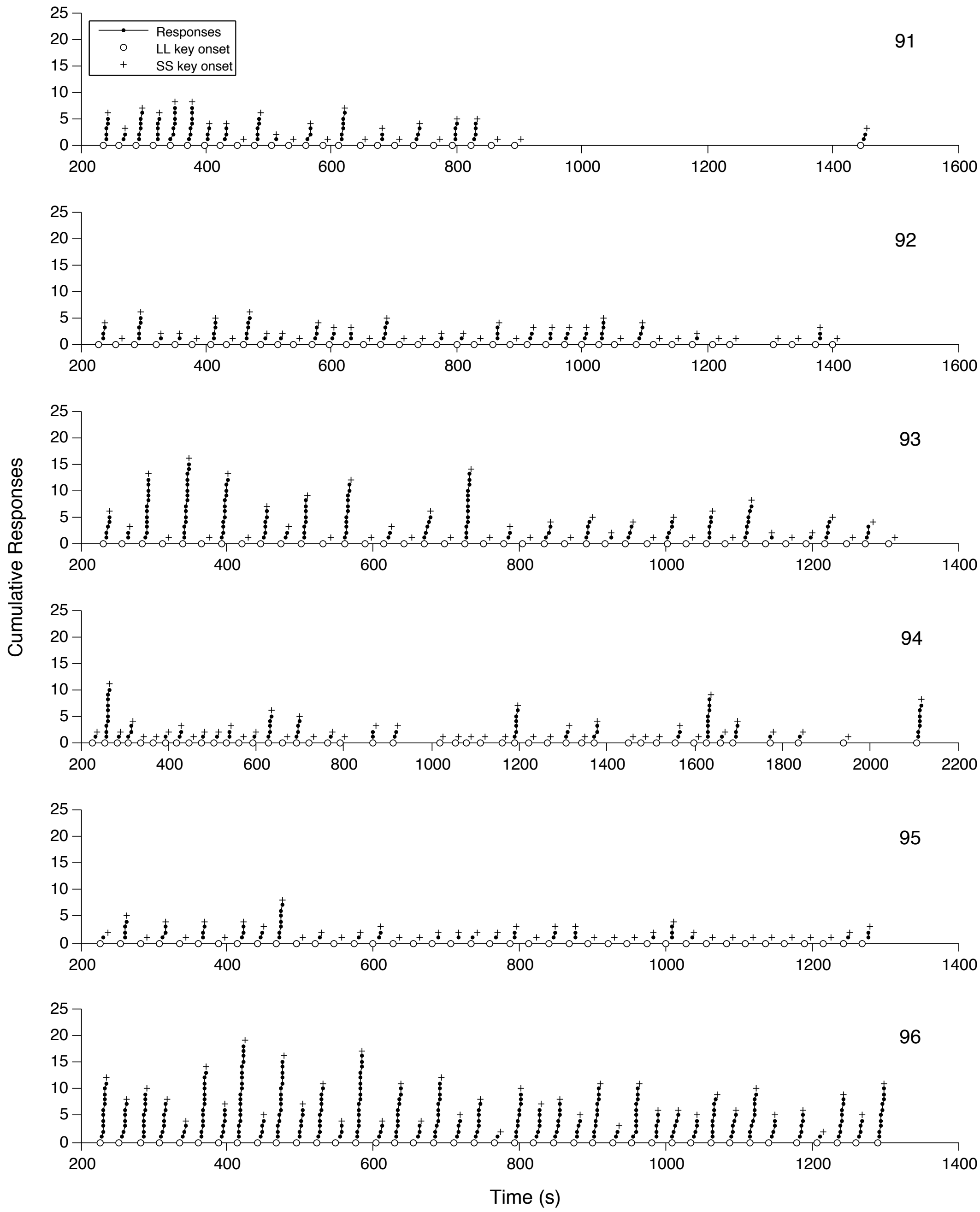

Figure 3.7. Cumulative responses on the LL key between the onset of the LL and the SS keys from the 9 s SOA session of the last descending series for each subject in Experiment 3. The unfilled circle (○) represents the onset of the LL key, the linked filled circle (●) represents the cumulative number of responses made on the LL key, and the cross (+) represents the onset of the SS key.

DISCUSSION

Experiment 3 attempted to address the possible problems that might have led to the SS outcome being exclusively chosen in the last two experiments. Possible colour bias was addressed by replacing red and green colours with blue and yellow colours. The previously excluded central key was included in the current procedure as used by Ishii and Sakagami (2002) to account for any possible effects of this variation on the results. Also, six days of forced choice trials were arranged to ensure the subjects experienced the LL outcome.

While Ishii and Sakagami (2002) showed changes in preference as the SOA value increased, the present study continued to show that the SS outcome was almost exclusively chosen by all subjects at all SOA values with the exception of subject 92. The proportion of LL choices for subject 92 was larger when the SOA values were smaller. That is, her performance was the opposite of the results obtained by Ishii and Sakagami (2002) and the prediction made by the discounting framework (see Figure 0.1). It is unclear why subject 92's performance deviated from rest of the subjects as the same contingencies applied to all the hens.

As previously noted, the response rates on the LL key for all subjects were not high. Specifically, the response rate was under 20 responses per minute on average for at least four out of six subjects. In contrast, Ishii and Sakagami (2002) showed that for three of their subjects, the response rate was more than 100 responses per minute on average, with one pigeon producing around 200 responses per minute when the SOA increased. The remaining two of their subjects responded around 60 to 70 responses per minute on average. It may be argued that the domestic hens may be slower in responding, and hence, did not produce similar response rates. However, Foster, Blackman and Temple (1997) used domestic hens in their study, and reported response rates up to around 200 responses per minute. Although the current subjects were capable to produce a response rate comparable to pigeons, their response rates were much lower than those reported by Ishii and Sakagami (2002). Moreover, with low number of responses made on the LL key seen in Figure 3.3, particularly when the smaller SOA values were used, it seemed that most of the subjects often just waited for the onset of the SS key without attempts to respond on the LL key. This was also confirmed in Figure 3.6 and Figure 3.7, in which it is noted that during some trials, the hens simply waited for the onset of SS key without responding on the LL key. Nevertheless, both the current study and Ishii and Sakagami (2002) showed that the response rates either increased or stayed about the same as the SOA increased.

Analysis of the latencies of SS choices (Figure 3.4) and mean number of switching responses (Figure 3.5) suggested that all subjects tended to make an SS response within 1 to 2 s after the onset of SS key with rare occasional switching responses made within 1 to 2 s. Ishii and Sakagami (2002) presented the switching responses on session basis, and thus, it seemed that there were more responses in total than the current study. However, if their results were calculated based on the average number of switching responses per trial as was done in the current study, their findings on the switching responses for most of their subjects should be comparable to the current results. However, some differences are noted. The number of LL responses decreased in general as the SOA value increased in Ishii and Sakagami (2002), while the current study showed that the number of responses either increased or stayed similar as the SOA increased. This difference may be a result of dependent measures of the proportion of SS choices and of the switching responses. To measure these switching responses, two following conditions needed to be met: the SS key onset and the SS choice. Thus, the decreasing number of switching responses in Ishii and Sakagami (2002) was a direct result of less SS choices made as SOA increased. This was not the case in the current study as the current subjects continued to choose SS outcome regardless of the different SOA values.

Breakdown of the events in the trials at the 9 s SOA in the last two series (Figure 3.6 and Figure 3.7) was to investigate the LL responding pattern. As all subjects had experienced the contingencies on the LL key, it should be assumed that the responding on the LL key was under the control of the contingencies on the LL key. Thus, the responding on the LL key should resemble the performance under a typical FI schedule. In other words, the response rates should accelerate as a function of delay to LL outcome (called FI scalloped pattern, see Ferster and Skinner, 1957). However, it is clearly not the case as the subjects either responded on the LL key in a constant and steady fashion or made only few or no responses on the LL key.

It may be argued that the current subjects were not sensitive to the passage of time. However, Taylor, Haskell, Appleby and Waran (2002) investigated the timing ability of domestic hens. Their results showed that the response rate accelerated when the time to the expected reinforcer was shortened. They concluded that domestic hens should be able to estimate when the reinforcer would be available, if there was a signal indicating the forthcoming reinforcer several minutes in advance. Thus, it seemed these current subjects should be able to estimate the delay.

This finding of lack of FI scalloped response pattern may be a result of the later onset of SS key. Theoretically, the responses on the LL key should be under the control of the contingencies on the LL key regardless of the contingencies on the SS key. However, Ferster and Skinner (1957) reported that in a concurrent schedule, when a response on one key is followed by a previously reinforced response on the other, the responses on that key would not only be under the control of the contingencies associated with that key but also under the control of the contingencies associated with the other key. In other words, the response pattern will be changed as the responses became controlled by the contingencies on both keys. This seemed to explain the lack of FI scalloped response pattern on the LL key as observed in Figure 3.6 and Figure 3.7. How well this argument can be applied to the current study is not clear. As Ishii and Sakagami (2002) did not report the cumulative responses in the trials, a comparison cannot be made. However, this should support the possibility that the later onset of SS key may actually change the responses on the LL key.

The above argument raises the possibility that the current results were actually due to the procedure employed. As noted, the present procedure failed to demonstrate changes in preference. However, conventional self-control studies with different procedural components have repeatedly shown preference shifts as a function of delay, such as Rachlin and Green (1972) and Green et al. (1981). Thus, comparison between the two procedures may address the question as to whether the current findings were a consequence of using an unconventional procedure.

First, the current study used an asynchronous presentation of the two keys (and hence a part of research question in the beginning) while a conventional self-control study uses simultaneous presentation of the two stimuli (e.g., Rachlin & Green, 1972; Green et al., 1981). As discussed, the arrangement of the later onset of SS key may change the response pattern on the LL key. However, in concurrent schedules, subjects tend to switch from one key to the other, and they can always switch back. Thus, the subjects can maximise the total payoff through switching, and hence, the responses on one key would also be under the control of the other (Ferster & Skinner, 1957). However, in the current procedure, switching from the LL key to the SS key would only minimise the payoff since only the SS outcome would be available. Thus, although it is possible that the changed FI response pattern may be due to the SS key, it is unclear if the choice making would be affected by the later onset of SS key.

Second, in a conventional self-control procedure, two FR 1 schedules on two keys (i.e., discrete trial procedure) are organised. A response on either of them would be a choice, making the other option unavailable, but the current study used an FI 10 s schedule associated with the LL key and an FR 1 schedule associated with the SS key. A response on the LL key after SS key onset will not terminate the SS key, thus making SS key constantly available until the receipt of either reinforcer. A literature search revealed some comparable studies using similar schedule arrangements. An early study by Ainslie (1974) organised a procedure in which pigeons could wait for an LL outcome or respond on a key to receive an SS outcome. The waiting for the LL outcome could not terminate the SS alternative. As a result, the SS outcome was constantly available until either outcome was available. His results showed that in 95% of the trials, eight out of 10 subjects responded on the SS key and received the SS outcome. Thus, it seems that having an alternative always available during the waiting may enhance impulsivity.

Another experiment by Logue and Peña-Correal (1984) involved a similar procedure with varied delay to reinforcer. They organised two keys. A response on the left key would lead to an LL outcome after a delay period. However, this response did not affect the presence of the right key, the SS key, but a response on the SS key would terminate two keys and lead to an SS outcome after 0.11 s delay. Logue and Peña-Correal (1984) then used a fading procedure similar to the one that Mazur and Logue (1978) used, in which the delay to LL outcome was gradually increased from 0.11 to 6 s. This procedure was designed to enhance self-control. For example, Mazur and Logue (1978) found that the LL outcome was always preferred when they decreased the delay to SS outcome.

In order to make sense of the data obtained by Logue and Peña-Correal (1984), two different choices, initial LL choice and final LL choice, were defined. Initial LL choice was defined as a subject pecking the LL key. Final LL choice was that the response on the LL key which led to the LL outcome. They reported that when the delay to the LL outcome increased to 6 s, the final LL choices differed from the results obtained by Mazur and Logue (1978) significantly. Specifically, for three out of eight subjects, the receipt of the LL outcome decreased to less than 10% of all outcomes. However, when the initial LL choices were examined, it was found that they did not differ from the results obtained by Mazur and Logue (1978) significantly. In other words, the switching responses from the LL key to the SS key may be related to the results they obtained. Logue and Peña-Correal (1984) argued that with a constantly available SS key, subjects would be more impulsive as they always have the opportunity to switch choices.

This arrangement may be responsible for some of the data in the current study. As some switching responses were seen, if the current study had employed one response requirement on the LL key after the SS key onset, more LL choices would have been made.

However, if the above procedural components were not responsible for the continuous exclusive SS choices, a theoretical question is raised as to when the point of shifting preference would be in the current study. According to Figure 0.1, it seemed that the temporal discounting account would be able to predict the shifts in preference at Time 2, but then the question is when this Time 2 was in the current experiment. In order to answer this question, the above-mentioned mathematical models of temporal discounting functions were turned to. Unfortunately, all models of discounting require a known discounting variable, *K*, in order to make a prediction, but the *K* value could not be derived until some data were available to put into the formula. That is, the prediction is really just a description. Also, to have the subjective value of LL outcome to be 0.0, all temporal discounting models would require the amount variable, *A*, to be 0.0 (see Equation 2), which was clearly not the case here. Although one may argue if *K* was extremely big so that the whole dominator was extremely big, it should give a *V* value close 0.0. Nevertheless, it must be noted that there was no function produced in the current experiment (i.e., *V* did not change across the SOA values), and thus, none of the temporal discounting functions would be able to describe the exclusive SS choices across all SOA values. Thus, the discounting functions are not able to either predict the shifting point or describe the current results. Thus, to answer this question, other choice models should be explored.

Another influential choice model for predicting and describing the choices when an organism faces two alternatives is the matching law. This model was not consulted previously. However, due to the inability of temporal discounting to predict or describe in current data, the matching law is called for help. The matching law was proposed by Herrnstein (1961). He found that the proportion of the responses distributed to a schedule matched the proportion of reinforcement obtained under that schedule. Herrnstein (1961) then expressed this relation mathematically as:

$$\frac{B_1}{B_1 + B_2} = \frac{R_1}{R_1 + R_2} \,, \qquad (7)$$

where B is the behaviour (e.g., responses or time spent on responding), and R is the reinforcement.

Later, Baum and Rachlin (1969) introduced the concatenated matching law to predict and describe preference when two alternatives differ on several dimensions such as delay and reinforcer magnitude. Their new model is expressed as:

$$\frac{B_1}{B_2} = \frac{R_1}{R_2} \bullet \frac{A_1}{A_2} \bullet \frac{D_2}{D_1} \,. \qquad (8)$$

In this new model, the behaviour, B is positively related to the rate, R, and the magnitude of the reinforcement, A. Notably, the behaviour is inversely related to the delay to reinforcement, D. In other words, the longer the delay is under one schedule, the fewer the responses will be made under that schedule.

In a self-control paradigm, only one reinforcer is accessible after making a response, and hence, the reinforcement rate, R, is 1. Thus, the concatenated matching law reduces to the following equation (Rachlin & Green, 1972):

$$\frac{B_{LL}}{B_{SS}} = \frac{A_{LL}}{A_{SS}} \bullet \frac{D_{SS}}{D_{LL}} . \tag{9}$$

To date, the self-control version of the concatenated matching law has been successful in predicting and describing laboratory self-control results, such as Navarick and Fantino (1976) and Rachlin and Green (1972).

Similar to the temporal discounting framework, it has been noted that he generalised matching law with free parameters to exponentiate the dimensional variables (e.g., *A* and *D*), would provide better description of the results (e.g., Green & Snyderman, 1980). However, the inclusion of free parameters would limit the prediction power of the model if no data were generated before the use the generalised matching law. Nevertheless, whether adding free parameters or not, the prediction of current results would be the same. This is due the immediacy to SS outcome in the current experiment. Since the SS outcome was available right after a response on the SS key across all the SOA values, D_{SS} would be 0 s for all SOA. According to the matching law (Equation 9), B_{LL} would always be 0.0 with or without power functions. Therefore, the matching law will predict exclusive SS choices at all SOA values, and hence, will predict that no discounting functions can be observed. This should explain the current results that the LL outcome was rarely chosen and there were generally no LL response after the onset of SS key (see Figure 3.5).

Nevertheless, Mazur (2000) argued that it would take 0.5 s for pigeons to move from the response key to the magazine. It seemed that 0.5 s delay to reinforcer should be taken into account. However, in the current study, the availability of the reinforcer was signalled by the magazine light alongside the presentation of the reinforcer. The magazine light should be considered as a secondary reinforcer as a result of continuous pairing with the primary reinforcer

(Cooper, Heron & Heward, 2007), and hence, the delay to the SS outcome should be considered to be 0 s. In fact, Mazur (2000) included 0.5 s delay to the SS outcome in his procedure in order to provide sufficient time for the subjects to move to the magazine. Thus, it seems plausible that the current results may be due to the value of the delay parameter. In other words, the delay to SS outcome should increase in order to generate shifts in preference as a function of different SOA values.

However, there have been results not consistent with the matching law prediction. For example, Davison and McCarthy (1988) noticed that the matching law failed to predict the results from the fading procedure used by Mazur and Logue (1978). Moreover, Ishii and Sakagami (2002) did demonstrate systematic shifts in preference in their results with the use of 0 s delay to SS outcome. Thus, although the matching law prediction is a plausible account to the current results, it does seem to be premature to conclude that the exclusive SS choices were due to 0 s delay to SS outcome.

However, if the unconventional procedural components and/or the use of 0 s delay to SS outcome were responsible for the current data, the variations made in the Experiment 1, the corrections to these variations in Experiment 2 and Experiment 3, as well as replacing the two colours were irrelevant to the results. This should explain why the data obtained in all three experiments were extremely similar,

In addition to the above accounts, it should be noted that species employed by Ishii and Sakagami (2002) were pigeons while the current study used domestic hens. If species difference did exist, it may be able to explain the difference between the results obtained by Ishii and Sakagami (2002) and the current results.

Lowe and Harzem (1977) compared the responding performances of rats and pigeons under FT schedules. As FT requires no response, the reinforcer is not contingent on responses, and consequently, decreasing cost by not responding would be the best strategy. Their results showed that the rats quickly learned to decrease, and they eventually ceased responding while pigeons continued to respond. It seemed that the learning ability seemed to differ significantly across the species. If the learning of domestic hens was somehow slower than pigeons, the procedure would need to be modified to suit the ability of the hens. In current study, the SOA value either increased or decreased session by session, if the subjects' behaviour failed to come under the control of the new SOA value quickly after the change, their performance would be interrupted by the contingencies associated with other SOA values. That is, they may fail to discriminate across the different SOA values quickly, despite that they have the ability to estimate the delay. Likewise, since the subjects experienced the SS outcome most of the time (and thus the contingencies associated with the SS key), fewer opportunities were provided for the subjects to experience the LL outcome. Thus, it is also possible that the performance did not come under the control of the contingencies on the LL key at all. If this is true, it may explain the lack of the FI scalloped response pattern seen above.

Tobin and Logue (1994) demonstrated that pigeons were more impulsive than rats while both pigeons and rats were more impulsive than human, when food was offered as a reinforcer. In other words, the degree of self-control differed across different species. Hence, it is reasonable to expect different degrees of self-control between pigeons and domestic hens. However, it is unclear why the differences were so large.

Overall, several accounts of possible sources responsible for the current results were discussed, including the use of the unconventional self-control procedure, 0 s delay to SS outcome, as well as possible species differences. In order to investigate which account is most plausible, in Experiment 4, the domestic hens will be placed in a conventional self-control procedure as used by Green et al. (1981). Thus, the two stimuli will be presented simultaneously with only one response required to make a choice and the delay to SS outcome will be relatively longer. Since Green et al. (1981) also used pigeons in their study, if the domestic hens choose the SS outcome exclusively in this procedure, a species difference may be concluded as a source for the exclusive SS choices in Experiment 1 to Experiment 3. If the hens shift preference so that the LL outcome becomes preferred as T increases, it is possible that the current results were a consequence of using an unconventional self-control procedure and/or the 0 s delay to SS outcome.

EXPERIMENT 4

The previous three experiments all produced data showing exclusive choices for the SS outcome. It was suggested that the previous experiments did not produce shifts in preference due to the unconventional self-control procedural components, the 0 s delay to SS outcome, or the different species being used in the current study. However, it was not conclusive which of the above accounts was responsible for the results in these experiments. To address this question, it is necessary to investigate if a conventional self-control procedure would produce shifts in preference with domestic hens.

Experiment 4 will replicate Green et al. (1981) using a conventional self-control procedure based on discrete trials. In Green et al. (1981), pigeons had to make one response to choose between two alternatives that were simultaneously presented. The delays to both outcomes were longer than 0 s. Thus, if the performance by the hens is comparable to the performance by the pigeons in Green et al. (1981), it is possible that the procedure used in Ishii and Sakagami (2002) may not be able to produce changes in preference. If the species difference was the reason for the previous data, the performance by the hens should continue to show impulsivity as they did in the previous experiments.

The performance of the previous subjects may be affected by the contingencies in Experiment 1 to Experiment 3. In other words, they may continue to choose the SS outcome exclusively as a result of the previous reinforcement history. Thus, six new hens will also be employed to see if they will demonstrate self-control, and hence, will serve to examine if the previous reinforcement history will affect the choices made by previously employed subjects in Experiment 4.

METHOD

Subjects

In addition to subjects 91 to 96 from the previous three experiments, another five Brown Shaver hens (numbered 101, 102, 103, 104 and 106) served in this experiment. All five new hens were approximately three years old at the commencement of this experiment, and had all participated in experiments previously. The weights, feed and conditions that the new hens housed were all the same as those for subjects 91 to 96.

Apparatus

Same as Experiment 1, with the houselight (see Method in Experiment 1) operative in this experiment.

Procedure

An experimental session consisted of 16 forced choice trials preceding 44 free choice trials. It was completed when all trials had finished or 40 min had passed.

The sequence of experimental events in a free choice trial was presented in Figure 4.1. Each free choice trial lasted for 30 s, and was followed by 10 s outcome period. A trial started with the onset of houselight. *T* was the time between onset of keys and the end of trial period, and varied between 2 and 28 s. After 30 – *T* s, both side keys were lit. The side keys in this experiment could be lit either red or green. The red key was associated with 2 s access to wheat (the SS outcome) and the following 8 s blackout in the outcome period. Thus, the red key was the SS key. The green key was associated with 4 s blackout followed by 6 s

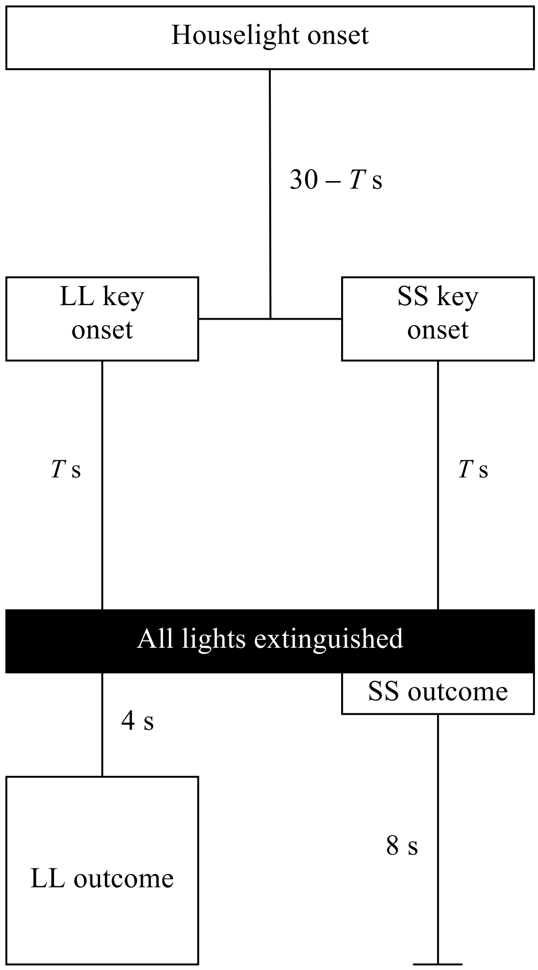

Figure 4.1. The sequence of the experimental events in a free choice trial for Experiment 4.

access to wheat (the LL outcome). Thus, the green key was the LL key. The two colours, their associated contingencies and the correspondent outcome periods were randomly and evenly distributed between the two sides. Once the subject had made a choice by making a response on either of lit keys, the other key was extinguished immediately, and only houselight and the chosen key were lit until the end of trial period. A subject could respond on the chosen key during *T* s delay but responding had no effect. Once *T* s delay had passed, the houselight was extinguished and 10 s outcome period started. Whether the SS or LL outcome period was in effect depended on the key the subject had pecked in the trial period. For example, if the subject responded on the SS key, only the SS key and the houselight would be lit. After *T* s delay, the houselight would be extinguished and the SS outcome would become available without any further delay, followed by 8 s blackout. If the LL key was chosen in the trial period, after *T* s delay, 4 s blackout would be in effect, followed by the LL outcome. If no response was made during a trial, this trial was regarded as an aborted trial and ended with 10 s blackout.

The preceding 16 forced choice trials were only different from the free choice trials in that only one key was lit during a forced choice trial. Either of the SS and LL keys and its correspondent contingencies were effective in half of the forced choice trials.

In Green et al. (1981), the time, *T*, varied across seven values. Due to the time constraints, only two extreme values, 2 and 28 s from Green et al. (1981) were used in order to show if the domestic hens would demonstrate preference shifts quickly. In Green et al. (1981), each *T* value was used for a minimum of 15 days, and *T* was only changed when the last five days had produced seemingly stable proportions of choice. Also due to the time constraint, the stability criterion in the current experiment only required choice proportions to be stable for five days, and then the *T* value was changed.

As mentioned, the six new hens were employed to examine if they could demonstrate self-control and their results were comparable to the results generated by the previously employed five subjects. The six new hens only served under the condition where 28 s *T* value was used.

RESULTS

The data from the last five sessions of each condition, using 2 and 28 s *T* values, were used to calculate the following: the proportion of the LL choices, the mean latency to choice, and the response rate (in seconds). The number of days that the each subject served is presented in Table 4.

Figure 4.2 presents the proportion of the LL outcome chosen by each subject in each condition. As shown in the upper panel of Figure 4.2, all of the previously employed subjects (subjects 91 to 96) chose the SS outcome most of the time except subject 93. Higher proportions of LL choices when *T* was 28 s than when *T* was 2 s can be seen for subjects 92 to 96. The differences in the proportions of the LL choices between two conditions were within 0.2 for all subjects except subject 93. It can be seen that subject 91 produced a slightly higher proportion of LL choices when *T* was 2 s. Also, subject 93 demonstrated relatively higher proportion of LL choices when *T* was 28 s, which reached around 0.5. However, the performance of subject 93 under the condition of 28 s *T* delay was related to the position preference favouring the right side. She made 90% of the choices in the last five sessions on the right key.

Table 4
The days each subject served in Experiment 4

Hen	Days (*T* = 2 s)	Days (*T* = 28 s)	Hen	Days (*T* = 28 s)
91	8	7	101	12
92	7	7	102	12
93	8	7	103	12
94	8	7	104	10
95	7	7	106	12
96	8	7		

Note. Subject 106 stopped after 12 days but her performance did not meet the stability criterion.

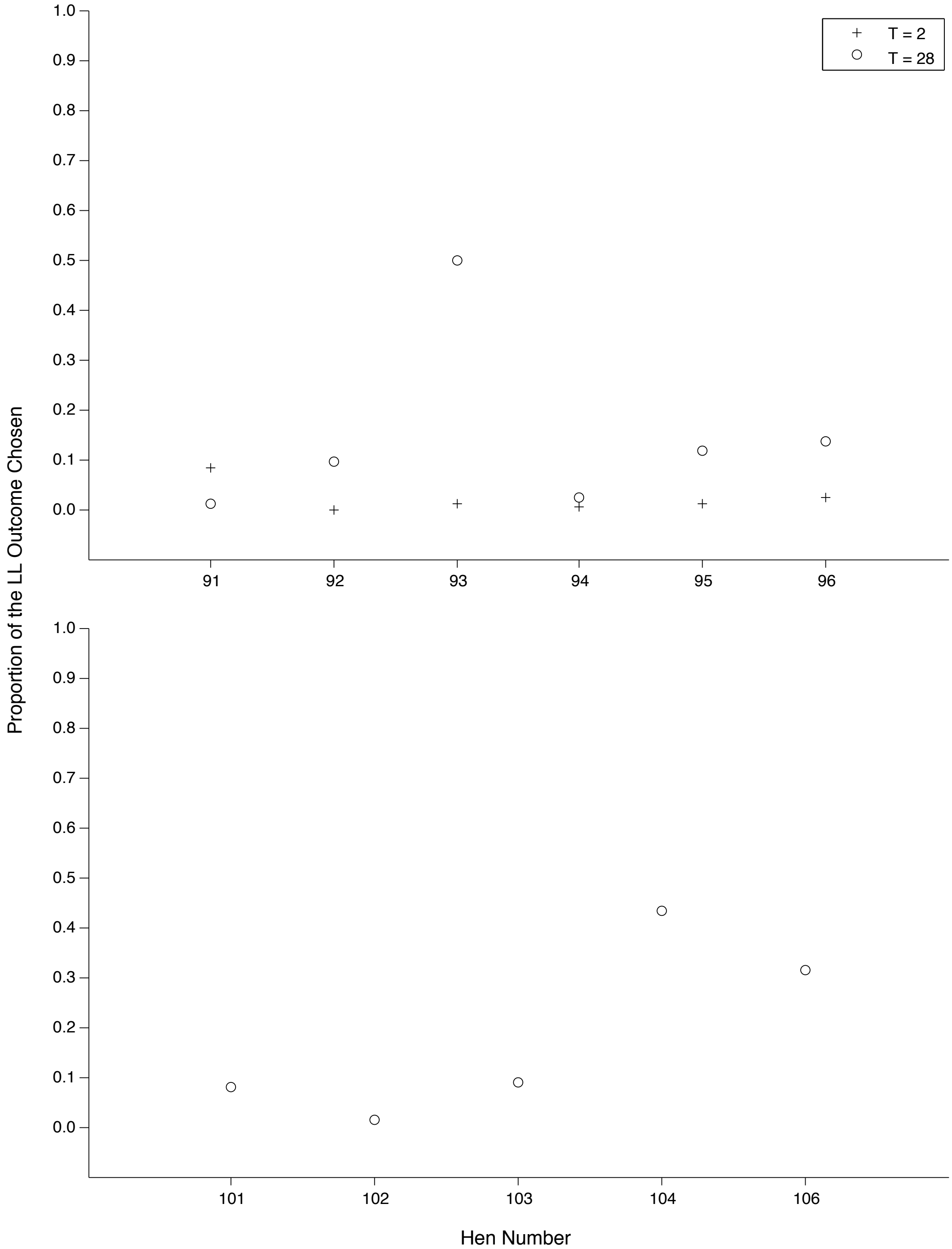

Figure 4.2. Proportions of the LL outcome chosen when *T* was 2 and 28 s for each subject in Experiment 4. The cross (+) represents the condition when *T* was 2 s. The circle (○) represents the condition when *T* was 28 s.

The results for subjects 101, 102, 103, 104 and 106 are presented in the lower panel of Figure 4.2. Figure 4.2 showed that these new subjects also demonstrated preferences for the SS outcome. For three out of the five new subjects, subjects 101 to 103, proportions of LL choices were around 0.1, and hence, comparable to the results from the previously employed subjects. The remaining two subjects, 104 and 106 showed higher proportions of LL choices. However, the performance of subject 106 was also related to the extreme preference towards the right key. She made more than 90% of choices on the right key in the last three sessions.

Figure 4.3 presents the latencies to choice for both groups of subjects. Similar to Figure 4.2, the upper panel shows the results from the previously employed subjects under the condition where *T* were 2 and 28 s, while the lower panel shows the results from the five new subjects when *T* was 28 s. When *T* was 28 s, the latencies to choice were significantly longer than when *T* was 2 s. The results from the new subjects were similar to those produced by the previous subjects. Specifically, for the previously employed subjects, the latencies to choice were around 1 s when *T* was 2 s, while the latencies reached around 8 to 12 s when *T* was 28 s. For the new subjects, although the latency for subject 102 was relatively shorter (around 6 s), latencies for the remaining new subjects varied from 10 to 12 s, and thus, similar to those obtained for subjects 91 to 96.

Figure 4.4 and Figure 4.5 present the mean responses per second on the SS and the LL keys for both groups of subjects. Figure 4.4 shows that the response rates for the previous six subjects were generally higher when *T* was 2 s than when *T* was 28 s. Also, the SS response rates were higher than the LL response rates in both conditions. However, the SS response rates were much higher than

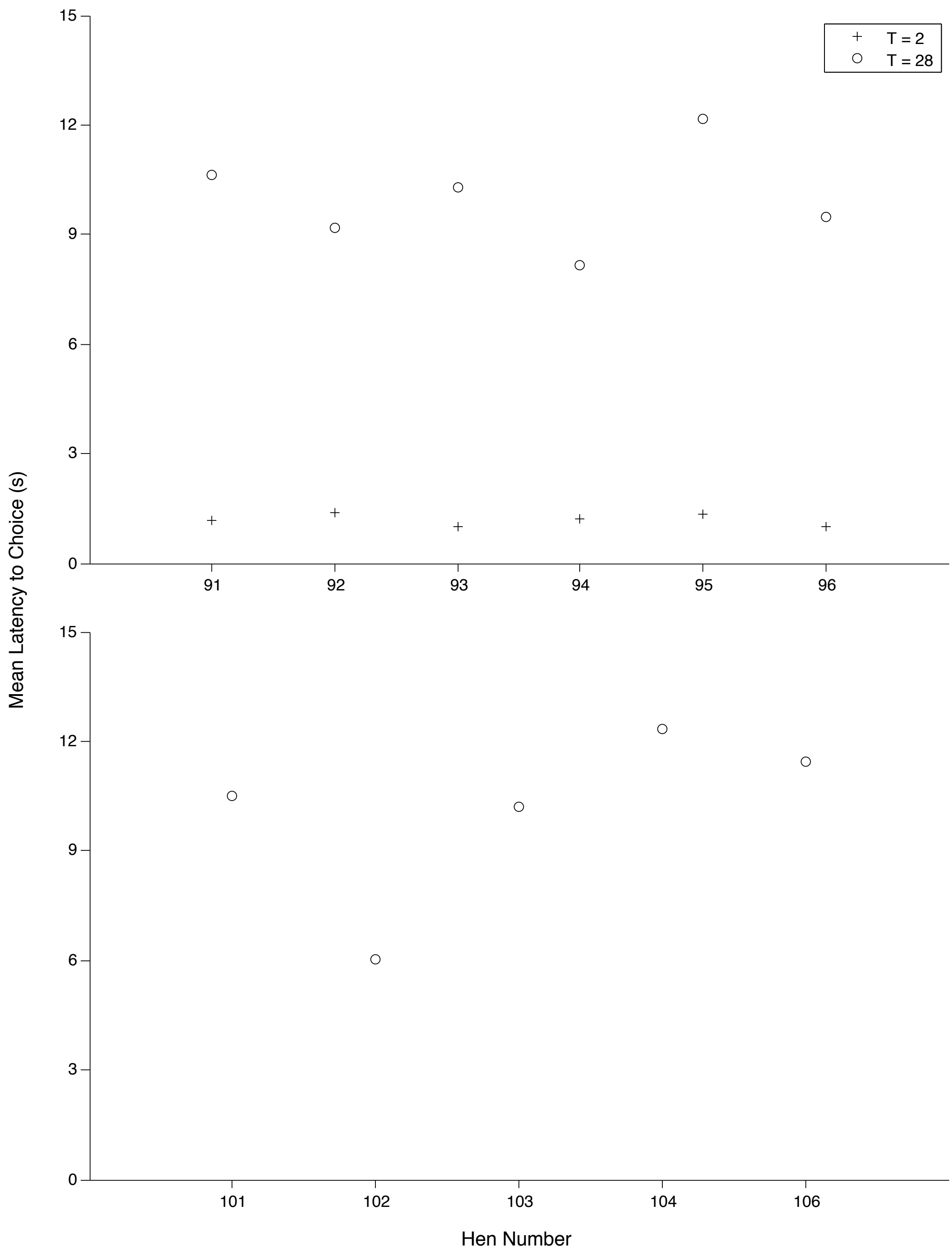

Figure 4.3. Mean latencies to choice when *T* was 2 and 28 s for each subject in Experiment 4. The cross (+) represents the condition when *T* was 2 s. The circle (○) represents the condition when *T* was 28 s.

the LL response rates when *T* was 2 s. Figure 4.5 shows the response rates for the five new subjects when *T* was 28 s. Similarly, the SS response rates for these new hens were slightly higher than the LL response rates, and these response rates were comparable to what was obtained by the previous subjects.

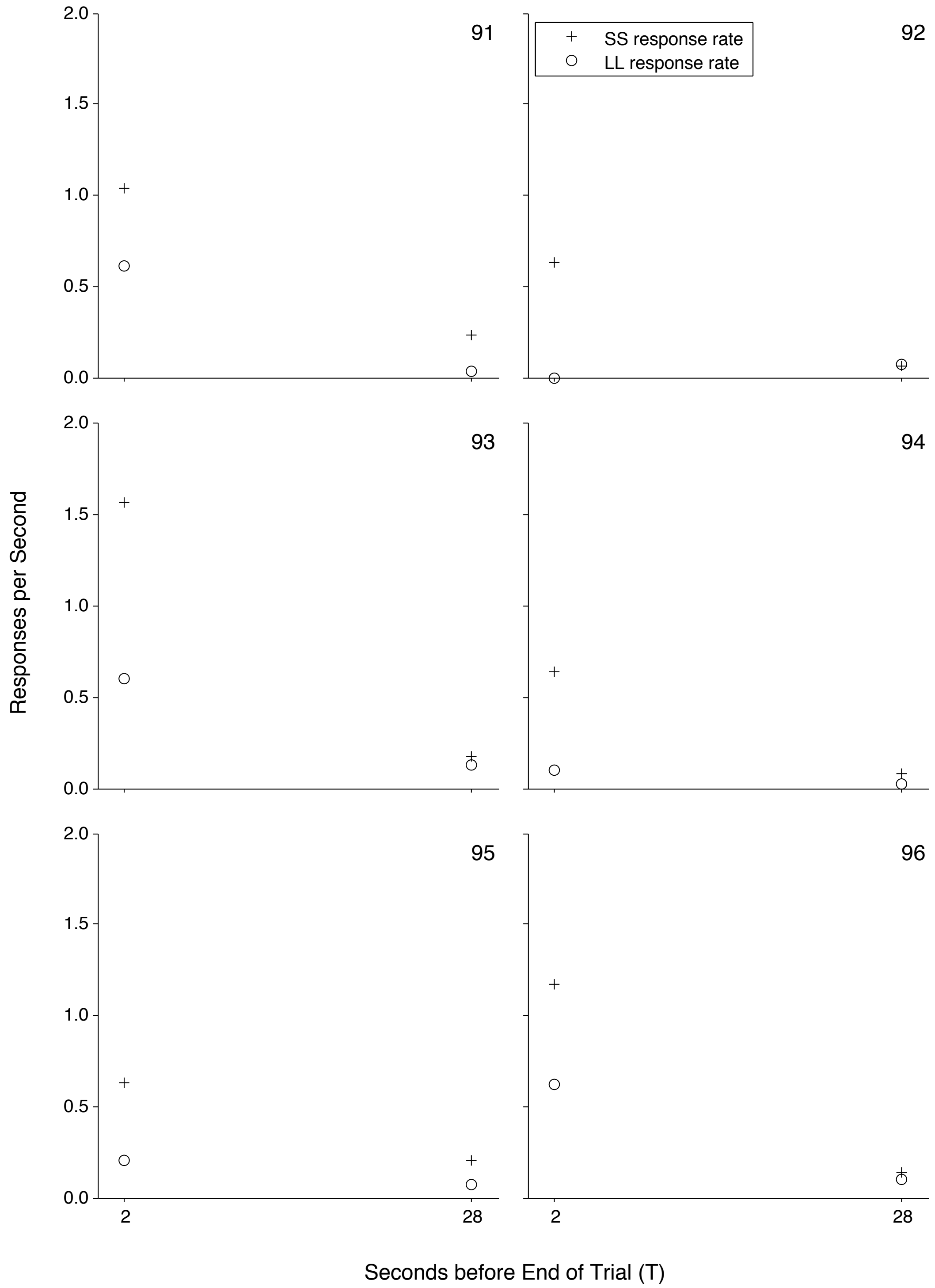

Figure 4.4. Mean responses per second on LL and SS keys when *T* was 2 and 28 s for each of the previously employed six subjects (subjects 91 to 96) in Experiment 4. The cross (+) represents the SS response rate. The circle (○) represents the LL response rate.

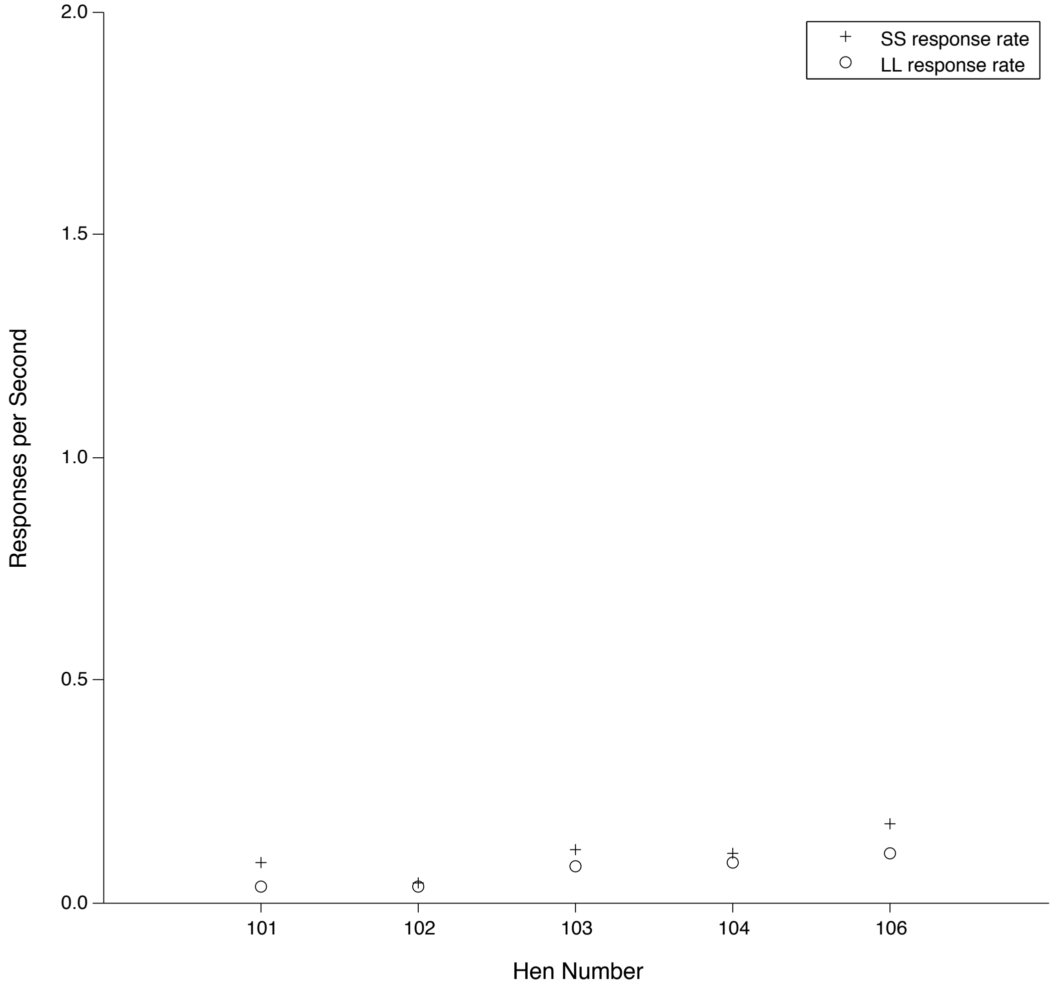

Figure 4.5. Mean responses per second on LL and SS keys when *T* was 28 s for each of the five new subjects (subjects 101, 102, 103, 104 and 106) in Experiment 4. The cross (+) represents the SS response rate. The circle (○) represents the LL response rate.

DISCUSSION

Experiment 4 attempted to replicate Green et al. (1981) in order to examine if the conventional self-control procedure would produce preference shifts with domestic hens. The findings showed that the current experiment failed to obtain the results similar to those obtained by Green et al. (1981). Green et al. (1981) showed that all their subjects strongly preferred the SS outcome when T was 2 s, while the LL outcome was strongly preferred when T was 28 s. In the current experiment, while the data obtained when T was 2 s were comparable to Green et al. (1981), the data from most subjects showed that the proportions of the LL choices only slight raised when T was 28 s. Hence, no preference shifts were observed.

Analysis of latencies to choice when T were 2 and 28 s did not differ from Green et al. (1981). There were generally shorter latencies (around 1 s) when T was 2 s, and longer latencies (around 10 to 12 s) when T was 28 s. Given that if a response was not made within 2 s when T was 2 s, the subject would not receive the reinforcer at all, it was expected the latencies to choice to be within 2 s when T was 2 s. Green et al. (1981) also argued that the increased latencies as the value of T increased were a result of response strength being inversely related to the delay (or T value) to the reinforcer. This should explain the increased latencies when T was 28 s in the current results.

The above account also confirmed that the response rates were slower when T was 28 s as shown in Figure 4.4 and Figure 4.5. This could be a direct result of a longer delay. The contingencies in the current experiment required only one response to make a choice within the delay. One response in 2 s would naturally produce higher response rate than one response in 28 s. In addition, for both conditions, the LL response rates were generally lower than the SS response rates. This seemed to be a result of response strength being inversely related to the delay as mentioned previously. Accordingly, since the contingencies associated with the LL key involved a longer delay to reinforcement than the contingencies with the SS key, response rates on LL key should be lower.

Comparing the response rates generated in the current experiment to the response rates in Green et al. (1981), when *T* was 2 s, the current response rates were lower than those obtained by Green et al. (1981). For example, Green et al. (1981) reported that the response rates were up to 2.5 responses per second while results from the current experiment found response rates were up to around 1.6 responses per second. It was noted in Experiment 3 that domestic hens are capable to produce around 200 responses per minute, or around 3 responses per second. Thus, this difference does not seem to be a consequence of species difference. However, it is not clear how this difference was relevant to choice making.

As mentioned, shifting preference was not observed in the current experiment, but higher proportions of LL choices were noticed for all subjects when *T* was 28 s. This raised a concern regarding procedural variations. As outlined, due to the time constraint, the current procedure deviated from Green et al. (1981) in two aspects, one was the use of only two extreme values, and the other was the stability criterion. The use of the two extreme values can be justified because shifting preference is not a result of ascending or descending series, but a result of different delay values. Therefore, this variation is plausible.

The second variation was the change of stability criterion, and this may produce the lack of shifts in preference as observed. Green et al. (1981) had each subject on one condition for at least 15 days and the condition changed only when the results from the last five days appeared stable, while in the current experiment, the stability criterion only required that the results from the last five days appear stable. This may produce the discrepancies between the current results and the results obtained by Green et al. (1981) because the subjects in Green et al. (1981) had more experience than the current birds since the current birds only completed up to a total of 12 days.

This could also explain the results from subjects 93 and 106 that they showed extreme position bias in favour of the right key. For example, subject 93 suddenly started to show position bias in the condition when *T* was 28 s with no signs of bias in the previous condition where *T* was 2 s. Subject 106 only showed position bias in the last 3 sessions and her proportions of LL choices was not stable during the condition in which *T* was 28 s. It seemed that they failed to discriminate between the contingencies, and hence, the position bias was developed and resulted in the equal preference for the outcomes.

If a large number of experimental sessions were conducted, subjects 93 and 106 would have had more experiences with both contingencies. As a result, discrimination between the consequences should be acquired, and should have resulted in the elimination of position bias, and possibly shifting preference. Thus, it may be suggested that the demonstration of position bias may actually be a part of learning process. If this was true for these two subjects, this could also be true for the remaining subjects. That is, the remaining subjects may seem to be stable at this point, but they may have started to show position bias at a later time before showing shifts in preference. However, Green et al. (1981) failed justify the use of 15 days as a part of stability criterion. They did not report how many sessions that each subject took to meet stability or the data obtained during these sessions before the stability was met. Thus, no conclusions can be made on this account at this point.

Experiment 4 also raised a theoretical question as to whether either of the two choice models (temporal discounting and the matching law) can describe the current results. If they can, they may shed some light on the current results. As mentioned, the matching law (Equation 9) has provided accurate prediction and description for the results by Navarick and Fantino (1976) and Rachlin and Green (1972), and it did predict the results from Experiment 3. For Experiment 4, the matching law would predict that at 28 s T delay, the LL outcome should be favoured. Accordingly, the subjects' behaviour did not follow the prediction of the matching law. Nevertheless, latencies to choice were noted, and according to the matching law, the later the choices were, the more likely the SS outcome was preferred. Even if the latencies were taken into account, the matching law would still predict the LL outcome to be preferred. It is highly unlikely that the preference of domestic hens cannot be described by the matching law. For example, Tannahill (2004) successfully employed the matching law to measure social preference in hens.

It should be noted that the matching law used in predicting the current results was the strict matching law, while Tannahill (2004) used the generalised matching law. Also, as noted in Experiment 3, the generalised matching law with added power functions should provide better description than its strict version (while sacrificing its power of prediction). Thus, the generalised matching law might be able to describe the current results. A form of the generalised matching law is presented here (Green & Snyderman, 1980):

$$\frac{B_{\mathrm{LL}}}{B_{\mathrm{SS}}} = k\left(\frac{A_{\mathrm{LL}}}{A_{\mathrm{SS}}}\right)^{x} \bullet \left(\frac{D_{\mathrm{SS}}}{D_{\mathrm{LL}}}\right)^{y}, \qquad (10)$$

in which k is the measure of bias, and x and y are the "measures of the potencies of delay and amount of reinforcement as determinants of choice" (p. 144). Using the parameters in Experiment 4, supposing there were no bias towards either outcome (k =1) and no latencies to choice, the generalised matching law still can describe the current data with a very small x value (e.g., $x < 0.4$) and a very large y value (e.g., $y > 18$). Thus, with three free parameters, the generalised matching law can actually describe the current results. Similar arguments can also be derived from the temporal discounting functions (e.g., Equation 2) with a large discounting value, K. Therefore, it is reasonable to suspect that the key to explain the lack of preference shifts with domestic hens here may be the values used in the parameters.

Abeyesinghe, Nicol, Hartnell and Wathes (2005) employed domestic hens under two contingencies, 2 s delay and 3 s access to food as the SS contingencies, and 6 s delay and 22 s access to food as the LL contingencies (called jackpot condition). They successfully demonstrated self-control. However, when the LL contingencies were 22 s delay and 22 s access to food (called standard self-control condition), their subjects were impulsive. Although they tried to demonstrate that the lack of preference shifts in standard self-control condition was due to the long delay, it should be noted that the difference between the magnitudes of the two outcomes in Abeyesinghe et al. (2005) was very large while this difference in the current study was relatively small.

Both Green et al. (1981) and Ishii and Sakagami (2002) used pigeons in their studies while current study employed domestic hens. The magnitude difference between reinforcers in current study was similar to the difference used in the studies with pigeons while a bigger reinforcer difference was used with domestic hens in Abeyesinghe et al. (2005). Thus, although it is not understood why the discrepancies in the results were so large between the two species, it is still sensible to suspect the difference in parameter values used with pigeons cannot be applied to domestic hens. Accordingly, it seems that the parameter values used with one species may not be used with another species even if the two species are similar.

Overall, Experiment 4 failed to show shifts in preference, but did show higher proportions of LL choices when *T* was 28 s. The implications of procedural variations in this experiment was discussed that if the subjects had more time to experience the contingencies, they may have shown shifting preference. With the help of the generalised matching law and the temporal discounting functions as well as the comparison between the parameters used in the other self-control studies with domestic hens, it was suggested that the difference in reinforcer sizes used with pigeons may not be used with hens. Implications were discussed that parameter values used with one species may not be applied to another.

GENERAL DISCUSSION

Experiment 1 to Experiment 3 attempted to employ an unconventional self-control procedure which involved asynchronous presentation of two alternatives as introduced by Ishii and Sakagami (2002). While Ishii and Sakagami (2002) demonstrated clear changes in preference from preferring SS outcome to LL outcome when SOA increased, Experiment 1 to Experiment 3 all showed exclusive preference for the SS outcome by most subjects despite the effort to correct the previous procedural variations and the continued use of forced choice trials in every session regardless of the SOA values. Several possible accounts that may be responsible for the results were discussed, including asynchronous onset of the alternatives, a constantly available SS alternative, the 0 s delay to SS outcome, and the different species.

To ascertain which account was responsible for the results in these three experiments, Experiment 4 used a conventional self-control procedure as used by Green et al. (1981) to investigate whether or not these subjects would demonstrate shifts in preference. New subjects were also used to examine if past reinforcement history affected performance by the previously employed subjects. The results from most subjects in Experiment 4 showed strong preference for SS outcome despite the T values varied. It was suggested that the differences between the results from Experiment 4 and Green et al. (1981) may be a result of less opportunity to experience the contingencies, and/or small difference between the two reinforcers.

However, although no shifts in preference was shown in Experiment 4, the results still demonstrated higher proportions of LL choices when T was 28 s than when T was 2 s. This was not seen in the first three experiments where exclusive

SS choices were obtained regardless of the SOA. Thus, it seems that the exclusive choices from the first three experiments were not a consequence of using a different species. Without enough evidences against the use of asynchronous schedule onset and the constantly available SS alternative, it seems that only the matching law provided a plausible account. That is, the data from the first three experiments were due to the use of 0 s delay to SS outcome. It also seems that the results from Experiment 4 were due to the small difference between the reinforcer sizes since other accounts were without theoretical or empirical support. Thus, even when delay to SS outcome was longer in the first three experiments, shifting preference would never occur in these experiments since the difference in reinforcer sizes was the same in all experiments in the current study, but higher proportions of LL choices should be seen as SOA increases.

It must be noted that the account that change of stability criterion that might have produced the results in Experiment 4 was not supported because Green et al. (1981) neither justified their stability criterion, nor reported the number of days that their subjects took to meet stability. They also failed to report data from the sessions before stability was met. Whether the subjects in Green et al. (1981) actually developed position bias or were unable to discriminate between the contingencies before their performance was stable remains unknown. Consequently, a conclusion regarding the effect of change of stability criterion in Experiment 4 cannot be made. This resulted in seeking help from the theoretical models. Thus, it is not clear whether the change of stability criterion or the small difference between reinforcer sizes contributed to the lack of shifting preference, even though it seems that the small difference between reinforcer sizes is more plausible with theoretical support from the matching law.

Similarly, in Experiment 3, Ishii and Sakgami (2002) failed to report the reason for using a central key. Since the current experiment continued to show exclusive SS choices with the inclusion of the central key (see Experiment 4), the effect of the central key is left in question. Also, in Experiment 3, it was noticed that the FI scalloped pattern was not apparent when the responses were made under an FI schedule. Hence, it was suspected that the responding on one schedule might have been disrupted by the later onset of another schedule. Unfortunately, this account cannot be validated either because Ishii and Sakagami (2002) did not report the patterns of responses on the FI schedule in their study. This also made it impossible to investigate whether the responding on the FI schedule being disrupted was related to the exclusive choice making seen in the first three experiments.

It is believed that the current study is not the only study that suffered from not reporting data and/or not acknowledging procedural components. Other studies replicating Green et al. (1981) or Ishii and Sakagami (2002) may face similar or different unanswerable questions due to this reason. Thus, an empirical concern is raised as to how much data should be reported and how many procedural components should be justified in published studies, and this does deserve some attention in the future.

Another concern raised in the current study was regarding the choice models used in the study. It is noted that the strict matching law was employed in Experiment 3 due to the fact that the temporal discounting functions were unable to make predictions with an unknown discounting variable, *K*, and the strict matching law successfully predicted and described the results from the first three experiments. However, in Experiment 4, the prediction made by the strict matching law differed from the results remarkably (and naturally it was unable to describe the results either). Thus, the help from the generalised matching law was sought, and it can describe the results from Experiment 4. However, similar to the discounting functions, the generalised matching law does not hold power of prediction either as it has three free parameters. Thus, none of the choice models employed in the current study was able to predict the results from Experiment 4.

Nevertheless, the use of the choice models may be justified for describing the data rather than predicting the data. However, whether they can actually describe the data is also in question. For example, the temporal discounting functions could not describe the data generated in Experiment 3 since the proportions of choices did not change across the SOA values, and remained extremely close to 0.0.

Furthermore, as noted, all forms of the matching law will predict exclusive choices with 0 s delay to reinforcer across all the SOA, while Ishii and Sagakami (2002) did report shifts in preference in their study. Accordingly, no forms of the matching law will be able to describe the preference shifts reported by Ishii and Sakagami (2002). The same problem comes with the discounting studies with humans, such as Green, Fry and Myerson (1994), in which the delay to the smaller hypothetical monetary reward was 0 s and shifts in preference was reported. Thus, neither the generalised matching law nor the strict matching law can describe the data from these human studies.

It does seem peculiar since both temporal discounting functions and matching law attempted to describe the allocation of choices as a function of a delay, and thus, should provide similar descriptions. Unfortunately, these models were not consistent in describing the data generated in the current study or the previous studies, where 0 s delay was used. Whether 0 s delay to reinforcement was an exception in terms of using the two choice models to account for the data is not clear. However, the fact that neither the discounting functions nor the matching law can account for all the data produced where 0 s delay was used should lead to some concerns regarding the empirical use of these choice models. Thus, more studies are required to investigate the power of description held by the two models.

Thus, whether the matching law has, in fact, provided a valid account for the exclusive SS choice in an asynchronous presentation of two alternatives remains a question, even though it seems to provide the only plausible explanation. Hence, it is suggested that the future studies are required to confirm that the results obtained by Ishii and Sakagami (2002) are actually replicable.

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