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Adaptation level effects in discrimination of flicker frequency

John C. Malone*, Maria E.A. Armento, Rita M. Nemeth, Eric J. Billington, Candice N. Carpenter, K. Brooke Andrews

Department of Psychology, University of Tennessee, Psychology, Knoxville, TN 37996-0900, USA

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Abstract

Pigeons accustomed to food reinforcement for responding in the presence of a 25-Hz flickering light were exposed to several sets of flicker-frequency stimuli arranged as increasing and decreasing series. In the first experiment, food was occasionally delivered for key pecks during 30-s periods of 25-Hz flicker appearing at the beginning, midway, and at the end of an ascending and descending series of nine frequencies, ranging from 13 to 37 Hz. These stimuli appeared for 15-s periods with no food available (extinction). Gradients of responding to flicker values in the ascending series differed from those in the descending series, showing displacements in peak responding toward the lower and higher frequency values, respectively. The same effects occurred when the sequence was changed so that a descending series was followed by an ascending series of frequencies. These effects are consonant with an adaptation level (AL) interpretation and were replicated in a second experiment in which durations of the extinction presentations were increased to 30 s. In a final condition, only a descending series was presented and displacement of peak responding from 25 Hz to a higher frequency stimulus, 28 Hz, was observed.

Keywords: Maintained generalization gradients; Adaptation level theory; Hysteresis; Sequential effects; Flicker frequency; Pigeons

1. Adaptation level effects in discrimination of flicker frequency

The study of stimulus control, traditionally called stimulus generalization and discrimination, is fundamental to an understanding of behavior and operant methods have proven particularly useful in this area. Indeed, in what was perhaps B.F. Skinner's last reference to the usefulness of operant methods, he pointed to the pivotal work of Guttman and Kalish (1956), that showed that empirical generalization gradients could be obtained using generalization testing in extinction after training with variable-interval (VI) reinforcement (Malone, 1999). Their work was the impetus for many subsequent studies, including those of one of Guttman's students, David Thomas, who showed that adaptation level (AL) effects accounted for data in a variety of human and animal studies of generalization gradient form (e.g. Thomas, 1993).

Work with both human and animal subjects has led to a bewildering array of variables that influence the shape of generalization gradients. One factor that is often, if not always, relevant is the nature of the particular set of stimuli used—the "context" of stimulation and sequential effects among stimulus presentations (e.g. Crawford et al., 1980; Hinson and Malone, 1980; Malone, 1974, 1975, 1976; Malone and Cleary, 1986; Malone and Rowe, 1981; Malone and Staddon, 1973; Nevin and Shettleworth, 1966; Rowe and Malone, 1981). Sequential effects, such as local

* Corresponding author. Tel.: +1-865-974-3341; fax: +1-865-974-3330.
E-mail address: jcmalone@utk.edu (J.C. Malone).

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contrast effects occurring among stimulus presentations, do influence overall gradient form, but appear insufficient to account fully for the overall form of the gradient.

Many factors determine the form of empirical generalization gradients—the literature is voluminous and not easily summarized. But Thomas (1993), after a long career devoted to understanding stimulus control, emphasized the usefulness of AL interpretations.

AL theory was promoted by Harry Helson (1964). He showed that judgments of stimuli used in psychophysical experiments, as well as judgments of esthetics and of the tastes, smells, and sights of daily life are *relative*. They are all made in reference to an *adaptation level*. If judgments are made of the values of stimuli arranged along a simple continuum, such as brightness, loudness, or flicker frequency, stimuli below AL tend to be judged as weaker (less intense, fainter) than values above AL, which are judged as stronger than their ordinal position warrants.

AL is not fixed—it is set and reset by stimuli immediately present (“focal” stimuli), background stimuli, such as those comprising a large set presented during a session, and residual stimuli, representing the pooled effects of past experience. AL effects have been demonstrated in all methods of psychological scaling (cf. Coren et al., 1993). AL accounts vary in complexity; Helson’s (1964) version required the calculation of weighted log means of values of stimulation during, preceding, and long preceding the presentation of a stimulus value. Only then could an AL be calculated and the effect of a current stimulus be determined. We use a simpler definition and one that is more prevalent in the literature.

Our pigeon subjects were accustomed to occasional food reinforcement for pecking in the presence of a 25-Hz flickering light. Our data show that when stimuli arranged along a continuum of frequency of a flickering light are presented in an ascending or descending order, the response to a specific stimulus value is influenced greatly by the several stimuli preceding it. When the preceding stimuli are low-frequency flickers, responding in a subsequent flicker stimulus occurs at rates that normally occur in higher frequency stimuli. For example, responding in a 22-Hz stimulus preceded by 13- and 16-Hz values, occurs at rates appropriate for 25-Hz stimulus values. It is in that sense that we refer to an AL effect.

We present data from two experiments showing the effects on gradient form that seem interpretable in these terms. The first experiment provided data that were clear in some birds and suggestive in others. A modification of procedure intended to enhance AL influences was included in the second experiment and the data that resulted were clear for all birds.

2. Experiment 1

In this experiment, the birds were exposed to a sequence in which ascending and descending series of nine flicker frequencies ranged from 13 to 37 Hz in 3-Hz steps. Flicker has proven a useful continuum for the study of stimulus control in pigeons, as demonstrated by Hinson and his co-workers (e.g. Hinson, 1988; Hinson and Higa, 1989; Hinson and Tennison, 1999). Each session began with a presentation of 25-Hz flicker paired with occasional food reinforcement, followed by an ascending series of flicker values, with 25 Hz as the midpoint, presented without food. A second period of 25 Hz with food reinforcement occurred, followed by a descending series of flicker values without food. A third period of 25 Hz with occasional food ended the session. The data of interest were the forms of the gradients of responding to the series of stimuli presented without food.

All birds had several months’ history of daily sessions in which 25 Hz appeared with food reinforcement and other stimuli appeared in extinction (EXT). That experiment, in preparation, assessed the effect of preceding stimulus values from the midrange or the extremes of several flicker-frequency continua on responding in specific stimuli and on the sharpness of the overall gradient. Thus, 25 Hz was significant to the birds from the outset of this experiment.

AL effects here would result in gradients displaced to the left (low-frequency end) during the ascending extinction series, since the low AL set by 13, 16 Hz, and perhaps 19 Hz should cause the birds to respond in 22 Hz (and perhaps 19 Hz) as if it were 25 Hz, the middle value, which was paired with food at the beginning, middle, and end of every session. During the descending extinction series, the gradient should be displaced toward the higher frequencies, as the AL “standard” set by the highest frequencies, 37 and 34 Hz, would lead the birds to respond in 28 Hz (and perhaps 31 Hz) as they would in 25 Hz. Responding in 22 and 28 Hz should clearly be different when appearing in the ascending and in the descending series.

3. Method

3.1. Subjects

Six White Carneau pigeons obtained from the Palmetto Pigeon Plant served. All were experienced with differential reinforcement for responding to a 25-Hz flickering light with many other flicker-frequency stimuli presented in EXT. The birds' weights were maintained at levels between 80 and 85% ad lib through restricted feeding.

3.2. Apparatus

The operant chamber was an aluminum box with a clear fiberglass door and interior dimensions of 26 cm × 28 cm × 34 cm. Two clear response keys were mounted on one wall, 14 cm apart, center to center, and 24 cm from the floor. A 5 cm × 6 cm food magazine opening was centered 19 cm below the keys. Only the right key was available and operative; the left was covered with black tape. A 7 W dc bulb mounted approximately 1 in. behind the key provided flicker stimuli. Those stimuli were provided by oscillators in a Coulbourne Instruments Lablinc L2T2, which also programmed the daily sessions. This was located in an adjoining room. Food reinforcement was 3-s access to mixed grain provided by a Harvard Model B feeder. White noise and a large sound-attenuating chamber enclosing the operant chamber masked extraneous noises.

3.3. Procedure

3.3.1. Ascending/descending

The birds were experienced with the operant chamber and the stimulus continuum, so they were immediately exposed to the experimental procedure. Each day the nine flicker stimuli appeared in extinction (i.e. key pecking was never reinforced with food) for 15-s periods. A 30-s, 25-Hz (S+) period appeared three times: at the beginning of each session, between the first and second (ascending and descending) series of nine extinction stimuli, and after the second series, ending the session. During these three S+ periods, responding was reinforced with 3-s access to mixed grain according to a fixed-ratio (FR) 8 schedule with a 50% probability of reinforcement at the end of each ratio. This was arbitrarily chosen to provide an effective level of occasional reinforcement.

Thus, 25 Hz (S+) appeared with reinforcement available for 30 s, followed by 15-s presentations of *all* frequencies (including 25 Hz) without reinforcement, in ascending order: 13, 16, 19, 22, 25, 28, 31, 34, and 37 Hz. That was followed by the second 30-s S+ period, after which the series descended: 37, 34 Hz, and so on to 13 Hz and a final 30-s S+ period. This occurred once per day per bird and was run for five sessions.

3.3.2. Descending/ascending

A second series was run for six sessions and was identical, except that it began with a descending series (from 37 Hz down to 13 Hz), followed by an ascending series. The three S+ periods were placed at the beginning, middle, and end, as in the previous series.

The procedure was a form of maintained generalization training (e.g. Malone and Staddon, 1973) and was designed to maintain response rates though the series of stimuli was presented in EXT. Periods of 25 Hz at the beginning, the midway point, and the end of the series ensured that 25 Hz remained a significant value and that responding either in the ascending or the descending series would be differently affected by an upcoming 25-Hz period.

4. Results and discussion

4.1. Ascending/descending

Fig. 1 shows percent responding in each frequency averaged over the 5 days of this condition for each bird. The dashed lines show responding when the series of EXT frequencies began with 13 Hz and continued with 16, 19, 22, 25, 28, 31, 34, and 37 Hz. The solid lines show responding during the subsequent series of decreasing frequency, from 37 to 34, 31, 28, 25, 22, 19, and 13 Hz. The ascending and descending series were separated by a 30-s period of 25 Hz accompanied by occasional reinforcement. Responding in that component, and in the identical components that preceded and followed the EXT

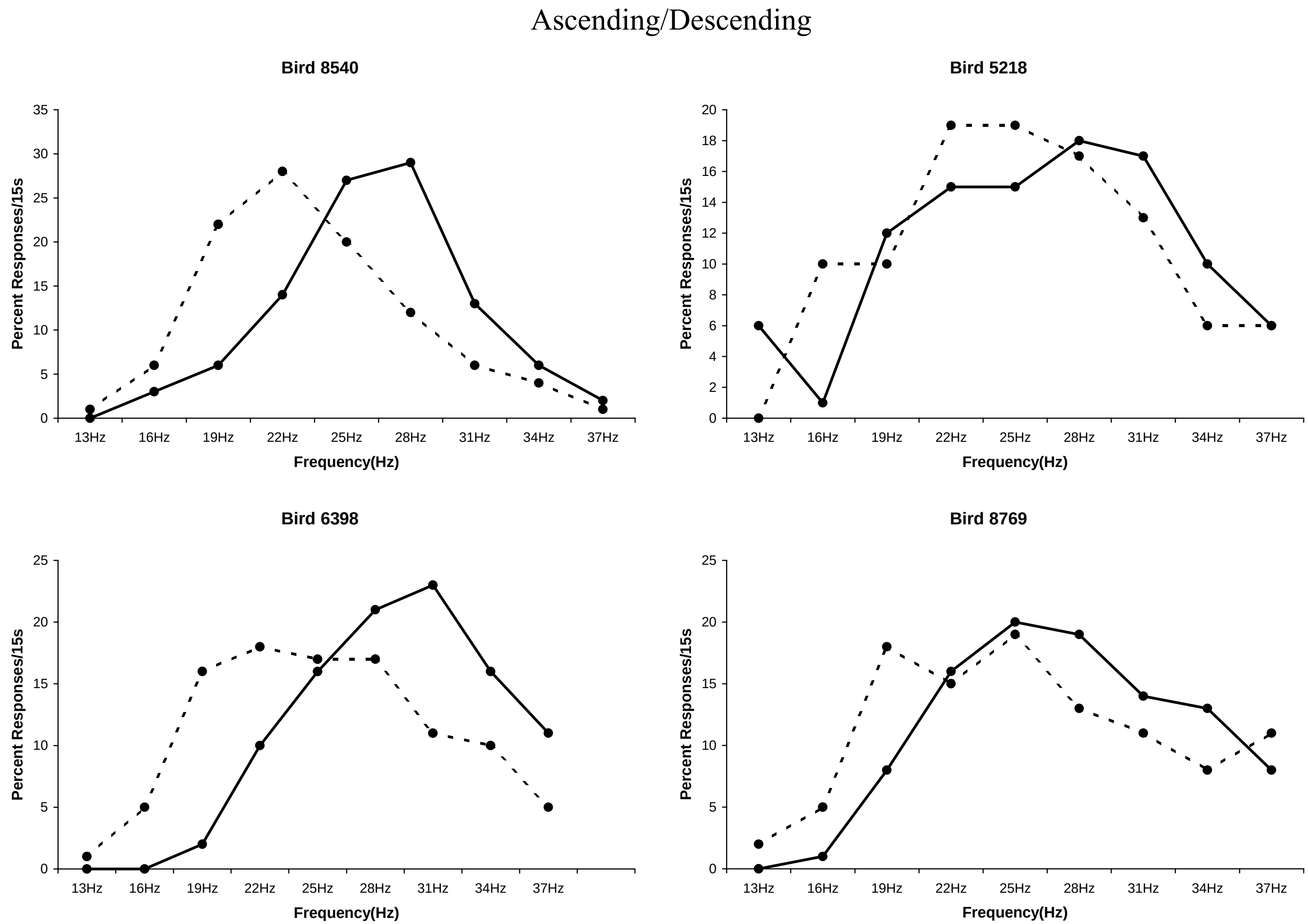

Fig. 1. Percent responses/15 s in the series of EXT stimuli during the ascending (dashed lines) and the descending (solid lines) series for individual birds. Averaged over the 5 days of the ascending/descending condition.

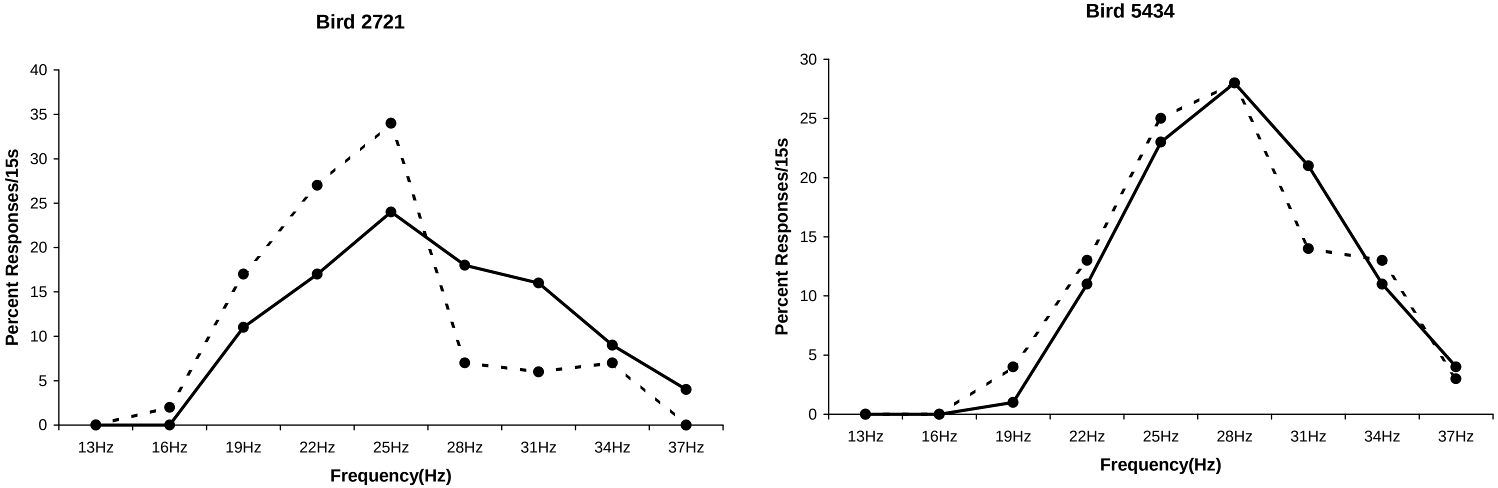

Fig. 1. (*Continued*).

series every day are not shown, since they are not relevant.

Bird 8540 most clearly showed the difference in gradient form resulting from the direction of the presentation series. Responding during the ascending series at the beginning of the session (dashed line) showed a peak at 22 Hz, not 25 Hz, and higher response rate in 19 Hz than in 25 Hz. The solid line shows the effect of reversing the series, progressing from 37 Hz through successively lower frequencies. The peak appeared at 28 Hz, not 25 Hz, and responding in 22 Hz was much lower than it was in the ascending series. All birds but 2721 showed elevated gradients on the high-frequency (right) end of the continuum in the descending series, reflecting elevated responding in 28 and 31 Hz after following 37 and 34 Hz. Except for Bird 8540, there were no sizable elevations in responding in 19 and 22 Hz during the ascending series, though five of the six birds did show elevated responding on the low-frequency (left) side of the figures.

4.2. Descending/ascending

Fig. 2 shows data presented in the same manner as Fig. 1, but during this 6-day condition, the descending EXT series of frequencies appeared first, followed by the 30-s period of 25 Hz with occasional food, followed by the ascending series of frequencies presented in EXT. Bird 8540 again showed clear effects, such that responding peaked at 22 Hz and the gradient was shifted left during the ascending series (dashed line), even though that series appeared after the descending series (solid line). Birds 8769 and 6398 also showed peaks at 28 Hz during the descending series and displacement of the gradients to the left (ascending) and/or the right (descending) appeared in the data of 8540, 5218, 6398, and 8769.

Fig. 3 shows the gradients averaged over all six birds and over the two conditions. Following an interpretation based on AL influences, the ascending gradients (dashed lines) are displaced to the left and the peak occurred at 22 Hz. The gradient resulting from the average of the descending series (solid lines) is peaked at 28 Hz and displaced to the right.

The important stimulus in the series was 25 Hz (S+), the value that had been and was paired with food when presented before, between, and after the two EXT series. The initial values in the series were 13 and 16 Hz, easily discriminable from 25 Hz. But these low-frequency stimuli set an AL, a context against which subsequent stimuli were superimposed. So, 19 Hz, following the low AL established by 13 and 16 Hz, was treated as higher in frequency and so judged as more similar to S+ than it would be when preceded by higher frequency stimuli—compare responding to 19 Hz (for Bird 8540 ascending/descending) in the dashed- versus the solid-line gradients (Fig. 1). Similarly, 22 Hz is apt to appear more like 25 Hz in the ascending sequence, viewed against the lower AL set by 13, 16, and 19 Hz, so responding to it was even higher. The solid dashed line showed the opposite effects during the descending sequence, so that 28 Hz was displaced to a lower frequency and appeared "S+ like," due to the high-frequency AL set by 37, 34, and 31 Hz.

5. Experiment 2

If the differences in the ascending and descending gradients found in the first experiment were due to AL effects, then these effects should be enhanced if component length were increased and exposure to AL-setting values were longer. In this experiment, presentations of the initial, middle, and final S+ (25 Hz) periods were lengthened to 60 s and presentations of the extinction stimuli were increased to 30 s, which should accentuate an AL effect. The series was an "ascending/descending" series, meaning that the frequency of the stimuli increased from 13 to 37 Hz and then descended from 37 to 13 Hz. All birds showed strong and clear effects. Due to his erratic performance in the first experiment, Bird 2721 was dropped and a new Bird 7286 was added. The schedule of reinforcement in the three 1-min 25-Hz (S+) components was changed to an FI 2-s with a probability of reinforcement of 1/5. This latter change was for ease of programming and was expected to have no effect on the data.

6. Method

6.1. Subjects

The subjects were those used in the first experiment, except that Bird 2721, whose behavior was always

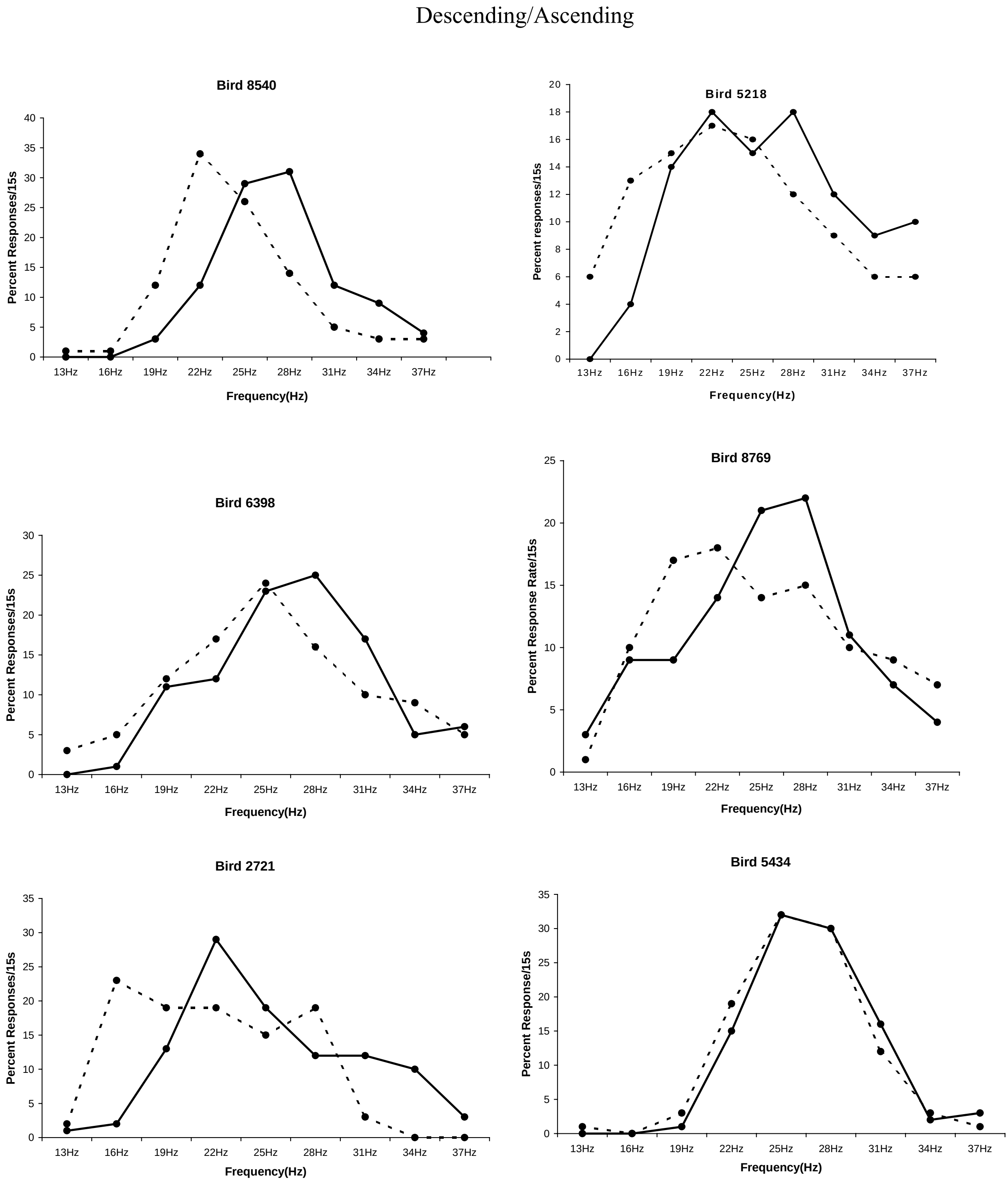

Fig. 2. Percent responses/15 s in the series of EXT stimuli during the ascending (dashed lines) and the descending (solid lines) series for individual birds. Averaged over the 6 days of the descending/ascending condition.

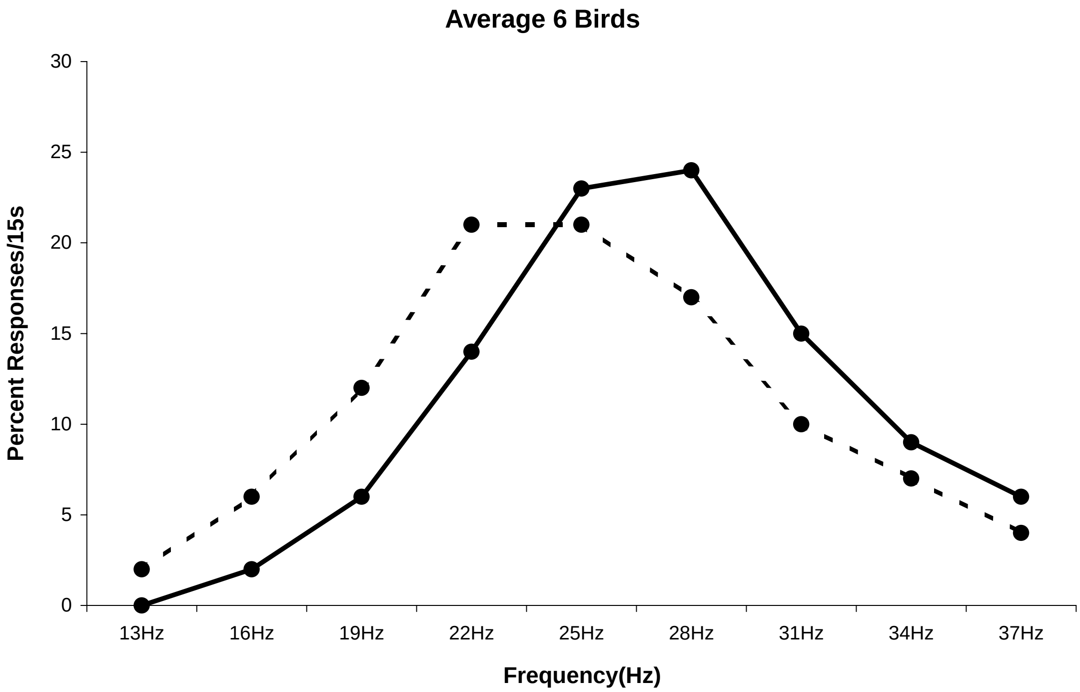

Fig. 3. Ascending gradients (dashed lines) and descending gradients (solid lines) averaged over all six birds during Experiment 1. The upper figure shows responses/15 s and the lower figure shows percent responding/15 s.

erratic, was replaced by Bird 7286. This latter bird had the same previous experience as the other birds.

6.2. Apparatus

The apparatus was that used in Experiment 1.

6.3. Procedure

6.3.1. Ascending/descending series

The first condition was the same as the "ascending/descending" segment of the first experiment; however, the periods of 25 Hz with reinforcement were increased to 60-s duration and the reinforcement schedule was an FI 2-s with a probability of reinforcement of 0.20. The series of EXT stimuli followed an initial 1-min 25-Hz period, and the series 13, 16, 19, 22, 25, 28, 31, 34, and 37 Hz appeared for 30-s periods, rather than 15 s, as in the first experiment. That series was followed by a second 25-Hz period with reinforcement, followed by a descending series of 30-s presentations ranging from 37 to 13 Hz. The series ended with a third 60-s period of 25 Hz with reinforcement.

6.3.2. Descending/descending series

This final condition was arranged as was the preceding "ascending/descending" condition, but only the descending series appeared. As in the previous condition, the session began with a 60-s period of 25 Hz accompanied by the same schedule of reinforcement as the first condition. Then each stimulus value appeared in EXT for 30-s periods in the order 37, 34, 31, 28, 25, 22, 19, 16, and 13 Hz. This was followed by another 60-s 25-Hz period with reinforcement and then a repetition of the descending EXT series, followed by a final 60-s 25-Hz period with reinforcement. This condition was run for nine sessions.

7. Results and discussion

Fig. 4 shows the data during the first 3 and the last 3 individual days of the ascending/descending condi-

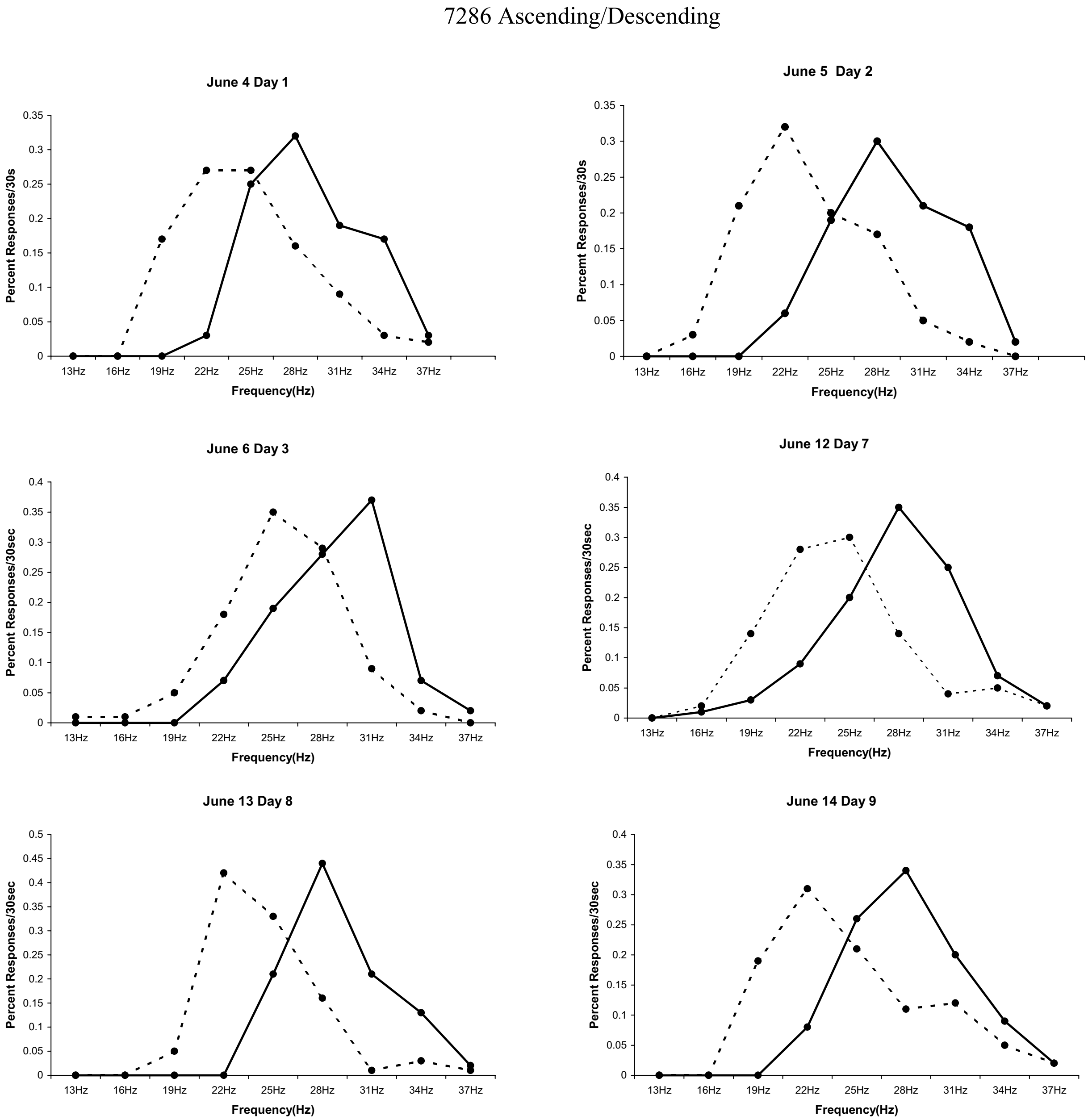

Fig. 4. Daily percent responses/30 s for Bird 7286 during the first 3 and the last 3 days of the ascending/descending sequence of Experiment 2. Dashed lines represent responding during the ascending sequence and solid lines represent responding during the descending sequence.

tion for newly added Bird 7286. Each data point represents percent responses/30 s for a single 30-s period of that EXT stimulus in that series. As in Experiment 1, dashed lines represent the ascending series, which appeared first, and the solid lines represent the descending series that followed. This bird showed clear and reliable differences in the ascending and descending gradients from the first day.

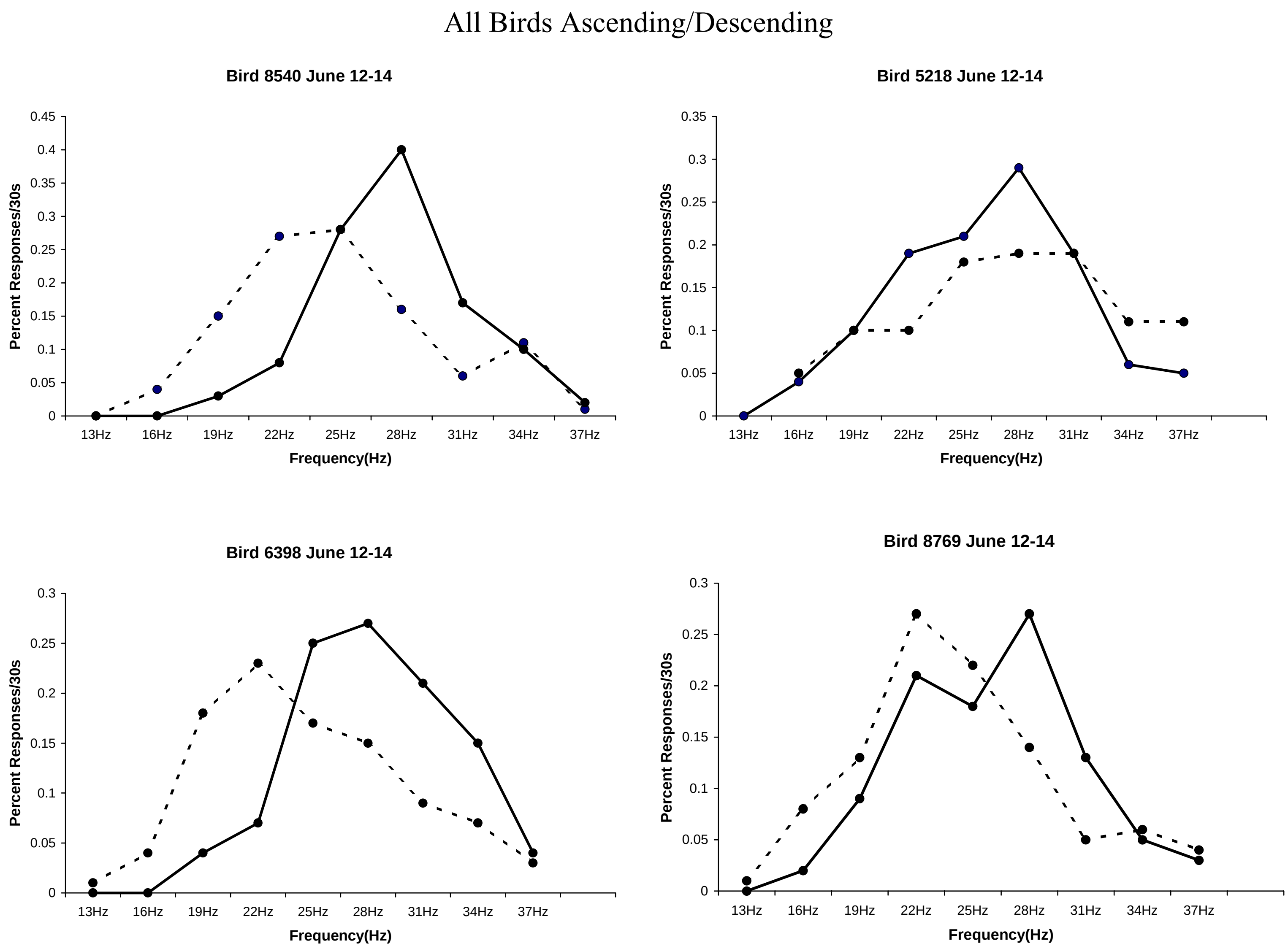

Fig. 5. Responding averaged over the last 3 days for each bird during the ascending/descending sequence of the second experiment. Dashed lines represent responding during the ascending sequence and solid lines represent responding during the descending sequence.

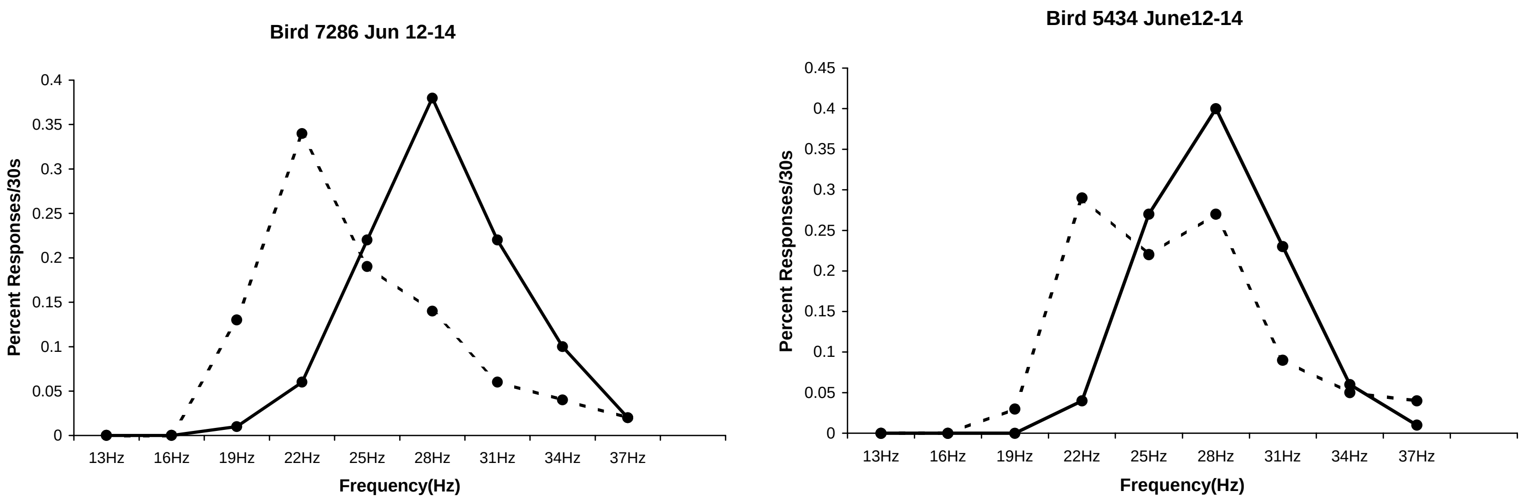

Fig. 5. (*Continued*).

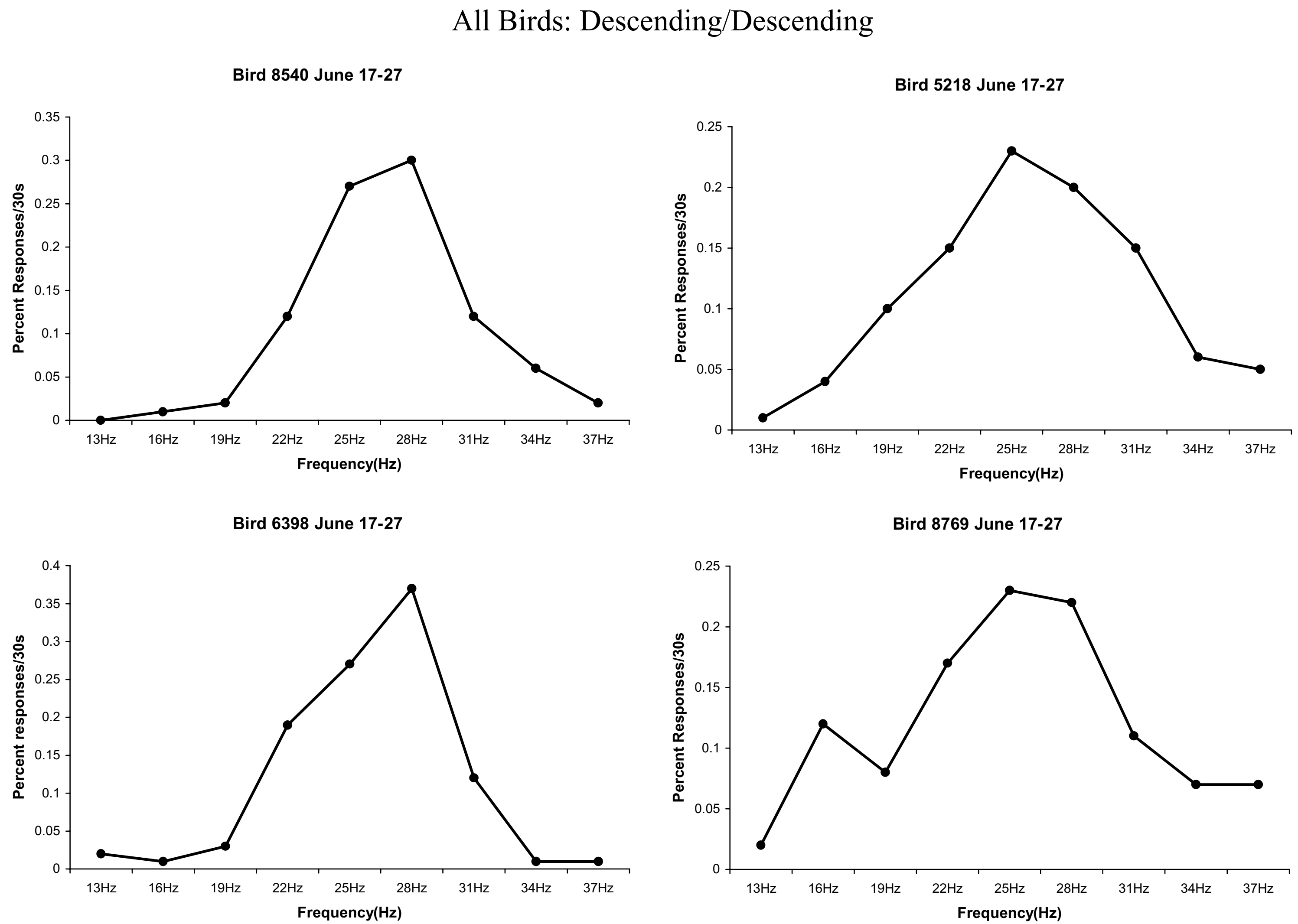

Fig. 6. Percent response rates for each bird during the nine sessions of the final condition. Two series of descending flicker frequencies were presented daily.

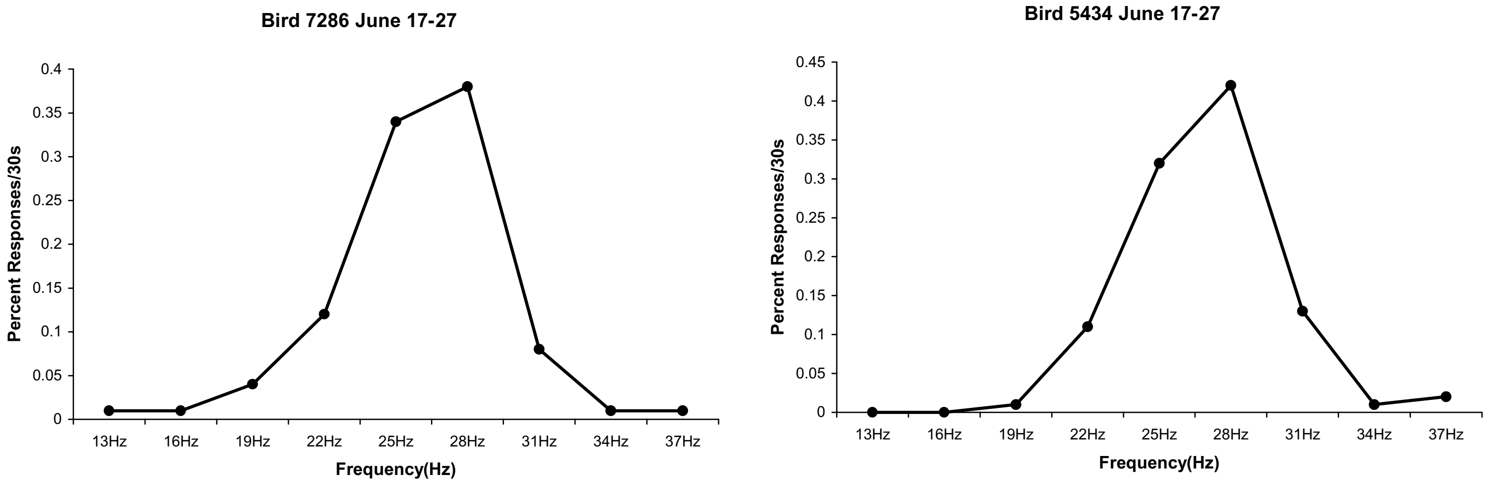

Fig. 6. (*Continued*).

As expected, the longer duration of the components (30 s, rather than 15 s) evidently promoted a stronger AL effect, so that 22 Hz was treated as 25 Hz during the ascending series and 28 or 31 Hz assumed that role during the descending series.

Fig. 5 shows the data of all six birds, averaged over the last 3 days of this condition. Gradients for the ascending series (dashed lines) for four of the birds (6398, 8769, 7286, 5434) peaked at 22 Hz and Bird 8540's gradient was displaced toward the lower frequencies. Only Bird 5218 failed to show some sign of symmetry between the ascending and descending gradients. The descending gradients (solid lines) all showed peaks at 28 Hz.

7.1. Descending/descending series

Fig. 6 shows averaged data for each bird over the 9 days of training—individual days could have been shown, but these gradients well represent daily performance. As is clear, gradients peaked at 28 Hz for all birds except 5218 and 8769, the same bird that performed poorly in the preceding condition (but see both birds' data in Experiment 1). Examination of daily data shows that all birds except Bird 8769 more often showed higher response rates in 28 Hz than in 25 Hz. This shows that a displacement of peak responding in the direction suggested by an AL interpretation does not require both an ascending and a descending series during a session.

8. General discussion

The important stimulus in these series was 25 Hz (S+), the value that was paired with food when presented before, between, and after the two EXT series. The initial values in the series were 13 and 16 Hz, easily discriminable from 25 Hz. But these low-frequency stimuli set an AL against which subsequent stimuli were imposed. So 19 Hz, following this low AL context established by 13 and 16 Hz, was displaced upward and so judged as more similar to S+ than it would be when preceded by higher frequency stimuli—compare responding to 19 Hz (for Bird 8540 ascending/descending) in the dashed- versus the solid-line gradients (Fig. 1). Similarly, 22 Hz was apt to appear more like 25 Hz in the ascending sequence, viewed against the lower AL set by 13, 16, and 19 Hz, so responding to it was even higher.

The solid lines frequently show the opposite effects during the descending sequence, so that 28 Hz is displaced to a lower frequency and appeared "S+ like," due to the high-frequency AL set by 37, 34, and 31 Hz. This appears in the data of four of the six birds in Fig. 6. Such effects must be common, so why have they not been reported more often in the literature of behavior analysis? It is not wholly attributable to a lack of concern with stimulus control.

Signal detection theory has frequently been applied to stimulus control data over the past several decades (e.g. Commons, 1979; Davison and Nevin, 1999; Dougherty and Wixted, 1996; Nevin, 1969). But AL theory has not received attention; research using operant methods and AL interpretations has appeared occasionally (e.g. Thomas, 1993), but not often. Yet, it seems clear that current context and recent and remote history are important in the determination of behavior and these are exactly the factors that define AL theory.

AL effects could be instances of the more general principle of hysteresis, or sequential effects that occur in organic and inorganic systems subjected to increasing and decreasing series of inputs. In practice, hysteresis has been used to refer to a general perseverative aftereffect, as when preferences for one alternative on a concurrent schedule persist after conditions are changed in a way that should alter preference (e.g. Davison and Hunter, 1979). In other cases, hysteresis has referred to other kinds of perseverative effects (Anger, 1983; Williams, 1989). AL effects are thus an instance of that more general effect.

We believe that AL effects more specifically describe our data, which show biases in responding to specific stimulus values as a function of the several immediately-preceding stimuli. While the stimulus series did constitute ascending and descending series of frequencies and thus fit the technical definition of hysteresis, that term has long been used to refer to a mere inertial lag, which is not what we found in these data. Further experiments will determine whether such ascending and descending series are necessary to produce these effects.

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