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Unpredictability reduces over-selective responding of individuals with ASD who have language impairments

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Abstract

Background: The phenomenon whereby behavior becomes controlled by one aspect of the environment at the expense of other equally-salient aspects of the environment (stimulus over-selectivity) is extremely common in many with Autism Spectrum Disorder (ASD). However, the theoretical mechanisms underpinning over-selectivity and its remediation are not well understood. Four experiments explored whether principles derived from associability accounts of learning, notably the concept of uncertainty, might allow better theoretical understanding of the phenomenon.

Method: Participants with ASD who had language impairments received simultaneous discrimination training (AB+/CD-), and were tested in extinction regarding the degree to which the separate elements (A and B) of the previously reinforced compound (AB+) controlled behavior.

Results: All experiments established the presence of over-selectivity; choosing one stimulus element to a greater-extent than the other. In Experiments 1 and 2, relative to a 100% feedback schedule, over-selectivity reduced when a 50%, but not a 25%, schedule of feedback was used. In Experiment 3, prolonged schedule exposure reduced over-selectivity. In Experiment 4, change from a 100% to a 33% schedule did not reduce over-selectivity.

Conclusions: These results suggest that unpredictability, rather than variability *per se*, or reinforcement reduction and change, reduces over-selectivity. This suggests that attentional mechanisms, especially uncertainty, may play a role in this phenomenon during its acquisition and remediation.

Keywords: over-selectivity; unpredictability; partial reinforcement; reinforcement reduction; remediation of over-selectivity; ASD.

Over-selectivity refers to situations in which behavior is controlled only by some elements in the environment, despite the presence of equally important and equally salient elements with respect to predicting outcomes (Koegel and Wilhelm, 1973; Koegel and Schreibman, 1977; see Dube, 2009; Ploog, 2010, for reviews). Over-selectivity is noted in a number of clinical populations (Bailey, 1981; Dube and McIlvane, 1999; Kelly, Leader, and Reed, 2016; Reed and Gibson, 2005), but is particularly pronounced in individuals with Autism Spectrum Disorders (ASD) who have intellectual and/or language impairments Kolko, Anderson, and Campbell, 1980; Leader, Loughnane, McMoreland, and Reed, 2009; Ploog and Kim, 2007; Reed, Broomfield, McHugh, McCausland, and Leader, 2009).

Over-selectivity has been explored using a number of procedures, such as match-to-sample (Broomfield, McHugh, and Reed, 2008; Dube and McIlvane, 1999), and simultaneous discrimination (Koegel and Wilhelm, 1973; Leader et al., 2009; Lovaas, Schreibman, Koegel, and Rehm, 1971; Reynolds and Reed, 2011a). In these procedures, participants are presented with compound cues comprising elements of equal salience that predict different outcomes, and they must learn to respond appropriately (e.g., AB+/CD-). However, when the elements of the compounds are tested individually in extinction (e.g., AvB, AvD, BvC, BvD), the elements from the previously reinforced compound control behavior to different degrees to one another despite having equal predictive importance and salience (Leader et al., 2009).

An important focus has been establishing mechanisms that produce over-selectivity (see Dube, 2009; Ploog, 2010; Reed, 2011, for reviews), and how this effect might be remediated in the light of these mechanisms (Dube and Wilkinson, 2014; Ploog, 2010). For individuals with ASD who have some intellectual and/or language impairments (Leader et al., 2009; Reed et al., 2009; 2012), especially those with low levels of verbal functioning (Kelly et al., 2015), an attentional deficit appears implicated in producing over-selectivity (Dube, 2009; Dube, Lombard, Farren, Flusser, Balsamo, and Fowler, 1999; Reed et al., 2009). This suggests that over-selectivity emerges as some individuals do not initially attend to all elements of a complex stimulus during training, so that some cannot control behavior during the test (see Dube et al., 1999).

Over-selectivity is similar to the more-often studied phenomenon of overshadowing (e.g., Mackintosh, 1976). Overshadowing is said to occur when, following presentation of a compound followed by a biologically-significant outcome (AB+), less responding is shown to elements compared to when they were trained alone (i.e., less responding to B after AB+ than to B after B+). Thus, overshadowing is the reduced control exerted by one stimulus (B) from a compound (AB+), relative to the control exerted when conditioned individually (B+); whereas, over-selectivity is defined by the relative relationship of the control acquired by elements A and B after simultaneous discrimination training. Nevertheless, much research has been devoted to exploring the mechanisms underlying attentional processes in conditioning (Mackintosh, 1974; Pearce and Hall, 1980; Le Pelley, 2004). Factors such as the outcome-predictiveness of the cue (Mackintosh, 1974), the level of uncertainty of the outcome (Pearce and Hall, 1980), and the learned cue value (Le Pelley, 2004), have all been suggested as important in driving attentional responses (Le Pelley, Mitchell, Beesley, George, and Wills, 2016). The current series of studies explored the degree to such concepts may be helpful in understanding over-selectivity - a phenomenon of clinical importance – that bears resemblance to compound conditioning studies, but which is procedurally different.

The above theoretical suggestion implies that manipulations impacting the degree to which stimuli control attention might impact levels of over-selectivity. If a manipulation increases attention to stimuli, then it might reduce levels of over-selectivity (Reynolds and Reed, 2011b; 2013). There are a number of possible ways in which attention to a stimulus can be altered (see Le Pelley et al., 2016, for a review), but Pearce and Hall (1980) suggest that unpredictable outcomes will serve to enhance attentional (observing) responses to stimuli associated with those outcomes (Kaye and Pearce, 1984). If uncertainty about the outcomes increases attention, then presenting outcomes according to partial schedules should increase observing responses/attention (Kaye and Pearce, 1984), allow the cues to be better learned, and reduce over-selectivity (Dinsmoor, 1985). Such increased attention to compound stimuli with unpredictable outcomes has been noted across a variety of conditioning procedures using a variety of measures (Beesley, Nguyen, Pearson, and Le Pelley, 2015; Boll, Gamer, Gluth, Finsterbusch, & Buchel, 2013; Griffiths, Mitchell, Bethmont, and Lovibond, 2015; but see Le Pelley et al., 2016, for some important caveats to this conclusion).

The impact of partial schedules of outcome on over-selectivity has been explored in experiments that used very different populations and procedures from one another, but little consistency has emerged from the results (cf. Dube and McIlvane, 1997; Koegel, Schreibman, Britten, and Laitinen, 1979; Reynolds and Reed, 2011b; Schreibman, Koegel, and Craig, 1977). This pattern of inconsistent results regarding the impact of partial outcome schedules from studies of over-selectivity mirrors that noted when the effects of manipulations that increase 'uncertainty' are studied using more traditional conditioning procedures (see Le Pelley et al., 2016). In fact, the differences in outcome in studies of over-selectivity are associated with many of the same factors that are associated with differences in outcome in more traditional learning paradigms – such as length of training, and surprise.

Reynolds and Reed (2011b) presented non-clinical adult participants with a two-component trial-and-error simultaneous-discrimination task (AB+/CD-) with either partial (50%) or continuous (100%) feedback for responses. Over-selectivity did not differ between the two feedback conditions, suggesting that attention may not be a prime driver of over-selectivity or its remediation. However, the sample used was non-clinical, and it has been suggested that the mechanisms of over-selectivity are different in such populations to those observed in individuals with language and/or intellectual impairments (Reed, 2011; Reed et al., 2009; 2012). Certainly, the verbal ability of participants plays a role in modulating the degree to which they over-select (Kelly et al., 2015), and verbal control has been shown to be an important factor modulating the mechanisms of attention (Mitchell, Griffiths, Seetoo, & Lovibond, 2012).

In contrast, when a simultaneous-discrimination task involving compound cues was studied by Koegel et al. (1979; see also Schreibman et al., 1977) with children with ASD with intellectual impairments, partial reinforcement introduced after a prolonged period of continuous reinforcement reduced over-selectivity. This study employed a much longer training period than used by Reynolds and Reed (2011b), and also found the remediation effect after a change in the value of the outcome (i.e., after a reduction in the rate of reinforcement). The presence of either of these factors (learned value or surprise) in the study reported by Koegel et al. (1979), compared to that reported by Reynolds and Reed (2011b), may play a role in explaining the different results, in addition to the level of functioning. However, Dube and McIlvane (1997) found greater stimulus control when continuous, rather than partial, outcomes were employed, using a match-to-sample procedure, after prolonged training with a sample with intellectual disabilities. The use of match-to-sample versus simultaneous discrimination may, of course, explain this discrepancy with the results reported by Koegel et al. (1979).

Thus, the effect of partial schedules of outcome on over-selectivity is unclear, and the mechanisms underlying this effect have not been established. Moreover, the aspects of partial outcome schedules implicated in remediation of over-selectivity are unknown. It is not known whether remediation of over-selectivity is the product of unpredictable (uncertain) outcomes, and hence increased associability (Kaye and Pearce, 1984; Pearce and Hall, 1980), when schedules of partial outcome are utilized. A variety of other theoretical factors have been considered in the conditioning literature (see Le Pelley et al., 2016), and these may have relevance for over-selectivity. For example, lower rates of reinforcement or outcomes (Dube and McIlvane, 1997), or a surprising change in the level of outcome (see Dickinson et al., 1976; Griffiths et al., 2015), have also been associated with the remediation of over-selectivity and with increased attention. Given the discrepancies in the literature, it is currently impossible to say which, if any, of these concepts might be theoretically important in understanding over-selectivity and its remediation. The current experiments explored the impact of partial reinforcement on over-selectivity in individuals with ASD, as they display high levels of over-selective responding, with a view to developing theoretical understanding of the phenomenon, and developing interventions to reduce levels of potentially disadvantageous over-selectivity.

Experiment 1

Experiment 1 investigated the effects of partial reinforcement on over-selectivity, in a simultaneous discrimination procedure (AB+/CD-) in children with ASD and intellectual and language impairments, by comparing partial outcome-schedules (25% and 50%) with a continuous (100%) outcome. If over-selectivity is reduced by uncertain outcomes maintaining associability (Pearce and Hall, 1980), then less over-selectivity should be seen with a 50% compared to a 100% or 25% schedule, because predicting the outcome on a 50% schedule (with feedback following a trial occurring strictly at chance) is more difficult than on a 25% schedule, where 3/4 stimuli will be followed by the same outcome. According to Pearce and Hall (1980), greater uncertainty of outcome on the 50% schedule should result in greater associability and greater levels of observing responding (Kaye and Pearce, 1984). In contrast, should over-selectivity be a function of non-reinforcement (Dube and McIlvane, 1997), then the 25% schedule should produce less over-selectivity than the 50% or 100% schedule.

Method

Participants

Individuals with lower levels of verbal functioning were targeted, as this population seems to be impacted by attentional mechanisms to a greater extent than higher-functioning populations (Kelly et al., 2015). Forty-five children with an ASD diagnosis made by a pediatrician independent to this study, using the DSM-IV-TR criteria, ADOS, and clinical judgment, were randomly divided into the three groups. All participants had a statement of special educational needs confirming ASD from an educational psychologist also independent to this study. Written consent from the participants' parents was obtained, and ethical approval was granted by the Psychology Ethics Committee of the University.

Two participants did not complete the training and were excluded. The remaining 43 (34 male; 9 female) participants (*n* = 15 for 100% and 25% groups, *n* = 13 for 50% group), had a mean chronological age of 12:6 (i.e. 12 years and 6 months; range = 5: 10–16:1) years. The participants had a mean parent-rated autistic severity of 75.37 (SD ± 20.91) measured by the Autism Behavior Checklist (ABC; Krug, Arick, and Almond, 1980). Their mean verbal mental age (British Picture Vocabulary Scale; Dunn, Dunn, Whetton, and Burley, 1997) was 7:9 (range = 2–12:8) years. The mean verbal IQ, measured by the standardized score calculated from the BPVS, was 61.04 ± 13.08 (range = 34–84).

Measures

British Picture Vocabulary Scale II (BPVS; Dunn et al., 1997) measures receptive vocabulary, verbal mental age, and IQ. It requires participants to choose one picture from four that best matches words spoken aloud by the experimenter. It has a Cronbach's alpha of .91.

Autism Behavior Checklist (ABC; Krug et al., 1980) measures autism severity, and consists of 57 items that describe typical autistic behaviors that relate to a range of aspects of ASD. A score of 68 or above indicates probable ASD, 54-67 indicates a moderate probability of ASD, 47-53 indicates a low probability of ASD, and below 47 indicates a typically-developing child. It has a Cronbach's alpha of 0.87.

Materials

Training Stimuli. Eight white laminated cards (10x10cm) contained compound stimuli (AB, CD, etc.), comprising two symbols (each 4x4cm from the wingdings font from Microsoft Word. Four different compounds were used, the compounds were randomly allocated to each participant, and each participant had the same compounds throughout training. Figure 1 (top panel) illustrates one set of training stimuli used.

Test Stimuli. Sixteen white laminated cards (10cm x 10cm) contained individual components of the compound stimuli. Each symbol was placed in the center of the card, and measured 4x4cm. The bottom panel of Figure 1 presents examples.

Figure 1

Procedure

The experiment was conducted in a small, quiet room in the participants' school. Experimenter and participant sat opposite each other across a table, with all stimuli out of view of the participant. At the start of the experiment the participants were told that they were going to play a guessing game, in which they had to find out which card the experimenter was thinking of, and the only way that they could do that was to pick a card and listen to what the experimenter said.

The training phase consisted of a two-component trial-and-error discrimination task (AB+ vs CD-). The experimenter placed two cards in front of the participant, each card comprising two symbols. Pointing to one card (AB) could receive positive feedback, and pointing to the alternative (CD) could receive negative feedback. Four different sets of stimuli were used randomly across participants, but each participant received only one AB and one CD stimulus. For each training trial, the participant was asked to: "*Point to the correct card*" (the response was also modeled). If that trial was scheduled to receive feedback, then the feedback was either: "*Yes, well done.*" (delivered with a smile and an edible reinforcer) for choosing the correct stimulus; or "*That is incorrect.*" (delivered with no expression) for choosing the incorrect stimulus. This feedback was presented according to a 100%, 50%, or 25% schedule. The trials designated as receiving feedback were predetermined by a random number generator, with the exception of the first trial which always received feedback. When the trial was not designated for feedback, the experimenter simply removed the cards after the response was made. The sequence of trials on which the correct stimulus was presented on the left or right was also pre-determined for each participant individually using a random number generator. Each trial lasted approximately 5s (if 5s passed without a response, the trial was abandoned and repeated). There was a 5s inter-trial interval. The training phase lasted until the participant made 10 correct responses in a row.

After a 2min break, the test phase started, during which participants were tested on the individual components of the stimuli used in training in order to assess levels of over-selectivity. The experimenter placed two cards in front of the participant. Each card contained one symbol; one card contained an element from the previously reinforced AB compound, and the other contained one element from the CD stimulus. Each of the four possible combinations (AvC, AvD, BvC, BvD) was presented 5 times. There were a total of 20 test trials. No verbal feedback was given to the participant during the test trials.

Results and Discussion

Participants in the 100% group took a mean 13.06 ± 4.81 (SD) trials to reach criterion; participants in the 50% condition took 22.00 ± 5.37 trials to criterion, and those in the 25% conditions took 20.20 ± 6.30 trials. A one-way between-subjects analysis of variance (ANOVA) revealed this difference was significant, $F(2,40) = 9.18$, $p < .001$, $\eta^2_p = .315$ [*95%CI* =. 078-.483]. Tukey's Honestly Significant Difference (HSD) tests revealed differences between 100% and 50%, and 100% and 25%, groups were significant, *p*s < .05. Thus, the partial outcome groups learned the initial discrimination more slowly than the continuously reinforced group (Leader et al., 2009; Reed and Gibson, 2005; Reynolds and Reed, 2011b).

Participants in the 100% group received an average of 13.60 ± 4.81 trials with feedback (100% trials); participants in the 50% group received 11.31 ± 2.66 trials with feedback (51.44%); and those in the 25% group received 5.20 ± 1.57 trials with feedback (25.71%). A one-way ANOVA revealed that the difference to be significant, $F(2,40) = 25.39$, $p < .001$, $\eta^2 = .559$ [.312-.787]. Tukey's HSD tests revealed pairwise comparisons between the 25% group, and each of the other two groups, to be significant, *p*s<.05.

Figure 2

The number of times that each element (A or B) of the previously reinforced compound (AB) was chosen during test was calculated for each participant. The stimulus (A or B) that had been selected more times was designated the ‘most’ selected stimulus, and the stimulus selected fewer times was designated the ‘least’ selected stimulus, irrespective of the physical identity of the stimulus (i.e., A or B). The percentage of times that the most- and least-selected stimuli were actually chosen was calculated for each participant, and is shown in Figure 2. These data suggests a greater difference between the most- and least-selected stimuli in the 25% and 100% groups, relative to the 50% group, which displayed a reduced difference between the stimuli.

A two-factor mixed-model ANOVA with stimulus (most versus least-selected) as a within-subjects factor, and group (100%, 50%, 25%) as a between-subject factor, revealed no significant main effect of group, $F(2,40) = 1.99$, $p = .149$, $\eta^2_p = .091[.000\text{-}.251]$, but a significant main effect of stimulus, $F(1,40) = 48.32$, $p < .001$, $\eta^2_p = .457[.320\text{-}.678]$, and a significant interaction, $F(2,40) = 5.45$, $p = .008$, $\eta^2_p = .214[.018\text{-}.391]$. Simple effect analyses revealed significant most and least differences for the 100% group, $F(1,40) = 5.02$, $p < .05$, $\eta^2_p = .112[.000\text{-}.300]$, and 25% group, $F(1,40) = 5.21$, $p < .05$, $\eta^2_p = .115[.000\text{-}.305]$, but not for the 50% group, $F < 1$, $\eta^2_p = .021[000\text{-}.165]$. Simple effect analyses revealed the group difference for the most-selected stimulus was not significant, $F < 1$, $\eta^2_p = .044[.000\text{-}.181]$; but was significant for the least-selected stimulus, $F(2,40) = 3.46$, $p < .05$, $\eta^2_p = .148[.000\text{-}.342]$. Tukey’s HSD tests revealed the difference between least selected stimulus for the 50% and 100%, and 50% and 25%, groups to be significant, ps<.05.

These over-selectivity effects replicate previous studies using 100% outcome schedules (Koegel and Wilhelm, 1973; Leader et al, 2009; Reed et al., 2009; Reynolds and Reed, 2011a), and suggest some forms of partial outcome delivery remediate over-selectivity (Koegel et al., 1979; Schreibman et al., 1977). The 50% condition showed no difference between most- and least-selected stimuli at test, and remediation consisted of an increase in selection for the least-selected stimulus. However, there was no over-selectivity remediation with 25% reinforcement.

These data suggest that partial outcomes can impact over-selectivity in an ASD sample with intellectual and/or language impairments (Koegel et al., 1979; Schreibman et al., 1977), as opposed to in a nonclinical sample (Reynolds and Reed, 2011b), where the mechanism of over-selectivity may not be attentional (Reed, 2011; Reed et al., 2009; 2012; see also Le Pelley et al., 2016). That only the 50% schedule produced remediation, suggests the effect may be produced by uncertainty about the outcome maintaining attentional responses (Pearce and Hall, 1980), because the 25% group (as well as 100%) has a more predictable outcome than a 50% schedule. These results do not suggest that reduction in reinforcement rates per se, nor a partial schedule per se, nor levels of feedback received, remediate over-selectivity – consistent with an attentional view of over-selectivity (Dube, 2009). Thus, the results are consistent with the view that attentional responses (sometimes characterized as ‘observing responses’) are prompted by the associability of the stimuli, which can be related to the unpredictability of the outcome (Kaye and Pearce, 1984; Pearce and Hall, 1980).

Experiment 2

The results from Experiment 1 suggest that unpredictability is a key determinant of whether over-selective responding will be remediated. However, the groups differed in the amount of feedback they received. Williams (1989) noted that discrimination learning can be dependent upon the number of reinforcers received, at least with rats, and the same might be true in the current procedure. The fact that acquisition was slower for 50% and 25% groups than for the 100% might reflect this impact. Although performance at test appeared unrelated to this factor – over-selectivity was not alleviated with the higher and lower levels of feedback in 100% and 25% groups – it was thought that an experiment controlling levels of feedback would serve to eliminate this possibility. It is worth noting that in hybrid models of attention (Le Pelley, 2004), the learned value of the cue is taken as an important driver of attention. If this were the case, then it might be expected that the 100% schedule would produce less over-selectivity, as it would produce the most attention to the cues, at least early in training (Le Pelley et al., 2016).

Participants were divided into three groups (100%, 50%, and 25%), but the number of feedbacks they received during initial training was equated using a yoking procedure. The number of feedbacks received by a ‘master’ participant in the 100% group became the number of feedbacks to be received by yoked participants in the 50% and 25% groups – yoked participants received training until they had received the same number of feedbacks as the master participant.

Method

Participants and Materials

Thirty-four children, different to those in Experiment 1, but recruited according to the same criteria, were initially recruited, but 4 did not complete the training, leaving 30 children (25 male; 5 female) in the study. These participants randomly divided into the three groups (*n*=10). Participants had a mean parent-rated autism severity (ABC) of 76.10 $\pm$ 13.08. Their mean chronological age was 12:66 (range = 7:6–15:1) years, and mean verbal mental age (BPVS) was 8:7 (range = 4:1–14:3) years. The mean verbal IQ (BPVS) was 70.87 $\pm$ 11.74 (range = 45–89). The measures and materials were as described in Experiment 1.

Procedure

The procedure was as in Experiment 1 except that a participant from the 100% group received the training and testing initially, and the numbers of trials with feedback received during training were recorded. A participant in each of the 50%, and in the 25%, groups then received training that continued until they received the same number of trials with feedback as received by the participant in the 100% group.

Results and Discussion

Participants in the 100% condition took an average of 14.50 $\pm$ 5.21 trials to reach criterion; participants in the 50% condition received 24.50 $\pm$ 5.82 trials; and those in the 25% conditions received 48.50 $\pm$ 11.27 trials. All groups received 14.50 $\pm$ 5.21 trials with feedback; for the 100% condition this was 100% of trials; for the 50% condition this was 58.09% of trials; and for those in the 25% conditions this was 29.29% of trials.

Figure 3

Figure 3 presents group-means for most- and least-selected cues at test. There was a greater difference between stimuli in the 25% and 100% groups relative to the 50% group. A two-factor mixed-model ANOVA (stimulus x group) revealed significant main effects of group, $F(2,27) = 12.92$, $p < .001$, η^2_p =. 498[.175-.643], and stimulus, $F(1,27) = 80.73$, $p < .001$, η^2_p = .749[.717-.901], and a significant interaction, $F(2,27) = 17.50$, $p < .001$, η^2_p = .565[.260-.698]. Simple effects revealed significant most-versus-least differences for the 100% group, $F(1,27) = 97.12$, $p < .001$, η^2_p = .782[.570-.855], and 25% group, $F(1,27)$ =

16.67, $p < .001$, $\eta^2 = .381[.102\text{-}.577]$, but not for the 50% group, $F(1,27) = 2.87$, p > .30, η^2_p =. 096[.000-.320]. Simple effect analyses revealed no group differences for the most-selected stimulus, $F < 1$, $\eta^2_p = .049[.000\text{-}.217]$; but for the least-selected stimulus, $F(2,27) = 27.45$, $p < .001$, $\eta^2 = .670[.403\text{-}.773]$. Tukey's HSD tests revealed all pairwise differences between the least selected stimulus to be significant, *p*s < .05.

These data replicate Experiment 1 and strengthen the view that outcome unpredictability is related to the reduction in over-selectivity. The 50% group showed no difference between the most- and least-selected stimuli at test, but this remediation was not seen in the 25% group. This was despite equal amounts of feedback in the three groups. One consequence of equating feedback across groups was that the number of training trials differed between the groups. This factor has not been noted as important in discrimination learning (Williams, 1989), but has been suggested as important for over-selectivity – with longer training producing less over-selectivity (Koegel et al., 1979; Reynolds and Reed, 2011b). This might reflect the impact of asymptotic cue value (Le Pelley, 2004). The current data suggested that length of training did not impact over-selectivity – with 25% group receiving more training than the other groups, and not showing remediation. However, the levels of training given in this study (around 50 trials for the 25% condition) are much lower than those noted in the two previous studies that have noted an effect (both used 100+ trials).

Experiment 3

Given Experiment 2, it is possible that the success of the 33% schedule used by Koegel et al. (1979), which is not entirely unpredictable (more so than the 50% schedule, and somewhat similar to the 25% schedule) was due, in part, to length of training, rather than partial outcome schedules. Experiment 3 investigated this suggestion by exploring the effects of a 33% schedule with short and long training. Participants experienced a 100% or 33% schedule until they reached criterion, and then were either tested at that point (short training), or were trained for a further 100 trials (long training). If length of training is a factor in remediating over-selectivity, then short but not long-trained groups should show over-selectivity irrespective of the schedule employed (based on the assumption that a 33% schedule does have some predictability, as 2/3 responses will be followed by no outcome). However, if the 33% but not the 100% schedule shows reduction in over-selectivity in both conditions, then unpredictability maintaining observing responses may be the important factor.

Method

Participants and Materials

Thirty-six children, different from those in Experiments 1 and 2, but recruited according to the criteria described in Experiment 1, were randomly divided into the four groups. Four participants did not complete training, leaving 32 participants (26 male, 6 female) in the study (*n*=8). Their mean chronological age was 11:14 (range=9:0–14:11) years, autism severity (ABC) was 71.39 $\pm$ 16.81, mean mental age (BPVS) was 4:11 (range = 2:1–8:11) years, and IQ (BPVS) was 45.57 $\pm$ 11.70 (range = 20–75). The apparatus and measures were as described in Experiment 1.

Procedure

The procedure was as described in Experiment 1 except participants received reinforcement on either a 100% or a 33% schedule during training, and were trained until they reached 10 correct responses in a row. The long training groups received an additional

100 trials of training with the appropriate reinforcement frequency for their group. The test phase was conducted as in Experiment 1.

Results and Discussion

Participants in the 100% short group took a mean 14.38 ± 3.85 trials to criterion, and the 100% long group took 18.25 ± 5.18 trials. Participants in the 33% short group took 22.88 ± 5.44, and those in the 33% long group took 21.25 ± 6.48 trials. A two-way between-subjects ANOVA (schedule x training) revealed a significant main effect for schedule, $F(1,28) = 9.35$, $p < .01$, $\eta^2_p = .250[.021-.473]$, but not for training, $F < 1$, $\eta^2_p = .013[.000-.091]$, nor for the interaction, $F(1,28) = 2.14$, $p > .10$, $\eta^2_p = .071[.000-.106]$. Participants in the 100% short group received an average 14.38 ± 3.85 trials with feedback (100%), and the 100% long group received 18.25 ± 5.18 trials with feedback (100%). Participants in the 33% short group received 7.62± 1.77 trials with feedback (33.38%), and those in the 33% long group received 7.12 ± 2.41 feedback trials (33.15%). A two-way between-subjects ANOVA (schedule x training) revealed a significant main effect for schedule, $F(1,28) = 53.57$, $p < .001$, $\eta^2_p = .657[.408-.770]$, but not for training, $F(1,28) = 1.86$, $p > .10$, $\eta^2_p = .062[.000-.271]$, nor for the interaction, $F(1,28) = 3.12$, $p > .09$, $\eta^2_p = .100[.000-.321]$. These results indicate that the schedule of reinforcement impacted the speed of discrimination learning; with the 33% groups taking more trials to learn the discrimination than the 100% groups (see also Leader et al., 2009; Reynolds and Reed, 2011b).

Figure 4

Figure 4 shows the mean percentage times the most- and least-selected elements of the previously reinforced AB compound were chosen at test for each group, calculated as described in Experiment 1. There was a relatively smaller difference for the longer-trained than for short-trained groups. However, there was relatively little difference in the level of selectivity depending on the type of schedule. A three-factor mixed-model ANOVA (stimulus x schedule x training) revealed significant main effects of stimulus, $F(1,28) = 81.76$, $p < .001$, $\eta^2_p = .745[.521\text{-}.967]$, and training, $F(1,28) = 10.29$, $p < .01$, $\eta^2 = .269[.045\text{-}.489]$, but not schedule, $F < 1$, $\eta^2_p = .001[.000\text{-}.009]$. There were significant interactions between stimulus and training, $F(1,28) = 11.92$, $p < .01$, $\eta^2_p = .299[.091\text{-}.507]$, but not between stimulus and schedule, $F(1,28) = 3.27$, $p > .08$, $\eta^2_p = .050[.000\text{-}.121]$, training and schedule, $F(1,28) = 1.27$, $p > .20$, $\eta^2_p = .043[.000\text{-}.091]$, or all three factors, $F(1,28) = 2.19$, $p > .20$, $\eta^2_p = .073[.000\text{-}.184]$. Simple effect analyses revealed a large-sized significant effect of stimulus for the short training groups, $F(1,28) = 33.96$, $p < .01$, $\eta^2_p = .548[.332\text{-}.769]$, and a relatively smaller-sized significant effect for the longer training groups $F(1,28) = 6.80$, $p < .05$, $\eta^2_p = .195[.009\text{-}.387]$.

These data replicated the over-selectivity in Experiments 1 and 2 for the short-trained 100% groups (Kelly et al., 2016; Koegel and Wilhelm, 1973; Leader et al., 2009; Reed et al., 2009). Extending training reduced the over-selectivity effect, which has previously been noted for a nonclinical (Reynolds and Reed, 2011a) and ASD (Schover & Newsome, 1976; Schreibman et al., 1977) populations. That partial reinforcement did not greatly reduce over-selectivity suggests that the results reported by Koegel et al. (1979) with their 33% schedule might have more to do with the length of training employed. It also suggests that partial reinforcement is not always enough to remediate over-selectivity, but only some forms of partial reinforcement will produce this remediation (such as when the outcome is particularly unpredictable).

Experiment 4

Another reason why Koegel et al. (1979; see also Schover and Newsom, 1976; Schreibman et al., 1977) may have obtained positive findings with a 33% schedule is related to the point during training at which the partial reinforcement was introduced. In the study reported by Koegel et al. (1979), the 33% schedule was introduced after extensive training on a 100% schedule. When a surprising change in the reinforcer value is introduced, it can produce greater learning about the elements of a compound stimulus (Dickinson et al, 1976; Holland, 1984) tested that this change restores associability and increases attention to a stimulus that would otherwise be ignored (Dickinson et al., 1976; Pearce and Hall, 1980). To explore further this possibility, Experiment 4 investigated whether a change from continuous to partial (33%) schedule would remediate over-selectivity. This would suggest that this mechanism underlay the results reported by Koegel et al. (1979). However, should the effect not be seen, then it would suggest length of training is the more plausible explanation of why remediation of over-selectivity was seen with this schedule by Koegel et al. (1979) and not in the present Experiment 3.

Method

Participants and Materials

Forty children with ASD, different from those in the previous three experiments, but recruited according to the criteria described in Experiment 1, as described in Experiment 1, were randomly divided into four groups (*n*=10). The participants had a mean chronological age of 7.10 (range=5–15) years, a mean autism rating (ABC) of 87.34 ± 12.79, a mental-age equivalence (BPVS) of 4:6 (range = 2–8) years, and a mean IQ (BPVS) equivalence of 60.41 ± 14.82 (range=22–85). The apparatus and measures were as described in Experiment 1.

Procedure

The participants were tested as described in Experiment 1, with the following exceptions. Participants in Group Continuous received AB+CD- training with 100% reinforcement until they had emitted 10 correct responses in a row. They then received a further 5 trials with 100% reinforcement. Group 33% received the same treatment, except with feedback given on 33% of the trials for both the initial criterion mastery and over-training phases. Group 50% received the same treatment, except with feedback on 50% of trials in both phases. Group Change received 100% feedback during the criterion mastery part of training, and on a 33% schedule for the over-training phase, which comprised 5 trials as for the groups above. Participants received testing as described in Experiment 1.

Results and Discussion

Group Continuous took a mean of 18.60 ± 2.76 trials to reach criterion, Group 33% took a mean of 22.70 ± 3.71 trials, Group 50% took a mean of 22.90 ± 3.69 trials, and Group Change took a mean of 16.40 ± 4.40 trials. A one-way between-subjects ANOVA revealed this difference significant, $F(3,36) = 7.48$, $p < .001$, $\eta^2_p = .384[.122-.535]$. Tukey's HSD tests revealed that both Groups 33% and 50% took longer than both Group Continuous and Change to reach criterion, *p*s < .05. As with the previous studies reported here (Leader et al., 2009; Reed et al., 2009; Reynolds and Reed, 2011b), partial outcomes impeded discrimination learning.

Figure 5

Figure 5 shows the group-mean percentage that the most- and least-selected elements of the previously reinforced compound stimulus (AB) were selected during the test phase. There was little difference between the most- and least-selected stimuli across the groups, except for the 50% group. A two-factor mixed model ANOVA (stimulus x group) revealed no main effect of group, $F < 1$, $\eta^2_p = .046[.000-.160]$, but a main effect of stimulus, $F(1,36) = 144.81$, $p < .001$, $\eta^2_p = .801[.661-.862]$, and a significant interaction, $F(3,36) = 10.70$, $p < .001$, $\eta^2_p = .471[.186-.606]$. Simple effect analyses revealed most-versus-least differences for Group Continuous, $F(1,36) = 19.82$, $p < .001$, $\eta^2_p = .348[.109-.531]$, Group Change, $F(1,36) = 20.83$, $p < .001$, $\eta^2_p = .367[.124-.567]$, and Group 33%, $F(1,36) = 9.63$, $p < .05$, $\eta^2_p = .211[.026-.413]$, but not for Group 50%, $F(1,36) = 1.63$, $p > .30$, $\eta^2_p = .043[.000-.218]$. Simple effects revealed no group difference for the most-selected stimulus, $F < 1$, $\eta^2_p = .029[.000-.119]$, but a significant difference for the least-chosen stimulus, $F(3,36) = 3.61$, $p < .05$, $\eta^2_p = .231[.002-.397]$. Tukey’s HSD tests revealed that Group 50% differed from each of the other groups, *p*s<.05, but there were no other pairwise differences, *p*s > .30.

An over-selectivity effect emerged with the 100% schedule (Koegel and Wilhelm, 1973; Leader et al., 2009; Reed et al., 2009), and this effect was not remediated by an over-trained 33% schedule, or by a change in schedule contingency. There was remediation with a 50% schedule. This suggests a change in schedule is not enough to remediate over-selectivity in those with ASD (see Reynolds and Reed, 2011b, for a similar result with a nonclinical population). Although it might be noted that the number of trials in the ‘over-training’ phase, during which the change was implemented, was relatively small.

General Discussion

The current research investigated the effect of partial outcomes on the remediation of over-selectivity in a sample with ASD, resolved some apparent discrepancies in the literature, and investigated potential mechanisms through which partial reinforcement may operate. Experiment 1 indicated that a 50% schedule resulted in reduction in over-selectivity. However, no reduction was noted with a 25% schedule. Experiments 3 and 4 demonstrated that a 33% reinforcement schedule had little effect on reducing over-selectivity, unless training had been continued for an extensive length of time. Experiment 4 noted that a change in schedule from continuous to partial (33%) did not remediate over-selectivity.

The current data help understand the apparently disparate effects of partial outcomes on over-selectivity noted in previous results (cf. Dube and McIlvane, 1997; Koegel et al., 1979; Reynolds and Reed, 2011b; Schreibman et al, 1977). There were a number of clear influences on the reduction of over-selectivity – such as longer training, which have been noted previously (Koegel et al., 1979). This well-established, and corroborated effect in this study, suggests that the impact of partial schedules may be seen more strongly on relatively weaker learned responses. Under these conditions, partial outcomes, when the outcomes are particularly unpredictable (such as with a 50% schedule), reduce levels of over-selectivity.

However, when the schedule has a leaner reinforcement density (providing more predictability again), such as the 25% schedule in Experiments 1 and 2, and the 33% schedule used in Experiments 3 and 4 (see also Koegel et al., 1979), then remediation becomes less pronounced (Dube and McIlvane, 1997). Any reduction in over-selectivity from a 33% schedule seems likely to be related to the length of training (see current Experiment 3 and Reynolds and Reed, 2011b). The mere change of the schedule as employed in some studies using a 33% schedule (Schreibman et al., 1977) is not enough to generate remediation

(Experiment 4; Reynolds and Reed, 2011b), and this unpredictability needs to be delivered over a sustained period of time (see also Schreibman et al., 1977). This conclusion should be tempered in the light of the consideration that the uncertainty account hinges on the finding that a 50% reinforcement schedule reduces over-selectivity, but that 33% and 25% schedules do not. What is missing are the converse conditions: that is, a 66% or 75% reinforcement schedule, with higher likelihood of reward, but still partial reinforcement, and exactly equal unpredictability to 33% or 25%. These latter two schedule should similarly fail to reduce over-selectivity, and could be studied in future experiments.

There are a number of possible theoretical explanations for the impact of uncertainty on over-selectivity. One account concerns the unpredictability of the outcome in such a partial procedure, which should generate greater attention through enhancing associability (Kaye and Pearce, 1984; Pearce and Hall, 1980). Cross-experimental comparison of the present data reveals the greatest reductions in over-selectivity were with 50% feedback, and were less pronounced with 33% and smallest with 25%. The current pattern of data from the ASD population fits well with the eye-gaze data provided from a typically-developing population, where more time is spent examining elements from cues with a more unpredictable relationship to an outcome (Beesley, Nguyen, Pearson, and Le Pelley, 2015). This pattern of results suggests that restoration of associability is a likely mechanism underlying removal of over-selectivity (Dube, 2009; Reed et al., 2009). However, it is important to note that it may be the current results are more applicable to populations with language or intellectual impairments than to other populations. Higher functioning individuals with ASD do not appear to be controlled by early processing deficits in attention, but rather by retrieval deficits (Reed, 2011). Moreover, a typically developing population does not seem to be affected by such changes in associability (Reynolds & Reed, 2013).

One aspect of precisely what ‘uncertainty’ is driving these results is worth some comment. The suggestion is that predicting the outcome on a 25% schedule is easier than on the 50% schedule. This is true if the presence/absence of feedback is the key thing for the participant. However, on trials with feedback, the components of the stimuli are all equally certain/uncertain as each other (e.g., A and B are both getting a 100% or a 50% schedule, depending on the condition). Clearly, what drives the phenomenon of spreading attention is not just about what happens on ‘reinforced’ trials, but across the whole session.

A couple of additional findings suggest potential roles for alternative mechanisms in addition to the restoration of associability. Experiment 4 failed to note a restoration of learning due to a change in the schedule (see also Reynolds and Reed, 2011b), which would be predicted by associability accounts (Dickinson et al., 1976). Moreover, the impact of length of training on over-selectivity is not totally consistent with an associability-based account (Pearce and Hall, 1980; Williams, 1989), as such accounts predict increases, not decreases, in over-selectivity as training continues (Reed, 2011). In contrast, the comparator account of over-selectivity (see Leader et al., 2009; Reed, 2011) predicts both reductions in the level of reinforcement, and increases in the length of training, would serve to reduce over-selectivity. This view relies on the suggestion that a comparator mechanism compares the relative strengths of all stimuli, and selects the ones most likely to lead to an outcome for action (Miller and Matzel, 1988; Reed, 2011). Reed (2011) suggested that this selection mechanism is based on the relative strengths of the stimuli. The discrepancies between relative strengths of poorly learned stimuli, such as with partial reinforcement, or stimuli trained for less time, would be greater than those with continuous reinforcement or over-training. This account, of course, implies that learning on a partial schedule is weaker, premised on the fact that participants take longer to reach criterion on such schedules.

However, as participants receive less feedback on these partial schedules, an alternative explanation is that learning may be faster, relative to the number of reinforcers obtained.

The current results provide a contribution to the understanding of over-selectivity for individuals with ASD who have intellectual and/or language impairments. However, it should be noted that the absence of a group without ASD makes the assumption that ASD is associated with greater than usual over-selectivity, dependent upon cross-experimental comparisons (e.g., Lovaas et al., 1971). To assess the relationship between ASD severity and levels of over-selectivity, the data from the four studies in the current study were pooled, creating a sample of 145 participants (albeit, exposed to somewhat different methodologies). A correlation between their ASD severity (measured by the ABC) and the level of over-selectivity (the difference between the most and least selected stimulus), revealed a marginally significant, small-sized correlation, $r = .160$, $p = .054$. This suggests that ASD severity does play some role in the generation of over-selectivity. There was no such correlation between the verbal mental age score (BPVS) and the level of over-selectivity, $r = -.027$, $p = .745$. A further limitation is that it is unclear whether the current observations generalise to different types of compound stimuli, and whether factors like similarity, proximity, etc., play a role. Certainly, it has been suggested that within-compound associations, which would be dependent upon such factors, are implicated in the development of over-selective responding (Reynolds & Reed, 2018).

Implications

Irrespective of the particular theoretical implications for understanding the nature of over-selectivity, the current results suggest that consideration of the principles derived from learning theory may be of help in developing treatments for this important clinical phenomenon. The theoretical insights gained from the consideration of learning theoretic principles, may illuminate practice especially in early teaching interventions, such as those derived from applied behavior analysis. For example, the use of a 50% training schedule during ABA procedures for individuals with ASD could be a potentially effective intervention for the remediation of over-selectivity. Such a partial reinforcement training schedule may also be beneficial when attempting to teach a discrimination between two complex stimuli to individuals with ASD who have language and/or intellectual impairments in order to maintain responding to each of the elements. Careful consideration should also be given to the adoption of fading procedures, whereby the rate of reinforcement provided during an ABA session for a particular behavior is reduced in order to generate maintenance of that responding post-intervention. The current results suggest that such fading should ideally not progress beyond a 50% schedule until evidence of over-selectivity is removed, as leaner schedules (e.g., 33%, 25%) may not be as effective in removing over-selective responding.

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Figure 1. Top = Example of training compound stimuli used (not to scale). Bottom = example of test stimuli showing an element from the compound.

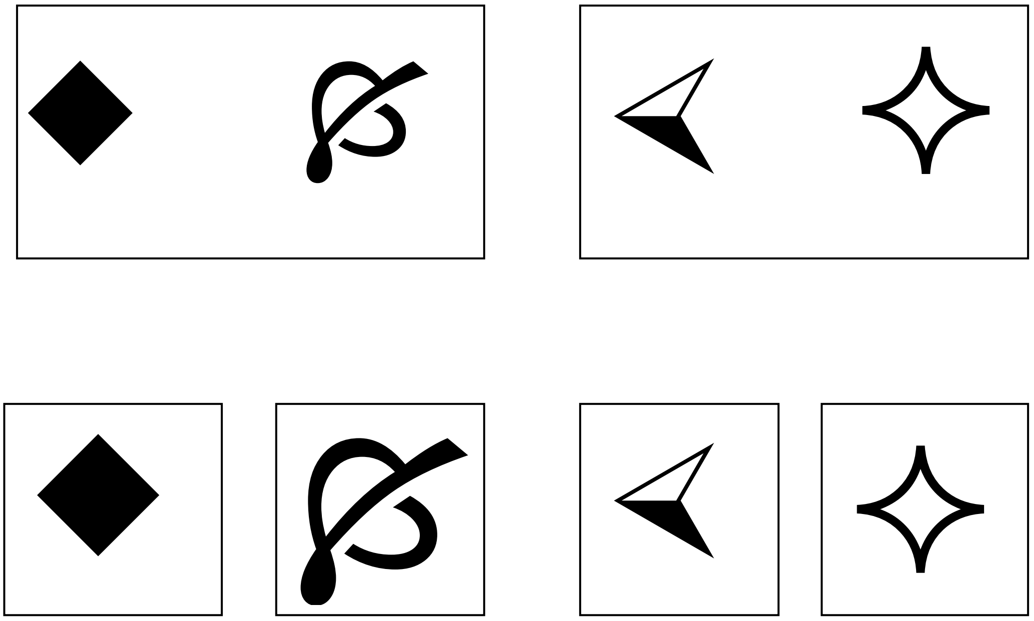

Figure 2. Experiment 1. Mean percent times that each stimulus of the cue complex (most and least selected) was selected during the test phase for each reinforcement schedule group (100%, 50%, 25%). Error bars = 95% confidence intervals. NB. Scale exceeds 100% only to accommodate error bars.

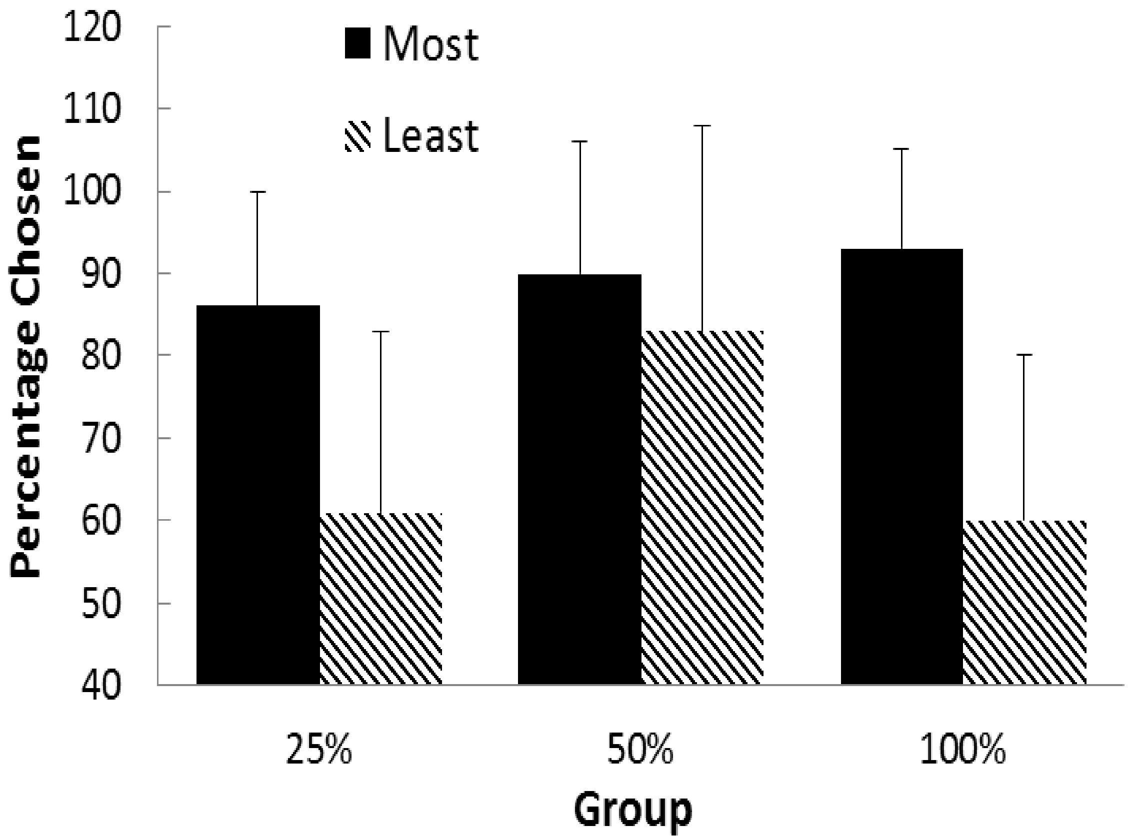

Figure 3. Experiment 2. Mean percent times that each stimulus of the cue complex (most and least selected) was selected during the test phase for each reinforcement schedule group (100%, 50%, 25%). Error bars = 95% confidence intervals. NB. Scale exceeds 100% only to accommodate error bars.

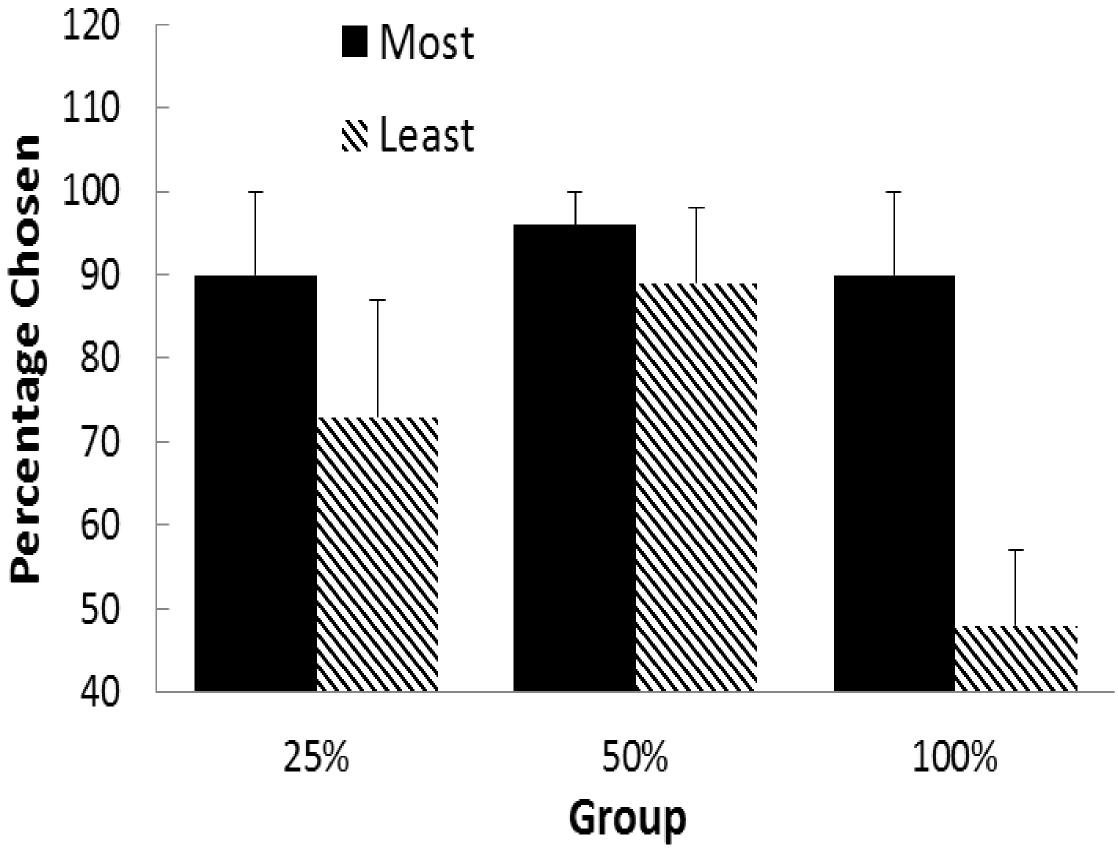

Figure 4. Experiment 3. Mean percent times that each stimulus of the cue complex (most and least selected) was selected during the test phase for each reinforcement schedule group (33% schedule, 100% schedule, short = 10 trials to criteria, long – overtrained). Error bars = 95% confidence intervals. NB. Scale exceeds 100% only to accommodate error bars.

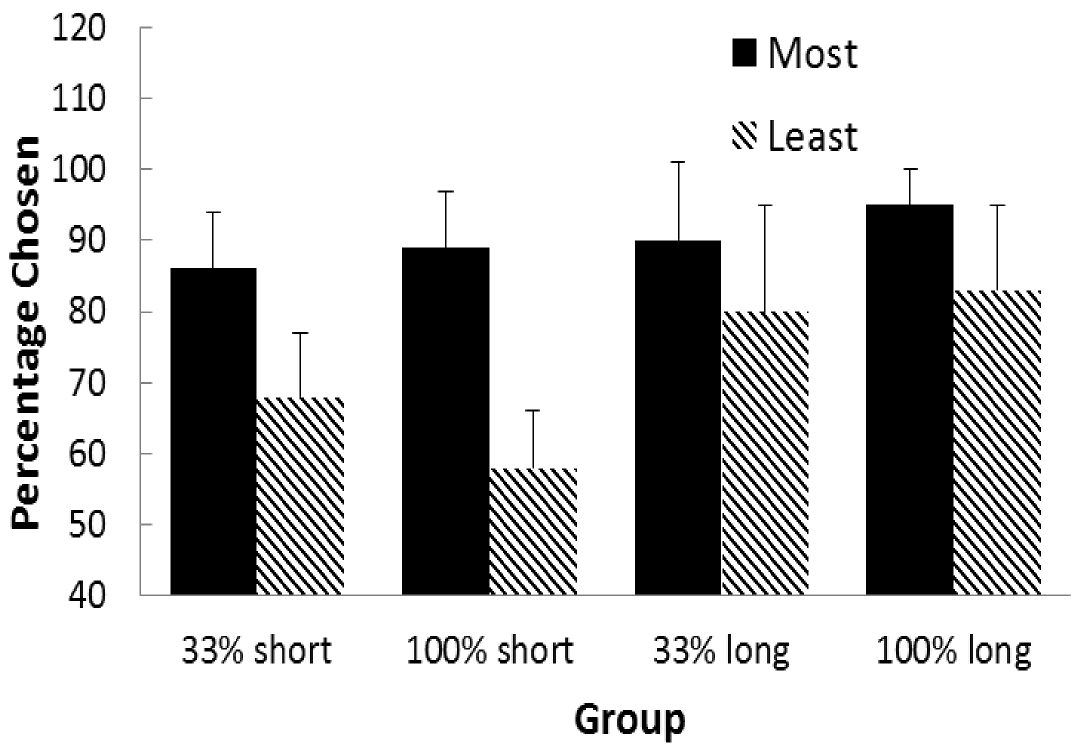

Figure 5. Experiment 4. Mean percent times that each stimulus of the cue complex (most and least selected) was selected during the test phase for each reinforcement schedule group (continuous = 100% schedule, partial = 33% schedule; change = 100% then 33%). Error bars = 95% confidence intervals. NB. Scale exceeds 100% only to accommodate error bars.