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Stimulus over-selectivity and extinction-induced recovery of performance as a product of intellectual impairment and autism severity

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Abstract

The current experiment investigated the factors associated with over-selective responding in a group of children with Autism Spectrum Disorder and the factors associated with the recovery of responding to a previously under-selected stimulus following extinction of the previously over-selected stimulus. The results demonstrated that participants showed over-selectivity, and demonstrated that extinction of the over-selected stimulus led to recovery of responding to the previously under-selected stimulus. For both over-selectivity, and recovery from over-selectivity, verbal functioning appeared to predict the effects most strongly, with greater over-selectivity in the lower functioning individuals, and greater recovery in the higher functioning individuals.

Keywords: Over-selectivity; Extinction; Comparator deficit; Intellectual Impairment; Autism Severity

'Stimulus over-selectivity' describes a phenomenon where an individual responds only to a subset of the stimuli present in the environment, and, thus, may restrict learning regarding the range, breadth, or number of features, of a stimulus (Lovaas, Schreibman, Koegel & Rehm, 1971; Dube, 2009; Ploog, 2010). Instances of over-selective responding are found in many clinical populations, including individuals with intellectual disabilities (Smeets, Hoogeveen, Striefel & Lancioni, 1985), learning disabilities (Bailey, 1981; Dube & McIlvane, 1999; Lovaas & Schreibman, 1971; Gersten, 1983; Litrownik, McInnis, Wetzel-Pritchard, & Filipelli, 1978); Rett's Disorder (Fabio, Giannatiempo, Antonietti & Budden, 2009), acquired brain injury (Wayland & Taplin, 1982), and schizophrenia (Feeny, 1972). Stimulus over-selectivity has also been demonstrated in typically developing individuals experiencing situations involving high cognitive demands (e.g., McHugh & Reed, 2007; Reed & Gibson, 2005; Reed, Savile, & Truzoli, 2012; Reynolds, Watts & Reed, 2012).

However, over-selectivity is very often noted in individuals with Autism Spectrum Disorders (ASD), and this failure to respond to all necessary or important cues in the environment may be a factor contributing to many of the problems seen in ASD, including: deficits in communication skills (e.g., Chiang & Carter, 2008; Reynolds, Newsom, & Lovaas, 1974; Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967); social behavior skills (e.g., Scherf, Behrmann, Minshew, & Luna, 2008; Schrandt, Townsend, & Poulson, 2009; Gena, Krantz, McClannahan & Poulson, 1996); learning skills (e.g., Varni, Lovaas, Koegel, & Everett, 1979; Koegel & Rincover, 1976; Walpole, Roscoe & Dube, 2007); and the ability to generalize acquired material (e.g., Rincover & Koegel, 1975; Falcomata, Roane & Pabico, 2007). Given the range of difficulties associated with over-selectivity, research has indicated that this phenomenon can also negatively impact overall quality of life (LeBlanc et al., 2005).

One well-researched theoretical perspective regarding stimulus over-selectivity is the 'attention deficit' view, which posits that over-selective responding is a product of an attentional deficit in sampling all of the component elements of a stimulus (see Dube et al., 1999). Components that are not attended to cannot be processed or learned about, therefore, only the elements of the stimulus that are attended to can subsequently control behavior (e.g., Lovaas et al., 1971; Koegel & Wilhelm, 1973; Dube & McIlvane, 1999; Dube et al., 1999). Research in support of this theory has employed eye-tracking technology, and has found that over-selectivity often is accompanied by a failure to observe all of the relevant stimuli (Dube et al., 1999).

An alternative mechanism has been suggested by a comparator theory (e.g., Reed, 2011; see also Miller & Matzel, 1988; Miller & Schachtman, 1985). This theory ascribes over-selectivity to a performance deficit, rather than an initial attention problem, and attributes this performance problem is attributable to an 'over-sensitive' comparator mechanism (Reed, 2011). It is suggested that the comparator is responsible for selecting which stimuli, out of a range of available stimuli, are the most important, and triggers responses to the most important stimuli available in the environment at the time. This view suggests that, relative to typically developing individuals, people with ASD may have a comparator mechanism that is over-sensitive to slight differences in importance between stimuli, and will respond only to a very narrow set of stimuli – failing to trigger a response to weaker, but still important, environmental cues and provoking an over-selective response (Reed, 2011; Reed, Broomfield, McHugh, McCausland & Leader, 2009; Leader, Loughnane, McMoreland, & Reed, 2009). In contrast, in typically developing individuals, have a relatively less sensitive comparator mechanism (i.e. one which will tolerate a larger discrepancy in the importance of stimuli before directing behavior toward one of these stimuli at the expense of the other), slight differences in the importance of stimuli would tend not to provoke selection of some stimuli, and each of the stimuli present would control behavior. That is not to imply that the comparator mechanism in typically developing children is not capable of selecting appropriate responses, but rather that it will not 'de-select' particular stimuli that have some relevance for the situation, but which is less than perfect.

Unlike attention deficit theories, the comparator theory suggests that post-learning manipulations of the previously over-selected cue should enable the under-selected cue to emerge to control responding. Reed et al. (2009) conducted two experiments to examine whether over-selectivity is the product of a post-acquisition performance deficit, rather than an attention problem. In both experiments, children with ASD were presented with a trial-and error discrimination task using two, two-element stimuli and participants over-selected in both studies. After behavioral control by the previously over-selected stimulus was extinguished, the previously under-selected cue emerged to control responding without direct training. This suggests that over-selectivity may be the result of a performance deficit, or retrieval failure and not a failure at the time of acquisition because such a finding provides evidence that the apparently underselected cue was actually attended to initially. However, although this effect was found in children with ASD who had higher intellectual functioning, it was not noted with more severely intellectually impaired children with ASD, suggesting that for these latter participants there was an attention-based explanation for the results. These results led Reed et al. (2012) to suggest that there may in fact be two forms of stimulus over-selectivity. One form may be due to an attention deficit and the other form may be due to a post-processing disorder. The form the over-selectivity effect takes is dependent upon the severity of the intellectual impairment.

The current research aimed to further examine these effects, and to investigate whether over-selective responding is a function of intellectual impairment or ASD severity. Previous research has revealed inconsistent results during analyses of stimulus over-selectivity in terms of both IQ and severity of ASD. Wilhelm and Lovaas (1976) concluded that over-selectivity was not an exclusive feature of ASD, but rather of intellectual disability more generally. Although over-selectivity is a phenomenon common in ASD, it is not restricted to individuals with this diagnosis, and, therefore, ASD is not a reliable predictor of over-selectivity (Ploog, 2010). However, similar to the results seen in Frankel, Simmons, Fichter, and Freeman (1984), Reed et al. (2009) found that the participants displayed a significant degree of over-selectivity, irrespective of IQ levels. In addition, this study will also examine recovery from over-selectivity by extending the investigation reported by Reed et al. (2009), who restricted their measurement of intellectual functioning to verbal functioning, to determine whether ASD severity and nonverbal functioning also impact over-selectivity recovery.

Method

Participants

Twenty-seven children with ASD (21 boys and 6 girls) were recruited from three Applied Behavior Analysis (ABA) schools for children with ASD and complex needs, and also from one mainstream primary school. All participants had a diagnosis of an ASD (either Autism or Pervasive Developmental Disorder- Not Otherwise Specified), which was made according to the DSM-IV-TR criteria, by a specialist pediatrician following referral from a general practitioner, both of whom were independent from this study. The participants chronological age ranged from 5:2 to 14:11 years (mean = 9:60 years, SD = 32.32).

Table 1 about here

Table 1 shows the mean (standard deviation) for the participants’ scores in terms of their autism severity (GARS-2 standard score; Gilliam, 2006), nonverbal intellectual functioning (Leiter-R standard score; Roid & Miller, 1997), and verbal functioning (PPVT-4 ability in months; Dunn & Dunn, 2007), as well as the Pearson correlation values between these scores. Inspection of these data shows that the sample was of a slightly greater than average ASD severity (i.e. the mean GARS was over 100), with low levels of nonverbal and verbal functioning, all of these scores were significantly correlated with one another.

Materials

Levels of over-selectivity were tested using laminated stimulus cards measuring 12cm by 10 cm, consisting of one black stimulus or two black stimuli on a white background (see Reed & Gibson, 2005). There were eight different picture stimuli: clock, flower, chicken, hand, eye, pencil, mouse, and book that were used as the elements for the compound stimuli. The compound stimuli (AB and CD) contained two of these stimuli, whilst other cards presented the individual element stimuli and contained one of the pictures from the compound stimulus.

Figures 1a and 1b about here

Measures

Gilliam Autism Rating Scale: Second Edition (GARS-2; Gilliam, 2006): The GARS-2 is a norm-referenced instrument that consists of 42 items describing the characteristic behaviors of individuals with ASD. The items are grouped into three subscales: stereotyped behaviors, communication and social interaction. The respondent uses the Likert scale to rate the frequency of the subscale items as: 0 (never observed), 1 (seldom observed), 2 (sometimes observed), or 3 (frequently observed). The obtained raw scores are converted into standard scores (mean = 10; SD = 3) which, when totaled, provides an Autism Index (mean = 100, SD = 15) for each participant. An Autism Index of 85 or higher, means that the probability of the individual having ASD is ‘very likely’, a score between 70 and 84 means that it is ‘possible’ that the individual has ASD, and a score of 69 or lower means that it is unlikely that the individual has ASD (Gilliam, 2006). The internal consistency, measured using Cronbach’s coefficient alpha (1951), is 0.94 for the total test. The test-retest reliability ranges from 0.64 to 0.84 and are all beyond the .01-level of significance.

Leiter-Revised (Leiter-R; Roid, & Miller, 1997). Six subtests from the Visualization and Reasoning Battery in the Leiter-R were used to attain a full non-verbal IQ score (mean=100, SD = 15) for each participant. The subtests included figure ground, design analogies, form completion, sequential order, repeated patterns and paper folding. This instrument has a reliability ranging from 0.91 to 0.93; a test-retest reliability of 0.9 to 0.96 and a 0.86 correlation with the WISC-III full scale IQ measure (Roid & Miller, 1997).

Peabody Picture Vocabulary Scale Fourth Edition (PPVT-4; Dunn & Dunn, 2007) measures children’s verbal mental age. This norm-referenced instrument has 228 test items that measure the receptive vocabulary of children by requiring discrimination of one target from an array of four pictures. This method of assessment does not require the child to speak, write, or read, but the child simply points to the picture cards as requested. The mean split-half reliability of the PPVT-4 is 0.94 and its test-retest reliability is 0.93 (Dunn & Dunn, 2007).

Procedure

The experiment was conducted in a quiet classroom free from distraction in the participant’s school. A classroom assistant familiar with the child was also present during testing. The Leiter–R (Roid & Miller, 1997), PPVT-4 (Dunn & Dunn, 2007), and the GARS-2 (Gilliam, 2006) were administered prior to testing.

Training phase. The stimuli were placed on the center of the desk half-way between the participant and the experimenter, who sat facing each other. Participants were presented with two white cards simultaneously with a verbal instruction to pick a card. Each card contained two black stimulus elements (see Fig. 1a). On each trial, the participant was presented with one compound stimulus (AB), that yielded a ‘yes’ response with a smile if selected and an alternative compound stimulus (CD), that yielded a ‘no’ response with no smile if selected. Thus, the participant's choice of stimulus AB (S+) was reinforced with verbal and social feedback whereas the selection of stimulus CD (S−) was not reinforced. The compound stimuli were counterbalanced across participants to avoid the potential confounding variable of some stimuli being intrinsically more salient than others. Participants reached criterion in the training phase once they chose the S+ ten times consecutively.

Test phase. Participants were presented with two cards simultaneously, each one comprising of just one picture from the compound stimulus (see Figure 1b). The pictures were paired so that the participants had a choice of a stimulus from the compound S+ and a stimulus from the compound S-. There were five trials for each combination of stimuli (i.e. A v C, A v D, B v C, B v D) giving a total of 20 trials. No feedback was provided by the experimenter to the student during test trials.

Extinction phase. The over-selected stimulus was determined (i.e., A, B, C or D) and was paired with one of four novel stimuli (E, F, G, or H). Participants received positive reinforcement for choosing the novel stimulus, and not the over-selected stimulus. Criterion was reached when the participants chose the novel stimulus ten times consecutively.

Re-test phase. The same test procedure was used as the first testing phase, with no feedback provided to the student.

Results

All participants successfully completed the training phase, taking a mean of 44.11 (± 31.40) trials to reach criterion. The number of times that each of the elements of the S+ stimuli (AB) was selected during the test phase was recorded in order that the most-selected and least-selected elements was calculated; the mean for the most-selected stimulus for the sample was 80.37 (± 18.70), and the mean for the least-selected stimulus was 58.15 (± 29.96). A paired-sample t-test revealed a large-sized significant difference, $t(26) = 4.06$, $p < .001$, $d = .926$. However, such an analysis will tend to produce a difference between the most- and least-selected stimuli. Further analysis of the data was undertaken, based on binomial theory, to determine whether the difference in the selection of the two stimuli was significantly greater than random chance (Reynolds & Reed, 2011a; Reynolds, Watts & Reed, 2012). To this end, the mean probability of choosing the two stimuli from the previously reinforced compound was calculated. The binomial equation then was employed to obtain the probability of choosing all possible combinations of A and B over C or D on 10 trials (i.e., the probability of obtaining 10 A, and zero to 10 B, the probability of obtaining 9 A, and zero to 10 B, etc., were calculated), and these values inserted into a 10×10 contingency table. The contents of this table were then multiplied by a 10×10 table containing the absolute 'A minus B' difference score for each combination. The resulting 10×10 table contained the expected frequency of obtaining each possible A minus B difference resulting from all possible combinations of A and B frequencies. The sum of the values in this table (multiplied by 10) provided an estimate of the most minus least selected difference, in percentage terms, expected by random variation of selection of A and B stimuli. Paired t-tests were then used to test this sum against the obtained data, in order to investigate whether significant over-selectivity occurred. On this basis, the expected difference between the most and least selected stimulus was 16.3%. A paired t-test was performed to compare the obtained difference (24.2%) between A and B to this expected difference based on chance, which indicated a moderate-sized significant difference (and, therefore, over-selectivity), $t(26) = 2.23$, $p < .05$, $d = .306$.

To determine whether there were differences between lower- and higher-functioning participants on each of the three variables in terms of the degree to which they showed over-selectivity, the sample was split to create two groups for each of these domains. For autism severity (GARS-2) a cut-off of 100 was used (as this specifies ‘average’ severity in the population), and this produced 13 participants with less severe ASD (mean = 78.38 ± 14.37, range = 55-100), and 14 in the higher severity group (mean = 141.64 ± 23.09, range = 102-165). For nonverbal intellectual functioning (Leiter-R), the sample was split at the median (50), which produced 13 participants in the lower intellectual functioning group (mean = 40.00 ± 5.75, range = 32-49), and 14 participants in the higher functioning group (mean = 70.21 ± 16.87, range = 50-97). For verbal intellectual functioning (PPVT-4) the sample was split at the median mental age in months (45), which produced 13 participants in the low verbal ability group (mean = 35.46 ± 5.80, range = 20-44), and 14 participants in the higher verbal ability group (mean = 60.00 ± 14.45, range = 45-95).

Figure 2 about here

Percentage times that each stimulus was chosen in the test phase was recorded for the lower- and higher-functioning groups in each domain, and these data are displayed in Figure 2. A two-way, mixed-model analysis of covariance (ANCOVA), with stimulus type (most verses least) as a within-subject factor, and group (lower and higher for the target domain) as a between-subject factor, with the scores for the other two non-target domains for that analysis as covariates, was conducted on each variable. For autism severity, the more severe group tended to display greater over-selectivity than the less severe group. However, while the ANCOVA revealed a statistically significant main effect of stimulus type, $F(1,23) = 10.48$, $p < .01$, *partial eta*^{2} = .313, there was no statistically significant main effect of group, F < 1, *partial eta*^{2} = .006, or interaction, $F(1,23) = 3.43$, p > .08, *partial eta*^{2} = .130. When the lower ASD severity group was compared against the required difference for a significant over-selectivity effect, as indicated by binomial theory (see above), there was a moderately-sized marginally significant (one-tailed) over-selectivity effect, $t(12) = 1.69$, $.06 > p > .05$, $d = .468$, when the more severe group was tested, this difference was statistically significant (one-tailed), $t(13) = 2.22$, $p < .05$, $d = .593$.

For nonverbal functioning, the higher functioning group tended to get more correct responses, but there was little difference in the level of overshadowing noted. The ANCOVA revealed a statistically significant main effect of stimulus type, $F(1,23) = 6.78$, $p < .05$, *partial eta*^{2} = .214, but no statistically significant main effect of group, $F < 1$, *partial eta*^{2} = .007, or interaction, $F < 1$, *partial eta*^{2} = .001. When the lower intellectual functioning group was compared against the required difference for a significant over-selectivity effect, as indicated by binomial theory (see above), there was a significant over-selectivity effect (one-tailed), $t(12) = 1.69$, $p < .04$, $d = .466$, when the higher functioning group was tested, this comparison did not quite reach conventional levels of statistical significance, $t(13) = 1.41$, $0.08 > p > .07$, $d = .377$.

For verbal functioning, the higher functioning group tended to get more correct responses, but there was little difference in the level of overshadowing noted. The ANCOVA revealed a statistically significant main effect of stimulus type, $F(1,23) = 4.52$, $p < .05$, *partial eta*^{2} = .164, but no statistically significant main effect of group, $F < 1$, *partial eta*^{2} = .014, or interaction, $F < 1$, *partial eta*^{2} = .001. When the lower intellectual functioning group was compared against the required difference for a significant over-selectivity effect, as indicated by binomial theory (see above), the was a statistically significant effect of over-shadowing (one-tailed), $t(12) = 2.17$, $p < .05$, $d = .631$, when the more severe group was tested, this was not significant, $t(13) = 1.24$, $p > .10$, $d = .331$.

A logistic regression was performed to determine if any of the values (autism severity, nonverbal intellectual functioning, or verbal functioning) predicted a demonstration of over-selectivity by the participants (see Reed & Wu, 2013). The predictors were the GARS, Leiter-R, and Peabody mental age (months), scores and the target was whether the participants showed a difference between the most- and least-selected stimulus of greater than 16.3% during test. The overall regression produced a significant result, *chi square* = 10.86, $p < .05$, -2LL = 25.64. In terms of the three predictors, this analysis revealed that only verbal functioning (odds ratio = 0.894, $p < .05$) was a significant predictor of over-selectivity (autism severity odds ratio = .979, $p > .10$; intellectual functioning odds ratio = .969, $p > .40$).

The mean percentage change from the test to the retest phase was subsequently calculated by subtracting the test score from the retest score. For the entire sample the previously most-selected stimulus showed a mean reduction in selection at retest of 20.37% ($\pm$ 36.64, ranging from -100 to 30), which was a statistically significant difference from zero, $t(26) = 2.89$, $p < .01$, $d = .397$. However, for the entire sample, the previously under-selected stimulus only showed a mean increase of 3.70% ($\pm$ 29.37, ranging from -80 to 50), which was not statistically different from zero, $t < 1$, $d = .126$.

Figure 3 about here

Figure 3 presents the change in the percentage times that each element of the compound stimuli across the two phases (post- extinction minus pre-extinction phase) for the lower- and higher-functioning groups in each of the three domains (based on the groups outlined above). A two-way, mixed-model ANCOVA (stimulus type x group), with the score in the other two non-target domains for that analysis as covariates, was conducted on each variable.

Both of the autism severity groups demonstrated a reduction in selection of the previously over-selected stimulus (more so in the less severe group), but only the less severe group demonstrated any numerical recovery in selection of the previously under-selected stimulus. The ANCOVA revealed a statistically significant main effect of stimulus type, $F(1,23) = 7.89$, $p < .01$, *partial* $eta^2 = .258$, but there was no statistically significant main effect of group, $F < 1$, *partial* $eta^2 = .011$, or interaction, $F(1,23) = 3.12$, p > 0.08, *partial* $eta^2 = .126$. Comparisons of the change scores against zero for the most and least selected stimuli for the lower severity group revealed a statistically significant reduction in the previously most selected stimulus, $t(12) = 2.17$, $p < .05$, $d = .603$, but not for the previously least selected stimulus, $t(12) = 1.26$ $p > .10$, $d = .350$. For the higher severity group, there was a statistically significant reduction in the previously most selected stimulus, $t(13) = 1.86$, $p < .05$, $d = .498$, but not for the previously least selected stimulus, $t < 1$, $d = .001$.

For nonverbal functioning, both lower and higher functioning groups showed a reduction in the previously over-selected stimulus, but only the higher functioning group showed any recovery in the previously under-selected stimulus. The ANCOVA revealed a statistically significant main effect of stimulus type, $F(1,23) = 6.40$, $p < .05$, *partial* $eta^2 = .218$, but no main effect of group, $F < 1$, *partial* $eta^2 = .010$, nor interaction, $F < 1$, *partial* $eta^2 = .007$. Comparisons of the change scores against zero for the most and least selected stimuli for the lower functioning group revealed a statistically significant reduction in the previously most selected stimulus, $t(12) = 2.26$, $p < .05$, $d = .628$, but not for the previously least selected stimulus, $t < 1$, $d = .001$. For the higher functioning group, there was a statistically significant reduction in the previously most selected stimulus, $t(13) = 1.76$, $p < .05$, $d = .469$, but not for the previously least selected stimulus, $t < 1$, $d = .235$.

For verbal functioning, both lower and higher functioning groups showed a reduction in the previously over-selected stimulus, and both showed some recovery in the previously under-selected stimulus, although this was more pronounced for the higher functioning group. The ANCOVA revealed a statistically significant main effect of stimulus type, $F(1,23) = 3.11$, $p < .05$, *partial* $eta^2 = .211$, but not of group $F < 1$, *partial* $eta^2 = .002$, or interaction $F < 1$, *partial* $eta^2 = .002$. Comparisons of the change scores against zero for the most and least selected stimuli for the lower functioning group revealed a statistically significant reduction in the previously most selected stimulus, $t(12) = 2.38$, $p < .05$, $d = .578$, but not for the previously least selected stimulus, $t < 1$, $d = .082$. For the higher functioning group, there was a statistically significant reduction in the previously most selected stimulus, $t(13) = 1.72$, $p < .05$, $d = .467$, but not for the previously least selected stimulus, $t < 1$, $d = .207$.

A logistic regression was performed to determine if any of the values (autism severity, nonverbal intellectual functioning, and verbal functioning) predicted whether the participant would show a recovery in the selection of the previously under-selected stimulus. The predictors were the GARS, Leiter-R, and Peabody mental age (months), and the target was whether the participant showed (or did not show) an increase in the selection of the previously under-selected stimulus. The overall regression produced a significant result, *chi square* = 5.84, $p < .05$, -2LL = 34.52. In terms of the three predictors, this analysis revealed that only verbal functioning (odds ratio = 0.949, $p < .05$) was a significant predictor of whether there was an emergence in responding to the previously under-selected stimulus (autism severity odds ratio = 1.003, $p > .80$; intellectual functioning odds ratio = 1.037, $p > .20$).

Discussion

The current study aimed to extend the investigation of the factors associated with over-selective responding in a group of individuals with ASD, and also with the recovery of responding to a previously under-selected stimulus following extinction of the previously over-selected stimulus. The results demonstrated that the participants showed a significant degree of stimulus over-selectivity, which replicates previous demonstrations of stimulus over-selectivity in individuals with ASD (Allen & Fuqua, 1985; Anderson & Rincover, 1982; Koegel & Wilhelm, 1973; Lovaas et al., 1971; Lovaas & Schreibman, 1971; Reed et al., 2009).

When ASD severity, nonverbal IQ, and verbal functioning were all placed in a model to predict whether over-selectivity occurred, only verbal functioning predicted this outcome significantly. This adds to the data, which suggest that over-selectivity is associated with intellectual functioning (Wilhelm & Lovaas, 1976) to a greater extent than with ASD severity. However, the current data also appeared to show that it was verbal functioning that was more important in predicting the emergence of over-selectivity than nonverbal intellectual functioning. This is a novel finding, and it will require further investigation to establish its generality beyond the current procedure. For example, the use of nameable stimuli in the materials, as in Reed and Gibson (2005), may have contributed to this effect. If abstract stimuli were employed, as in McHugh and Reed (2007), then such a result may not have been generated.

Recovery from over-selectivity, that is, an emergence of behavioral control by the previously under-selected stimuli was also demonstrated in the current study (Reed et al., 2009; Leader et al., 2009; Broomfield, McHugh, & Reed, 2008; Reynolds et al., 2012). Recovery from over-selectivity was predicted by the verbal functioning of the participants, which was associated with recovery of responding to the previously under-selected stimulus, rather than by their nonverbal intellectual functioning, or their autism severity. This effect was also noted by Reed et al. (2009), in terms of verbal functioning.

Regarding the theoretical relevance, the emergence effects support the suggestion that stimulus over-selectivity for some higher verbally functioning individuals may be the result of a retrieval/comparator deficit (Reed, 2011). That is, individuals with ASD may not over-select just because they are not initially attending to each of the compound stimuli (Lovaas, Koegel, & Schreibman, 1979), as post-acquisition retraining of learned about stimuli should have no impact on previously unattended cues. This finding may potentially be procedural in nature and explained as an artefact of the paradigm employed. However, Reed et al. (2009; 2012) suggested that there may be two forms of over-selectivity: one due to an attention deficit and one a post-processing deficit, with individuals with lower functioning being predominately impacted by attention processes. The current results also support such a distinction. That is, one form of over-selectivity may be produced by an attentional deficit at the encoding stage of learning, and that form would not be impacted by the post-learning manipulation conducted in this and other studies (see Reed et al., 2009). This type of result appears common in those with lower levels of intellectual functioning or higher levels of cognitive impairment (see McHugh & Reed, 2007) In contrast, individuals with higher levels of intellectual functioning appear susceptible to post-learning manipulations that suggest the over-selective response is not entirely an encoding issue, but could be a performance issue (see Reed, 2011). Thus, it is likely that at least two mechanisms may underlay over-selectivity and that they may be differentially noted in different populations.

The fact that only the more mildly verbally-impaired children showed the re-emergence phenomenon (i.e., increased responding to the previously under-selected cur after extinction of the alternative cue) also raises questions about the precise nature of this effect.

Given the current results, it is difficult to know precisely whether the finding reflects the operation of verbal labelling processes in modulating the over-selectivity effect. Certainly, some researchers (e.g., Trabasso & Bower, 1968) have referred to verbal labelling as playing an important role in selective attention, and also in performance versus attentional explanations of over-selective responding in typically functioning individuals. Given this, the role of verbal labelling in over-selectivity effects warrants further examination.

One potential limitation is that no intermittent reinforcement was used during training and that the change from a continuous schedule of reinforcement in the training phase to extinction in the test phase may be problematic in terms of generalization decrement. Reynolds and Reed (2011b) investigated the effects of schedules of reinforcement on over-selectivity and found in Experiment 1 that intermittent reinforcement did not result in a reduction of over-selectivity when compared to a continuous schedule of reinforcement. Furthermore, results from Experiment 2 indicated that intermittent reinforcement actually increased over-selectivity. One methodological component that could be modified in the current study would be to re-present trials with the compound stimuli from the training phase during the testing phase to ensure the original discrimination was maintained in the test phase (Reed & Gibson, 2005).

Another limitation may be that a novel stimulus was not used in the re-test phase. In the current study participants were presented with two stimuli in this phase, the previously under-selected stimulus versus the extinguished previous S+. It may be suggested that an increase in responding to the previously under-selected stimulus is explained by the participants responding to "other" stimuli, following the extinction phase. For example, the children may have started responding to any other stimulus besides the over-selected stimulus (i.e. started responding to "novel" or "other" stimuli). This would not be remediation of over-selectivity in the sense that the previously under-selected stimulus has now acquired performance strength, but would just be responding to a novel stimulus. Of course, in practical terms this would still represent an opportunity to teach children about previously unresponded-to cues. However, to investigate this issue further, future studies should test the previously under-selected stimulus versus the extinguished previous S+ versus a novel stimulus in the re-test phase.

The current study made within-ASD comparisons as over-selectivity has been reliably found in this clinical population (e.g., Lovaas et al., 1971; Chiang & Carter, 2008; Scherf et al., 2008; Varni et al., 1979; Koegel & Rincover, 1976; Rincover & Koegel, 1975). Since the first study on over-selectivity, typically developing individuals have regularly been employed as control groups (e.g., Koegel & Wilhelm, 1973) and results have shown that they do not demonstrate over-selective responding (Lovaas et al., 1971). Future research of the over-selective phenomenon within the autism spectrum should include a non-clinical control group to allow further confirmation that this remains the case. Furthermore, the current paradigm should also be investigated with typically developing individuals as the main study sample.

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Table 1. Mean (standard deviation) scores for the samples' autism severity (GARS-2 overall standard score), nonverbal intellectual functioning (Leiter-R overall standard score), and verbal functioning (PPVT-4 ability in months), and the Pearson correlations between these scores.

	Mean (SD)	**Nonverbal Functioning**	**Verbal Functioning**
Autism Severity (GARS-2 standard score)	111.19 (37.41)	- .464*	- .456*
Nonverbal Functioning (Leiter-R standard score)	55.67 (19.86)		.640**
Verbal Functioning (PPVT-4 ability in months)	48.19 (16.12)		

* p < .05, ** p < .001

Figure Captions

Figure 1(a). Example of complex stimuli (AB) and (CD)

Figure 1(b). Example of single element stimuli (B) and (D)

Figure 2. Percentage times that each stimulus was chosen in the test phase was recorded for the lower- and higher-functioning groups in each domain: IQ = nonverbal intellectual functioning (Leiter-R); Verbal = verbal functioning (PPVT-4); ASD = autism severity (GARS-2).

Figure 3. Mean change in the percentage times that each element of the compound stimuli across the two phases (post- revaluation minus pre-revaluation phase) for the lower- and higher-functioning groups in each of the three domains: IQ = nonverbal intellectual functioning (Leiter-R); Verbal = verbal functioning (PPVT-4); ASD = autism severity (GARS-2).

Figure 1(a) top

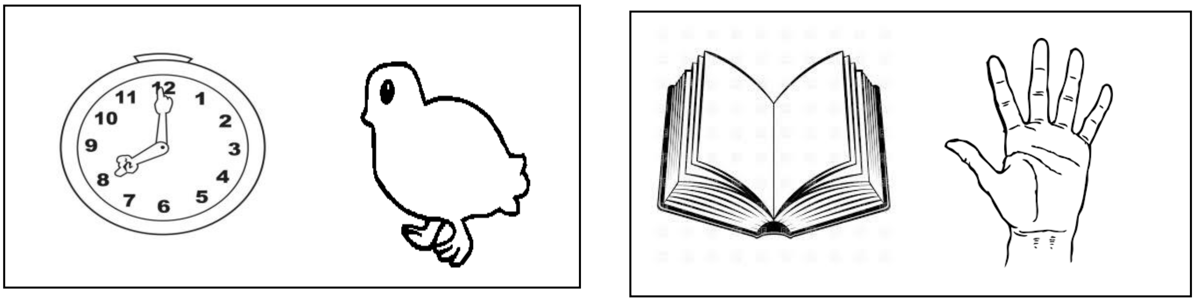


Figure 1(b) top

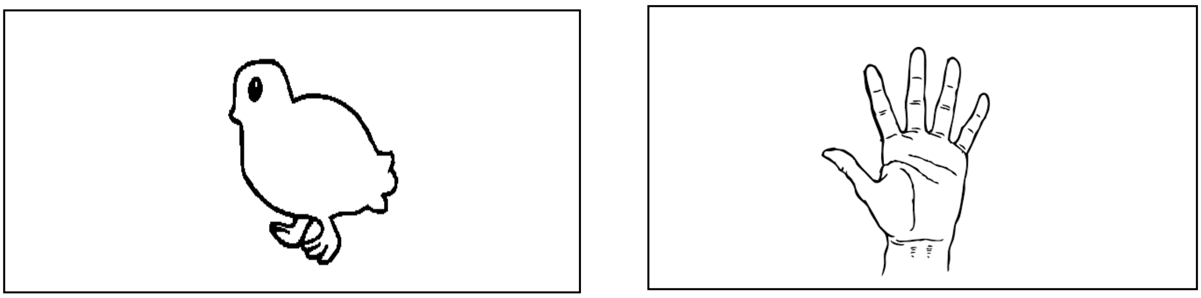
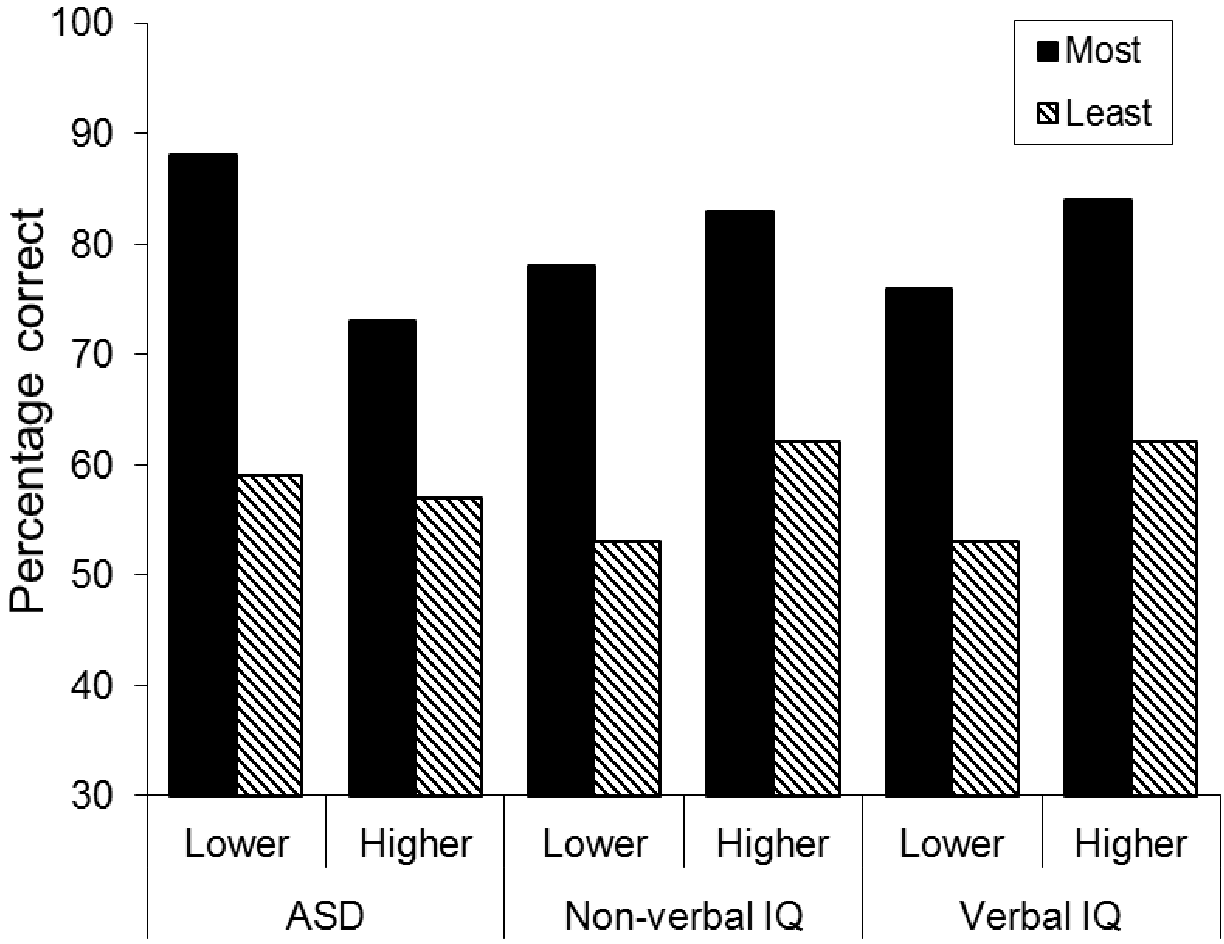


Figure 2 top


Percentage correct
100
90
80
70
60
50
40
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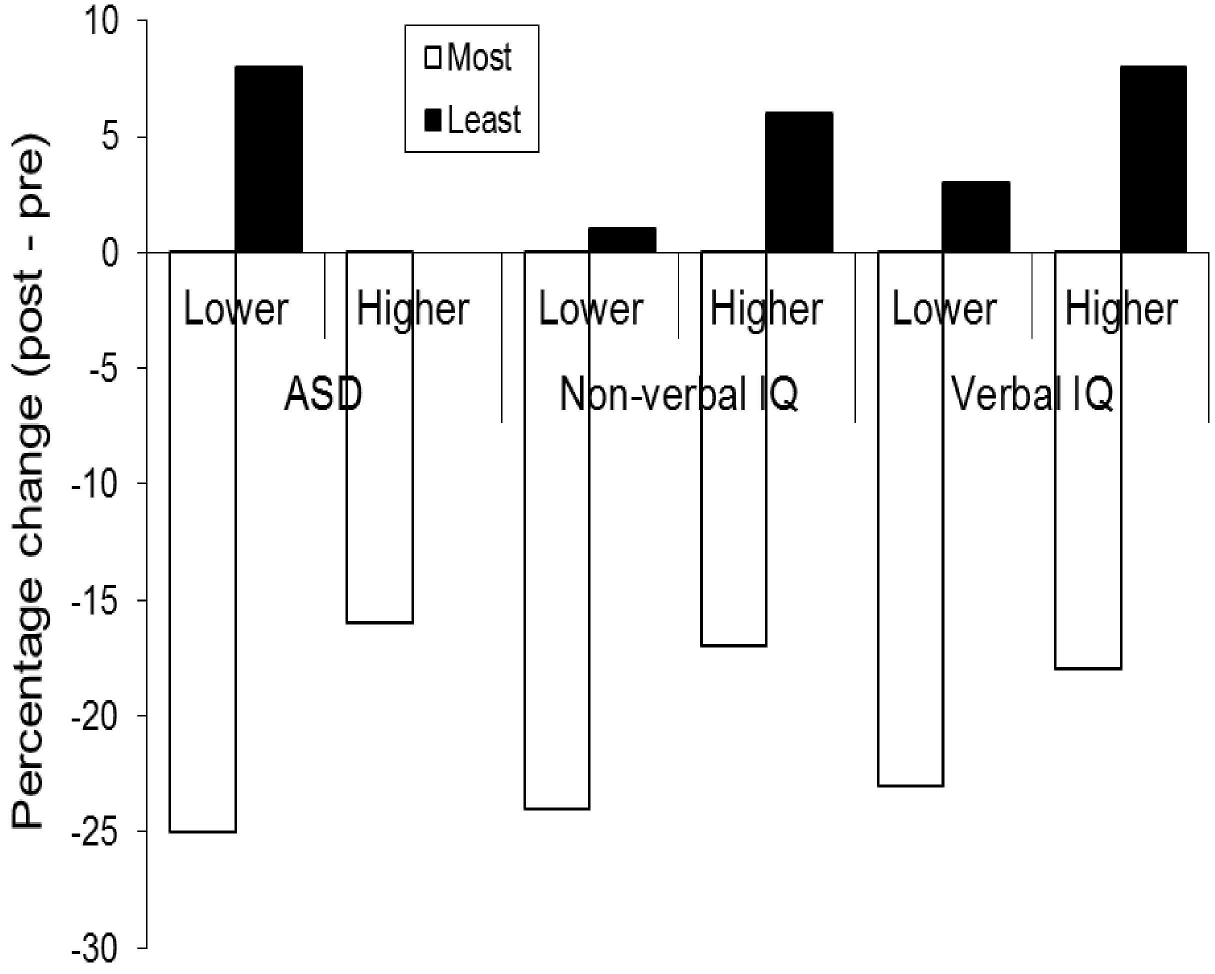
Most
Least
Lower
Higher
Lower
Higher
Lower
Higher
ASD
Non-verbal IQ
Verbal IQ

Figure 3 top



10
5
0
-5
-10
-15
-20
-25
-30
Percentage change (post - pre)
Most
Least
Lower
Higher
Lower
Higher
Lower
Higher
ASD
Non-verbal IQ
Verbal IQ

Appendix: Individual data for the percentage of times that each of the elements of the S+ complex stimuli was selected during the test and re-test phases. Mean data for the entire sample is also provided.

Participant	**Test: most-selected**	**Test: least-selected**	**Re-test: most-selected**	**Re-test: least-selected**
1	70	60	90	90
2	80	60	90	90
3	60	40	60	60
4	100	100	100	100
5	70	60	30	60
6	80	80	20	60
7	100	0	0	0
8	50	30	40	60
9	100	100	100	90
10	100	100	80	70
11	100	40	80	70
12	40	30	60	50
13	70	60	90	100
14	100	100	100	100
15	100	30	40	10
16	90	60	80	70
17	90	90	100	100
18	100	0	0	10
19	70	80	70	60
20	70	60	50	40
21	80	70	0	30
22	50	30	60	60
23	100	90	80	50
24	70	30	40	30
25	50	50	60	80
26	90	80	90	100
27	80	50	50	60
Mean	**80.00**	**58.52**	**61.48**	**62.96**