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ORIGINAL PAPER

Stimulus Overselectivity in Typical Development: Implications for Teaching Children with Autism

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Abstract Stimulus overselectivity is widely accepted as a stimulus control abnormality in autism spectrum disorders and subsets of other populations. Previous research has demonstrated a link between both chronological and mental age and overselectivity in typical development. However, the age at which children are developmentally ready to respond to discriminations involving simultaneous multiple cues has not been established. Thirty-seven typically developing preschoolers completed a task requiring response to simultaneous cues (color and shape) to establish the age at which typically developing children can successfully respond to multiple cues. Results demonstrate that typically developing children under 36 months of age have difficulty responding to multiple cues. Implications for behavioral treatment for autism are discussed.

Keywords Development of conditional discriminations · Overselectivity · Behavioral treatment · Pivotal response training · Autism

This research formed part of the first author's doctoral dissertation, which was conducted under the supervision of the second and fourth authors at University of California, San Diego.

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Introduction

Stimulus overselectivity refers to control of an individual's behavior by a subset of the elements of a compound stimulus presented during discrimination learning (Lovaas et al. 1979, 1971). Lovaas et al. (1971) first identified the phenomenon four decades ago as an abnormality in attention or stimulus control in children with autism spectrum disorders (ASD). Since then, research has consistently demonstrated that many children with ASD, as well as other developmental delays, display difficulty responding to multiple components of a compound stimulus both within and across modalities (see Ploog 2010 for a comprehensive review). After the initial identification of overselectivity in individuals with ASD (Lovaas et al. 1971), further research revealed the same attentional phenomenon in other populations, including typically developing preschoolers (Bailey 1981; Bickel et al. 1984; Brack 2001; Dickson et al. 2006; Dube and McIlvane 1997; Fairbank et al. 1986; Huguenin 1997; McHugh and Reed 2007; Schneider and Salzberg 1982). Studying overselectivity in typically developing children provides useful insight into the process of stimulus control of behavior as well as its role in the formation of complex concepts (McHugh and Reed 2007), and it continues to be a dynamic area of behavior analytic research (Ploog 2010).

It is clear from the literature that there exists a strong association between overselectivity and both chronological age and developmental level (Ploog 2010). First, several studies have demonstrated that the number of cues to which a child can respond in a discrimination task, known as breadth of learning, increases reliably with chronological age in typically developing children (Eimas 1969; Fisher and Zeaman 1973; Hale and Morgan 1973; Schover and Newsom 1976; Wilhelm and Lovaas 1976). For example, in Eimas's (1969) study, all children ages five to nine responded appropriately to both components when the task involved only two cues. However, there was a significant correlation between children's ages and the number of cues to which they responded appropriately for tasks involving three and four cues. Similarly, Hale and Morgan (1973) demonstrated that 8-year olds responded appropriately to more color and shape cues than 4-year olds in a two-cue conditional discrimination that involved multiple values for each feature (i.e., five colors and five shapes). Studies examining developmental level have shown a similar relationship with breadth of learning (i.e., positive correlation between mental age and number of cues appropriately responded to) for both typically developing (Eimas 1969) and clinical populations (Katoh and Kobayashi 1985; Schover and Newsom 1976).

Further support for the relationship between development and overselectivity comes from the elimination of between-group differences in overselectivity for clinical populations and their typically developing peers when matched on mental age. For example, Schover and Newsom (1976) demonstrated that children with ASD and typically developing children who were matched on mental age displayed similar response patterns in the type of simple simultaneous discrimination task that is traditionally used to determine overselectivity. They found that the children who displayed overselective responding clustered at the lower end of the 2 years 9 months to 9 years 6 month age range in both groups. Similarly, Kovattana and Kraemer (1974) hypothesized that differences in mental age accounted for the similar performance of verbal children with ASD and their typically developing peers on a three-cue conditional discrimination task.

Despite the clear relationships between overselectivity and both chronological age and developmental level, it remains unknown at what age typically developing children may be expected to respond to multiple elements of a compound stimulus. Previous research has not identified a minimum age or developmental level at which children reliably respond to more than one simultaneous cue. Although several studies have tested typically developing children matched on mental or chronological age as a control group for children with ASD, little information is provided on which of these children, if any, respond overselectively (e.g., Gersten 1983; Hale and Morgan 1973; Koegel and Wilhelm 1973; Rincover and Ducharme 1987; Schover and Newsom 1976; Wilhelm and Lovaas 1976). No study to date has explored overselectivity in young, typically developing children for the purpose of determining the age at which response to multiple cues can be reliably expected. In addition to providing important evidence on stimulus control of behavior in young children, determining a lower age bound for normal simultaneous attention could have crucial implications for individualization and age-appropriate expectations in ASD intervention.

As the age of reliable ASD diagnosis continues to drop (Landa et al. 2007), increasingly younger children are receiving service and interventions that were originally designed for their school-aged peers (Corsello 2005). One popular evidence-based approach, pivotal response training (PRT), explicitly requires that therapists incorporate conditional discriminations (i.e., discriminations requiring response to simultaneous multiple cues) to enhance the child's ability to response to multiple cues in the environment. In discussing PRT, practitioners indicated they often omit response to multiple cues in their teaching, as they feel it may not be developmentally appropriate for the youngest children with ASD in their programs (Stahmer et al. 2009). If a developmental boundary could be determined for overselectivity, it may allow practitioners to appropriately omit this component of PRT for the youngest children with ASD. Based on previous studies demonstrating some overselectivity in typically developing preschoolers (e.g., Bickel et al. 1984), it is likely that many children with ASD receiving special education services may be functioning below the developmental level at which typically developing children respond to multiple cues (Corsello 2005). This type of treatment individualization based on child characteristics will allow practitioners to focus on the aspects of intervention that are likely to have the maximum impact for each child, rather than applying a 'one size fits all' approach.

The current study assessed young typically developing children on a simultaneous multiple cue discrimination task to identify a lower developmental boundary for this task. A two-component discrimination assessment was utilized in this experiment because it is the simplest test for overselectivity and thus appropriate for even the youngest children. The results will provide valuable information on the stimulus control of behavior in young children and inform appropriate adaptations for evidence-based practice for ASD.

Methods

Participants

Thirty-seven participants, ages 19–50 months (M = 34.1, SD = 9.4, 59 % male) were recruited through a local childcare program. This age range was selected based on previous studies indicating overselectivity in typically developing children at these ages (Bickel et al. 1984; Hale and Morgan 1973; Schreibman and Lovaas 1973). A flier and descriptive letter explaining the study were given to parents through the children's 'mailboxes' in their classrooms at the childcare facility. Interested parents returned the letter and consented to their child's participation and to experimenter access of school records. Of the parents contacted through the initial flier (n = 52), a total of a 71 % (n = 37) returned the letter to express interest. All the families who expressed initial interest agreed to allow their children to participate. Ages and Stages Questionnaires (ASQ; Bricker and Squires 1999) completed by teachers as part of routine care at the childcare center were available for 76 % (n = 28) of participating children. The ASQ is a brief questionnaire that allows the adult to assess the child in the natural environment and screen for developmental delays and areas of difficulty. No children participating in the current study displayed delays in the five areas assessed by the ASQ: communication, problem solving, personal/social, fine motor or gross motor. Additionally, family medical history forms (available for 92 % of participants) indicated that no children participating had any first-degree relatives with ASD.

Procedure

An experimenter conducted the discrimination learning assessment described below with each participant. Experimenters for this study included the first author and a trained research assistant who had experience working with young children. The task took place during the children's regular day at school. Arrangements were made with the child's classroom teacher for one of the experimenters to work independently with the child, either at a small table or area on the floor within the child's regular classroom or in another available room on the school campus.

Each testing session began with a brief warm-up period in which the experimenter interacted with the child with several motivating toys such as squishy balls and colored markers in order to build rapport. During this period, the experimenter naturalistically tested whether the child could receptively and expressively identify colors and shapes (e.g., "Can I have the green marker?", "Ooh, what color is that fish you drew?"). The experimenter probed three colors (from the list red, orange, yellow, green, blue, purple, pink) and two shapes (from the list square, circle, triangle, star) receptively and expressively for each child and recorded all responses. This was done to determine if expressive and receptive knowledge of the type of features being tested (color and shape) contributed to a child's overselective responding. This knowledge was not used as inclusion criteria for the study. After the experimenter judged the child to be comfortable in the testing situation, she began the discrimination learning assessment, as described below. At the conclusion of the discrimination learning assessment, children were given a small prize for participating and returned to their classroom.

Discrimination Learning Assessment

The discrimination learning assessment used in the present study was modeled after similar simultaneous discrimination learning paradigms designed to assess overselectivity in young children and individuals with ASD and other developmental disabilities (Eimas 1969; Koegel and Wilhelm 1973; Ploog and Kim 2007; Schover and Newsom 1976; Schreibman 1975). A two-cue, simultaneous conditional discrimination was used to assess children's response to two features of a compound stimulus, color and shape. Children completed a series of trials in which an experimenter presented two blocks of different shapes and colors and instructed the child to select one block. The children were first trained to choose the block designated by the experimenter as "correct." Once they demonstrated mastery of the discrimination, test trials were presented in which the color and shape features of the original blocks were separated and combined with novel values. A complete and detailed description of the task is provided below.

Assessment Materials

Materials included a set of six, 2-inch by 2-inch wooden blocks. Each block represented a unique combination of the features of color and shape. Two blocks were used as training stimuli for all participants: a green cube and an orange pyramid. Four blocks were used as testing stimuli for all participants: a green T, an orange T, a pink cube, and a pink pyramid (see Fig. 1). These color and shape feature values (including the use of novel color and shape feature values during testing) are identical to the ones used by Schover and Newsom (1976) with the exception that blocks (three dimensional shapes) were used in the present study as opposed to figures on cards (two dimensional shapes). The decision to use three dimensional shapes was motivated by the desire for the materials in the assessment to be similar to objects encountered in children's everyday routines (i.e., a colorful set of building blocks) and to actively capture children's attention. The assessment consisted of repeated presentations of pairs of blocks to the child with instructions to choose one of the blocks. The experimenter conducted a training phase (a minimum of 30 trials and a maximum of 80, depending on the child's performance) and a testing phase (30 trials). Both phases are described in detail below.

Training Procedure

Training trial blocks were the green cube and orange pyramid. To begin the assessment, the experimenter held up one of these two blocks for the child and said "[Child's name], this is the correct block" and handed it to the child

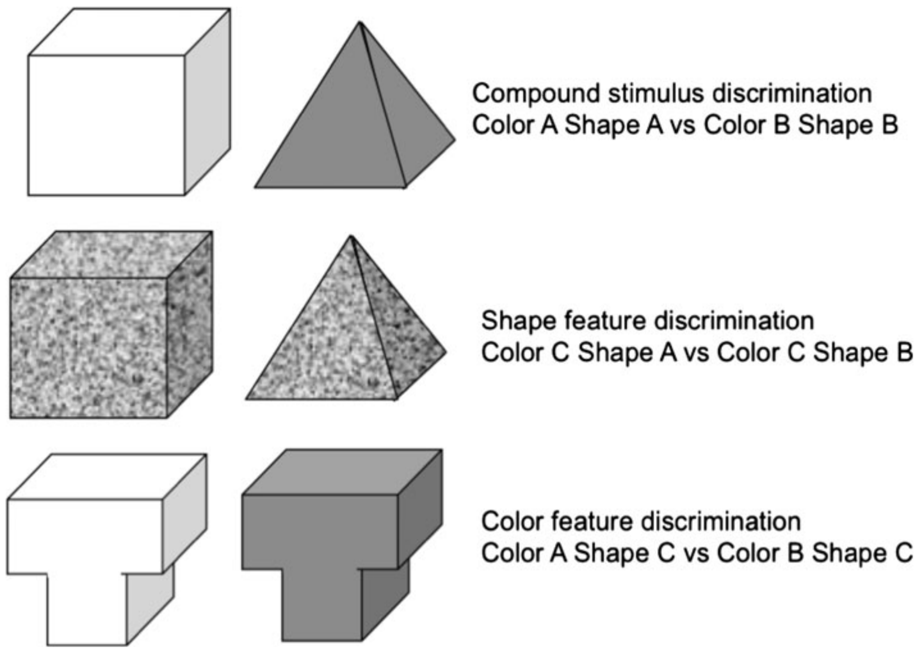

Fig. 1 Representation of stimuli; *six colored blocks* of the types shown were used for all training and testing trials

for a few seconds. She then took both blocks, removed them from the child's view briefly, presented the blocks by setting them on the table in front of the child, and gave the cue "Give me the correct block" followed by a pause for the child to respond. If the child indicated the appropriate block (either by taking and extending the block towards the experimenter, pushing the block across the table, or touching the block and making eye contact), the experimenter provided praise using phrases such as "That's the correct block! You got it!" Crucially, the experimenter never named either of the features of interest (color or shape) of the blocks. If the child did something unrelated to the tasks with the blocks (e.g., stacked the blocks on top of one another), the experimenter removed both blocks from the table and re-presented the cue. If the child failed to respond or began to respond incorrectly, the experimenter immediately prompted the correct answer at the necessary level of support (e.g., full physical prompt for failure to respond, gestural prompt for a child beginning to respond incorrectly). On subsequent trials (after at least two initial correct independent responses from the start of the training trials), the experimenter utilized a no-no-prompt strategy (e.g., the experimenter responded with "No" for two consecutive trials to which the child responded incorrectly, then removed the blocks and presented the next trial; if the child moved to respond incorrectly for a third consecutive trial, the experimenter immediately prompted the correct response. Immediate prompting was continued until the child responded correctly and independently across two trials). The experimenter recorded the child's response after each trial (Correct, Incorrect, Prompted, or No Response). The block designated as correct (green cube or orange pyramid) was randomized across participants, as was the position of the correct block on each trial (designated on the data sheet). Correct responses were initially continuously reinforced with praise and tangibles, such as a spinning top, a sensory ball, or small snacks. After one block of ten trials at 80 % or more correct, the experimenter moved to a schedule wherein responses were reinforced on an average of one reinforced correct trial out of three correct trials (variable ratio 3; VR3) to reduce discrimination between the training and subsequent testing trials. This schedule of reinforcement was selected based on previous studies utilizing similar tasks (e.g., Koegel and Wilhelm 1973; Schover and Newsom 1976). Given the young age of the children tested, some schedule of reinforcement was necessary to maintain interest in the task. On unreinforced trials, the experimenter responded to any child response by saying "Thank you" or "Okay" in a neutral tone of voice. Training trials continued until the child achieved at least 80 % correct responding across two sets of ten trials on the VR3 schedule of reinforcement. After the child reached the criterion for discrimination mastery, the test procedure was begun.

Test Procedure

To determine which elements (color and/or shape) were functional in controlling the child's responses, the experimenter randomly interspersed test trials of the color feature blocks (green T and orange T) as well as the shape feature blocks (pink cube and pink pyramid) with the training stimuli (green cube and orange pyramid). The testing phase consisted of ten trials of each of the three types of

Table 1 Assessment performance classifications

Category	Definition
Normal Simultaneous Responding	Child correctly responded to both color S+ and shape S+ features at 80 % correct or better. Child maintained at least 80 % correct responding to the compound S+ during test trials
Overselective Responding	Child correctly responded to the compound S+ and one feature S+ (shape or color) at least 80 % of the time while responding to the other S+ feature at chance (25–75 %)
Failure to Acquire	Child did not maintain at least 80 % correct responding to the compound S+ during test trials. Therefore, all responses were considered random and results were not considered further
Other (Preference)	Child correctly responded to the compound S+ and one feature S+ (shape or color) at least 80 % of the time while responding to the other S+ feature below chance (under 25 % correct), indicating a preference for the S− feature in that discrimination

discrimination trials (compound stimulus, color, and shape) to determine whether the child could accurately identify both features of the 'correct' compound stimulus in a separate discrimination. For example, if the child learned to select the green cube during training trials, then the green T (color feature) and pink cube (shape feature) were the correct responses for each of the feature discriminations. The correct color/shape features are referred to as S+ features of the discrimination. Order of presentation of each type of trial (compound stimulus, shape features, or color features) was randomized across participants, as was the position of the correct block. Trials were conducted in the same manner as training trials except for the nature of the stimuli presented and the schedule of reinforcement. Reinforcement was provided only for correct responses to the trials of the training stimuli, in order to prevent inadvertent learning of the correct feature answers during testing. The experimenter responded neutrally (e.g., "Okay" or "Thank you") to all child responses on test trials, identical to the unreinforced VR3 trials during the training phase. The experimenter also provided reinforcement for behaviors unrelated to the assessment trials throughout the testing period, such as attending to the materials or staying at the table, in order to maintain child motivation to participate in the assessment.

Assessment completion required that the child respond within 1 min of stimulus presentation to each of the 30 testing trials. If the child appeared to lose interest in the task or could not be redirected from attempts to leave the testing area within a period of 20 min, testing was discontinued. For these participants, a second session of testing was conducted on the following day. If the participant was unable to sustain attention to the task on the second day, testing was discontinued and data for that participant were considered incomplete.

Data Analysis

Upon assessment completion, participants' performance on the discrimination task was classified into four categories based on the proportion of correct (S+) responses in each type of discrimination: normal simultaneous responding, overselective responding, failure to acquire, or other. Operational definitions based on this assessment for each of these performance categories are identical to previous research and provided in Table 1 (Eimas 1969; Gersten 1983; Wilhelm and Lovaas 1976). A cut-off of 80 % correct or better was used based on the 95 % cut-off for a binomial distribution (i.e., there is a 5 % or less chance that a child could respond to 8 or more out of 10 trials correctly if she was responding randomly). For those children who responded to at least one of the sets of feature trials at 80 % or better, we used logistic regression to test for a relationship between chronological age and level of response to the second feature.

Results

Training

The majority of participants (n = 26, 70 %) met mastery criterion for the training discrimination in the minimum 30 trials (10 trials with continuous reinforcement, 20 trials at a VR3 schedule of reinforcement). There was a significant, negative correlation between participants' age and the number of training trials required to meet mastery criterion ($p < .05$). The maximum number of training trials to meet mastery required by any participant was 70. Three participants were unable to complete the assessment, as determined by failure to respond to at least 10 trials (either correctly or incorrectly) in a period of 20 min on each of 2 days; these three participants were among the youngest that participated in the assessment (19–24 mos; M = 22, SD = 2) and were not considered further.

Testing

All 34 participants who successfully completed the training trials were also able to complete the 30 test trials. Figure 2

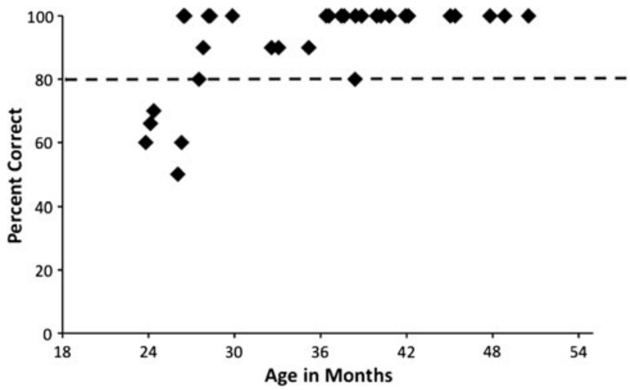

Fig. 2 Performance on the compound stimulus discrimination during testing phase for participants who completed the assessment. The *dotted line* indicates required percent correct to consider the training discrimination maintained. Participants performing below this percent correct are considered "Failure to Acquire" (see Table 1)

shows participants' performance on the 10 trials of the compound stimulus discrimination during the 30 trials of the testing phase. This performance indicates the participant's ability to maintain the compound stimulus discrimination throughout the testing phase. Of the 34 participants who successfully completed the test trials, 6 were unable to maintain 80 % correct responding or above to the compound stimulus discrimination (failure to acquire). These participants represented the younger end of the age range (24–26 mos; M = 24.92, SD = 1.03) and their responses to the separate S+ features were not considered further (e.g., Lovaas et al. 1971). The remaining 28 participants successfully responded to the compound stimulus discrimination at 80 % or above during the testing phase, indicating maintenance of the compound stimulus discrimination learned during training and valid comparison of separated features to determine overselectivity.

Figure 3 displays individual participants' performance on the color and shape feature trials conducted during the testing phase. Eight participants displayed overselective responding (Participants A, B, C, F, H, I, J, and O in Fig. 3), defined as chance responding to one S+ feature (less-preferred feature; M = 50 % correct, SD = 12) and correct responding to the other (preferred feature; M = 88.75 % correct, SD = 8.34). Five of these participants responded exclusively to the shape S+ (Participants B, F, H, I, and O) and the remaining three responded exclusively to the color S+ (Participants A, C, and J). A total of 19 participants displayed normal simultaneous responding; this group of children was significantly older (M = 41.68 mos, SD = 4.92) than both the failure to acquire group and the overselective group ($p < .05$). One participant responded at 90 % correct to both the compound S+ and the shape feature S+ , but below chance to the color feature S+ , indicating a consistent preference for the color feature S− (green, in this instance). This participant was excluded from the logistic regression, as the below chance performance likely indicates the participant was responding to some unknown (and unintended) element of the stimulus. There was no correlation between the numbers of shapes or colors a child could expressively or receptively identify and their percent correct responding to the S+ component discriminations ($p > .05$).

Statistical Analysis

Percent correct for the less-preferred cue for each participant is shown in Fig. 4. A logistic regression considering the factors of age and percent correct on the less-preferred cue feature trials showed a significant relationship between children's chronological age and their performance on the less-preferred cue ($p < .001$). As expected, younger children were more likely to display overselective responding. Analysis of the logistic regression model indicated that, on average, children cross the threshold of 80 % correct at 36 months of age (see Fig. 4). These data indicate that children are likely to display overselectivity prior to their third birthday, but consistently respond to simultaneous multiple cues at 36 months and later.

Discussion

The results of the present study suggest that young children cannot be expected to reliably respond to simultaneous multiple cues until after 3 years of age. These data are consistent with previous research demonstrating stimulus overselectivity in typically developing preschool children, and extend this knowledge by suggesting the specific age at which young children typically develop this capacity. The current study supports the notion that overselective attention should be understood as a general developmental cognitive delay rather than a specific deficit in ASD or other disorders.

Despite the determination of a lower developmental bound for normal simultaneous responding, age should not be considered the sole determinant of overselectivity. Previous studies report overselectivity in children with ASD and mental retardation with mental ages above this mark (e.g., Rincover and Ducharme 1987; Schover and Newsom 1976; Wilhelm and Lovaas 1976) and therefore other factors may also be contributing to this attentional abnormality. It should also be noted that some studies have reported overselectivity in typically developing children above this developmental level (e.g., Bickel et al. 1984). The fact that children over 3 years were able to respond to a conditional discrimination in this experiment may be explained by the simplicity of the current discrimination paradigm: two cues within a single modality (visual),

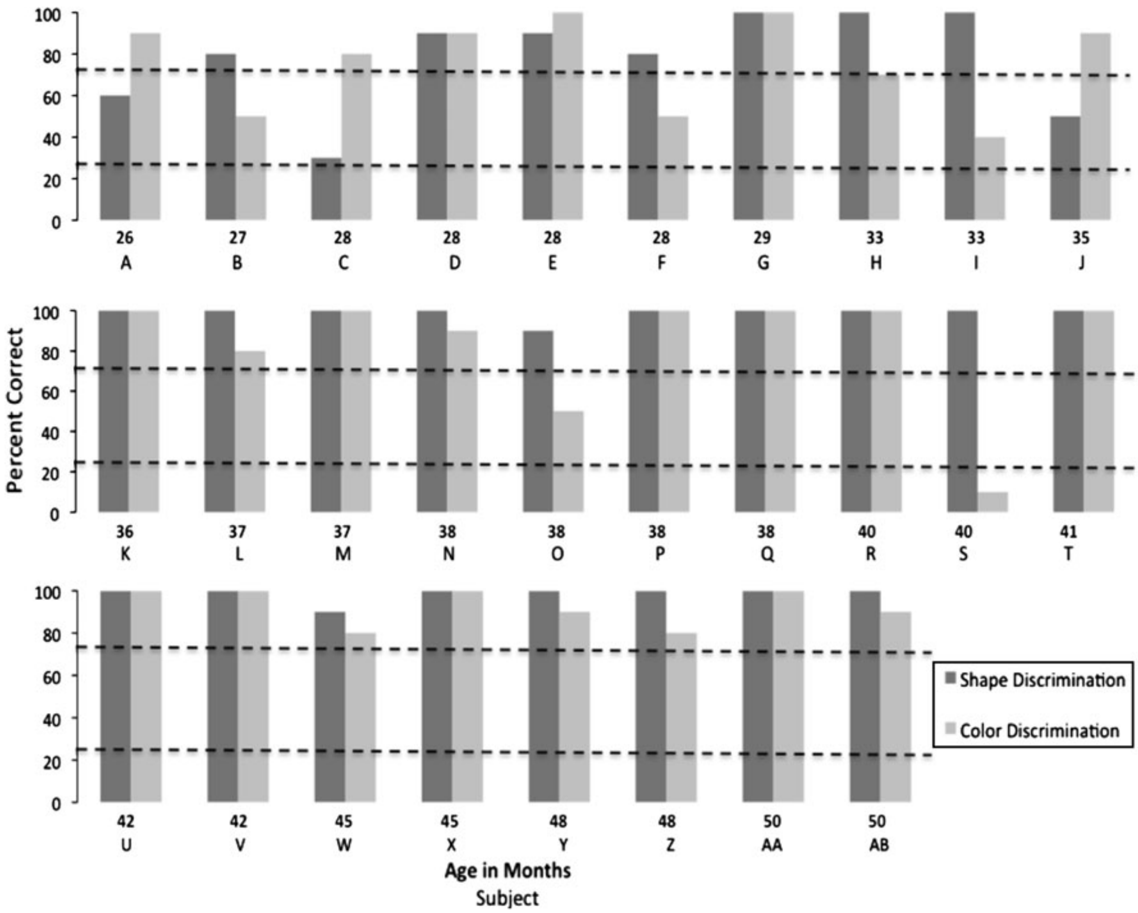

Fig. 3 Percent correct on shape and color feature discriminations during the testing phase for individual participants. The area between the *horizontal dotted lines* indicates chance performance. Performance for one discrimination above *the upper line* (i.e., 80 % or above) and one discrimination between the *two lines* (30–70 %) was considered overselective responding (see operational definitions in Table 1)

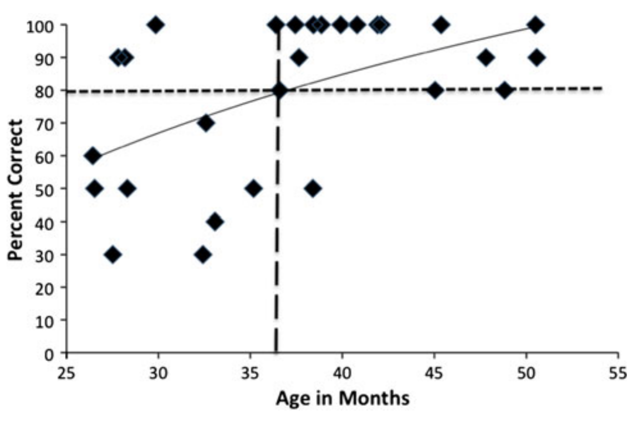

Fig. 4 Percent correct on the less-preferred cue and regression line. The *horizontal dotted line* at 80 % correct indicates above chance responding. The *solid line* represents the regression line. The *vertical dotted line* highlights the intersection of the regression line with above-chance performance, which indicates normal simultaneous responding. This *dotted line* crosses the ordinate at approximately 36 months

presented in materials that were familiar to the participants. Studies that have demonstrated overselectivity in children above 36 months of age have utilized more complex discrimination learning tasks, such as compound auditory cues (Bickel et al. 1984) or visual discriminations with more than two features (Eimas 1969). The simple version of the task used here allowed insight to the youngest possible age that typically developing children would be successful. Future research should focus on how age and developmental level relate to more complex versions of simultaneous discrimination paradigms.

These results have important implications for practitioners' use of PRT with young children with ASD. Because ASD is often diagnosed around 3 years of age, and because many children with ASD have concomitant intellectual disability, it is likely that many young children who are receiving intervention services have a mental age below 36 months. Based on the results of the current study, it is inappropriate for practitioners to target response to multiple cues with these children, as the ability is beyond their developmental stage. Anecdotally, practitioners reported that response to multiple cues did not seem developmentally appropriate for many children on their caseload (Stahmer et al. 2009) and this observation has now been supported by returning to basic research.

There are several limitations of the current study. Children's performance is only assessed on one type of discrimination task. Future research should address whether the same patterns are observed for alternative types of discrimination assessments, such as successive discrimination paradigms (Lovaas et al. 1971; Schreibman et al. 1986), and non-visual modalities. Bickel et al. (1984) reported overselectivity in typically developing preschoolers who are 35 months of age and above using auditory stimuli, suggesting that modality may play a role in the course of overselectivity. The current experiment used objects (blocks) and cues (colors and shapes) that are very familiar to young children. Thus, future experiments should focus on extending this exploration to other similar tasks. These results also do not provide any insight as to whether children's responding is a result of limited stimulus control or stimulus control hierarchy (i.e., unspecified stimuli controlling responding; Bickel et al. 1984), nor do they provide information on the question of attention versus non-attention forms of overselectivity (Reed et al. 2009), as these determinations were beyond the scope of the current study. Lastly, the exclusive use of chronological age, on the assumption that the children tested are of average intelligence (and therefore chronological age is equivalent to mental age), is potentially problematic. Although the children were screened for risk for developmental delay, specific mental ages were not obtained. It may be that the participants in this experiment did not represent an average population, and therefore the results may be skewed or the determination of a lower bound for normal simultaneous responding incorrect. Future work should attempt to replicate these findings and include direct measurement of mental age in order to further support the fact that typically developing children under 36 months of age are likely to display overselectivity.

Overall, the results of this study support practitioner's intuition that conditional discriminations are not developmentally appropriate for all children with ASD. When utilizing PRT or similar naturalistic behavioral methods that call for embedding conditional discriminations within teaching interactions, it is likely that practitioners may appropriately omit this component for children with a developmental age under 36 months. This finding represents an important step towards tailoring intervention based on child characteristics for children with ASD.

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