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BRIEF REPORT

EYE TRACKING ASSESSMENT OF STIMULUS OVERSELECTIVITY IN INDIVIDUALS WITH MENTAL RETARDATION

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Stimulus overselectivity, or restricted stimulus control, refers to stimulus control that is atypically limited with respect to range, breadth, or number of stimuli or stimulus features (Lovaas, Koegel, & Schreibman, 1979; Schreibman, 1997). Overselectivity may be associated with learning difficulties in individuals with developmental disabilities like autism and mental retardation (e.g., Remington & Clarke, 1993). For example, overselectivity is evident in special-education classrooms when students learn to identify printed words by their initial letters only (Kledaras, Dube, Flusser, McIlvane, & Potter, 1999, May).

For several years our laboratory has been examining overselectivity with matching-to-sample tasks that display more than one sample stimulus per trial (e.g., Dube, 1997; Dube & McIlvane, 1997, 1999; Stromer, McIlvane, Dube, & Mackay, 1993). Stimulus control by an atypically limited number of sample stimuli indicates overselectivity. One question concerns the relation between overselectivity and observing behavior. Effective observing behavior is a prerequisite for accurate visual discrimination (Dinsmoor, 1985; Schroeder, 1997). Does overselective responding result from failure to observe all of the relevant stimuli? To begin to answer this question, we have initiated studies with an eye tracking apparatus.

The purpose of this brief report is to describe the training program we have developed to teach individuals with mental retardation to participate in eye tracking sessions. We will also report our method for data analysis and some typical results.

Subjects

Participant DTM was a 12-year-old young man with moderate mental retardation (Peabody Picture Vocabulary Test mental age equivalent score 4.2 years). For contrast, we will also present eye tracking data for LCN, a nonclinical adult.

Matching-To-Sample Apparatus, Stimuli, and Procedures

A computer presented stimuli on a 15-inch touchscreen-equipped monitor, recorded matching-to-sample responses, and controlled a token dispenser. Experimental stimuli were black abstract forms (examples are shown in Figure 1), approximately 1 x 1.5 cm, displayed on a white background. In each session, different stimuli appeared on every trial. DTM received tokens for correct responses, and tokens were exchanged for a variety of items after sessions.

On simultaneous matching-to-sample trials (see Figure 1), sample stimuli remained visible throughout the trial. On delayed matching-to-sample (DMTS) trials, the sample remained displayed until the participant touched it, and then it disappeared and the comparisons were presented immediately (0-s delay). Thus, the participant controlled the duration of the sample display period in DMTS.

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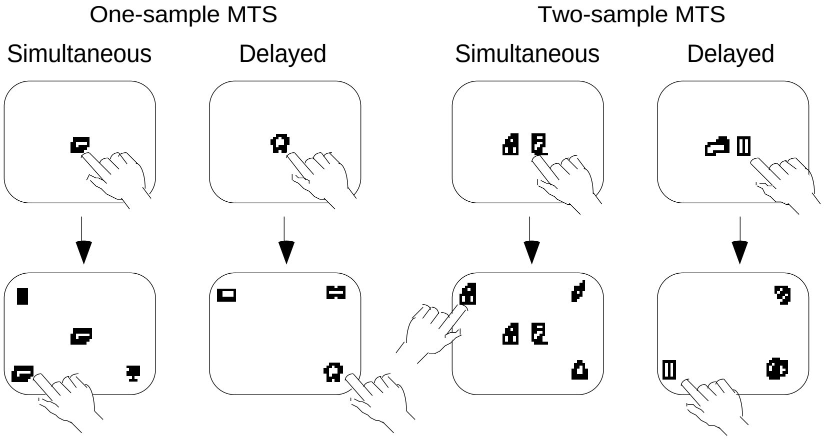

Figure 1

In preliminary matching-to-sample tests with the first three tasks shown in Figure 1, both participants had high accuracy scores (93%-100%). These results verified the prerequisite skills for an evaluation of overselectivity with the two-sample DMTS task.

The two-sample DMTS task is illustrated in the rightmost column of Figure 1. On each trial, one of the sample stimuli appeared as the correct comparison, but, during the sample display period, the participant could not predict which one it would be (i.e., the correct comparison was identical to the left and right samples equally often in an unpredictable order). As expected, LCN's accuracy scores were always above 95%, indicating no overselectivity with this task; regardless of which sample appeared as the correct comparison, she was able to match it. DTM's mean accuracy score for 12 sessions was 62% (range 47% to 72% with no trend). The intermediate accuracy scores indicated that he was able to match one but not both sample stimuli (for a detailed analysis see Dube & McIlvane, 1997).

Eye Tracking Apparatus

The eyetracking laboratory is equipped with an ISCAN head-mounted eye tracking system (ISCAN Corp., Burlington, MA; http://www.iscaninc.com). Figure 2 shows the major components of the eyetracking apparatus. The head-mounted imaging systems consist of two miniature video cameras, an infrared light source, and a double-sided dichroic mirror. The mirror reflects light from certain angles but appears transparent to the participant. The scene camera shows the central portion of the participant's field of view as reflected on the outside of the mirror. The eye camera tracks eye movements from the reflected image of the eye on the inside of the mirror via a corneal reflection system. Because these imaging components are head-mounted, it is not necessary to immobilize the participant's head during recording.

A computer running ISCAN Point-of-Regard Data Acquisition software processed and integrated the video signals. The result was a real-time video field-of-view image with a superimposed cursor indicating the participant's point of gaze. VITC timecode was added, and the composite video image was displayed on the scene monitor during sessions and recorded on videotape. Examples are available at http://www.shriver.org/Research/Psychological/EyeTracking/index.htm.

Preparing Participants with Mental Retardation for Eye Tracking Sessions

Because the headgear is delicate and expensive, training was conducted with a plastic replica. We have initiated training with 14 individuals with mild to moderate mental retardation; two indicated that they did not want to wear the headgear, and the rest completed training successfully and participated in eye tracking sessions. Six of these individuals, with mild mental retardation, completed all preliminary training via verbal instructions in one introductory session. Six other individuals, including DTM, required more extensive training, as described below.

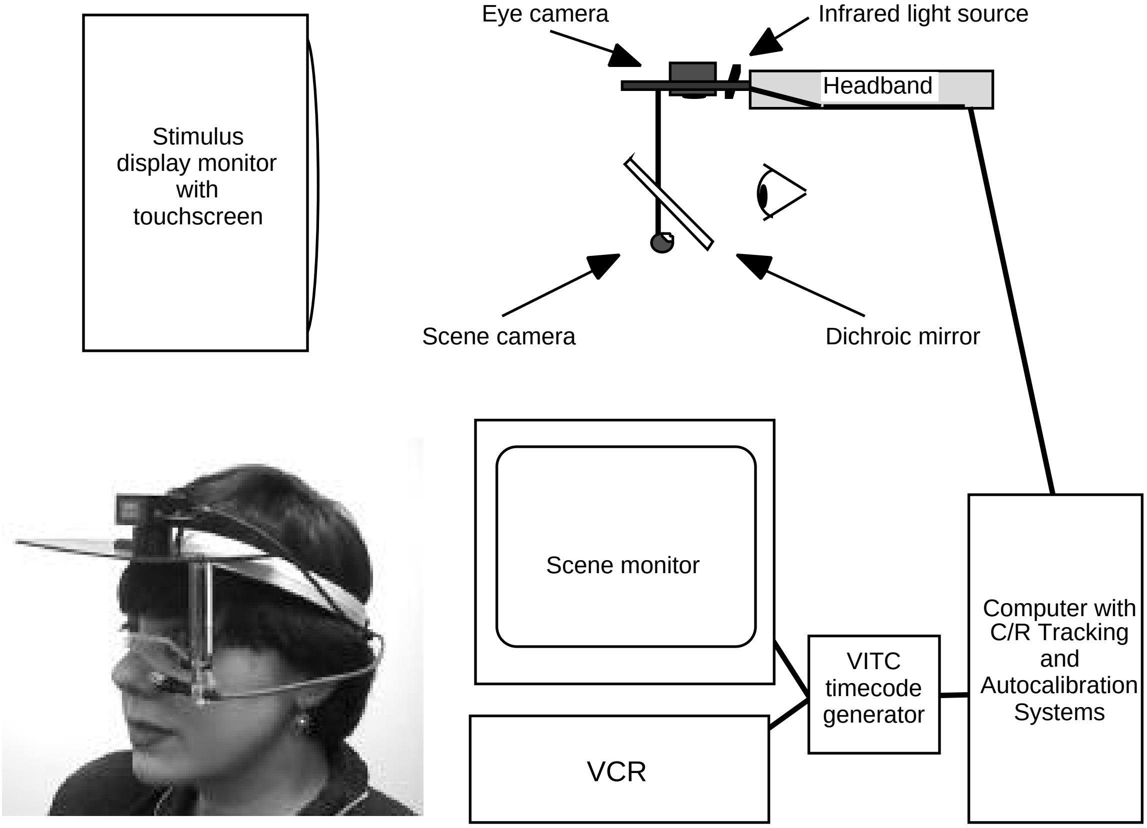

Figure 2

Introductory session. The initial training goals were to teach the participant to allow the headgear to be put in place, refrain from touching it, and request its removal appropriately. Thus far, all participants have learned by instruction or modeling to make appropriate removal requests. During subsequent sessions, the trainer reviewed the procedure to request removal and provided intermittent verbal praise for keeping hands down and away from the headgear.

Calibration training. For calibration, the participant must hold the head in one position while fixating on 2 x 2 cm targets presented successively in the center and four corners of the stimulus presentation monitor. Each fixation must be held for about 3 or 4 seconds, long enough for the experimenter to enter calibration data via keyboard. During calibration, the trainer stood behind the participant and gently held the head still. To provide contingencies to maintain fixations, fixation targets were small color pictures of common objects, and participants were trained to name the pictures aloud as they were displayed. To discourage anticipatory eye movements to the next fixation location, a series of different pictures was presented in each location. A second trainer controlled the pace of target presentation, provided verbal consequences to participants for naming the targets, changed the target location as necessary, and dispensed tokens for successful completion of calibration sequences.

A complete calibration sequence lasted about 15-20 seconds. The criterion for completing this stage of training was two consecutive sessions with six complete calibration sequences in each session. Six were required because it is sometimes necessary to repeat the calibration sequence several times for apparatus adjustments during actual eye tracking sessions.

Increasing session duration. The final stage of training built tolerance for wearing the headgear. After completing the calibration routine, participants continued to wear the head-

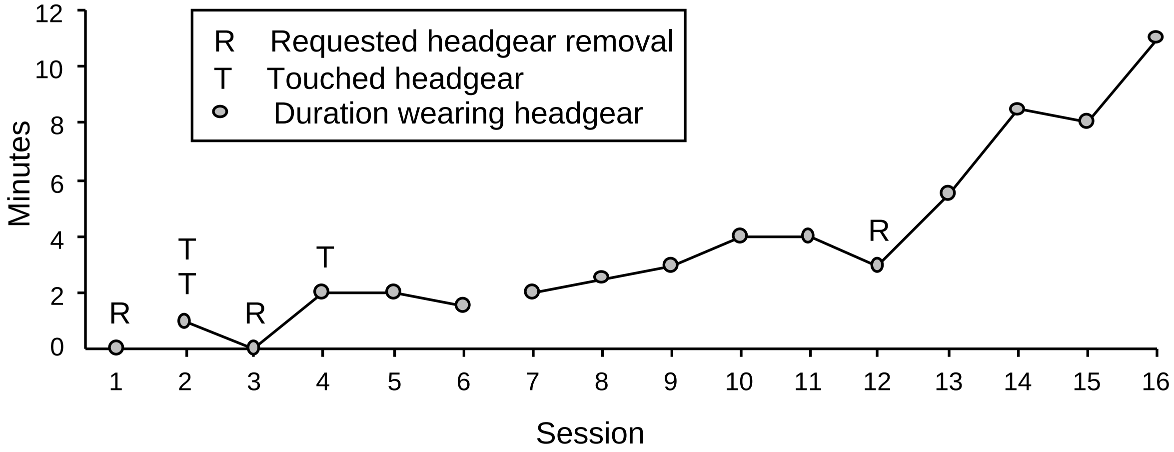

Figure 3

gear while performing the two-sample DMTS task. Over sessions the number of DMTS trials increased gradually from 2 to 36 trials.

Figure 3 shows DTM's training data. The points show minutes per session wearing the headgear while performing calibration and DMTS tasks. "R" and "T" indicate instances in which DTM requested headgear removal or touched the headgear, respectively. In his introductory session, he requested removal of the headgear while it was being adjusted. Calibration training took place in Sessions 2 to 6, as the number of calibration sequences was increased to six per session. An exception was Session 3, in which DTM requested headgear removal before the first calibration sequence. In Session 7, two matching-to-sample trials were introduced following the calibration routine, and the number of matching-to-sample trials was increased to 39 by Session 16. All of these sessions were complete except for Session 12, in which DTM requested headgear removal after six matching-to-sample trials. During training, DTM touched the headgear only three times, twice in Session 2 and once in Session 4.

Eye Tracking Evaluation of Observing Behavior

Eye tracking sessions included 36 two-sample DMTS trials. Eyetracking videotapes were analyzed with OCS Tools software (Triangle Research Collaborative, Inc., Research Triangle Park, NC; http://www.trctech.com) and a computer equipped with a card that read timecode directly from videotape. To code the videotapes, the experimenter used a jog/shuttle control to advance the tape to frames in which events of interest occurred and entered identifying codes on the computer keyboard. Analyses included the following events: onset of sample stimuli; observations of left, right, or neither sample; and offset of sample stimuli. An observation of the left or right sample stimulus occurred in frames where the point-of-gaze cursor was within approximately 2° of visual angle from the center of the stimulus. This distance was chosen because it is the diameter of the foveal area of greatest acuity (Bennett & Rabbetts, 1989; Hochberg, 1988). The target area around each sample stimulus was estimated by extrapolation from the point midway between the two samples, which was 2 cm from the center of each sample (approximately 2.1° visual angle at a viewing distance of 55 cm). An observation of neither sample stimulus occurred when the samples were present but the point-of-gaze cursor was not within either target area.

Interobserver agreement for videotape coding was determined by comparing records prepared independently by two different experimenters. The comparison included all video frames from both records that were coded for the events listed above. Percent agreement was calculated by dividing the total number of frames with agreements by the total number of frames with agreements plus disagreements. Percent agreement for DTM's data in Figure 5 was 96.5% (1499/1554 frames).

Figures 4 and 5 show trial-by-trial records of observing behavior on the two-sample DMTS

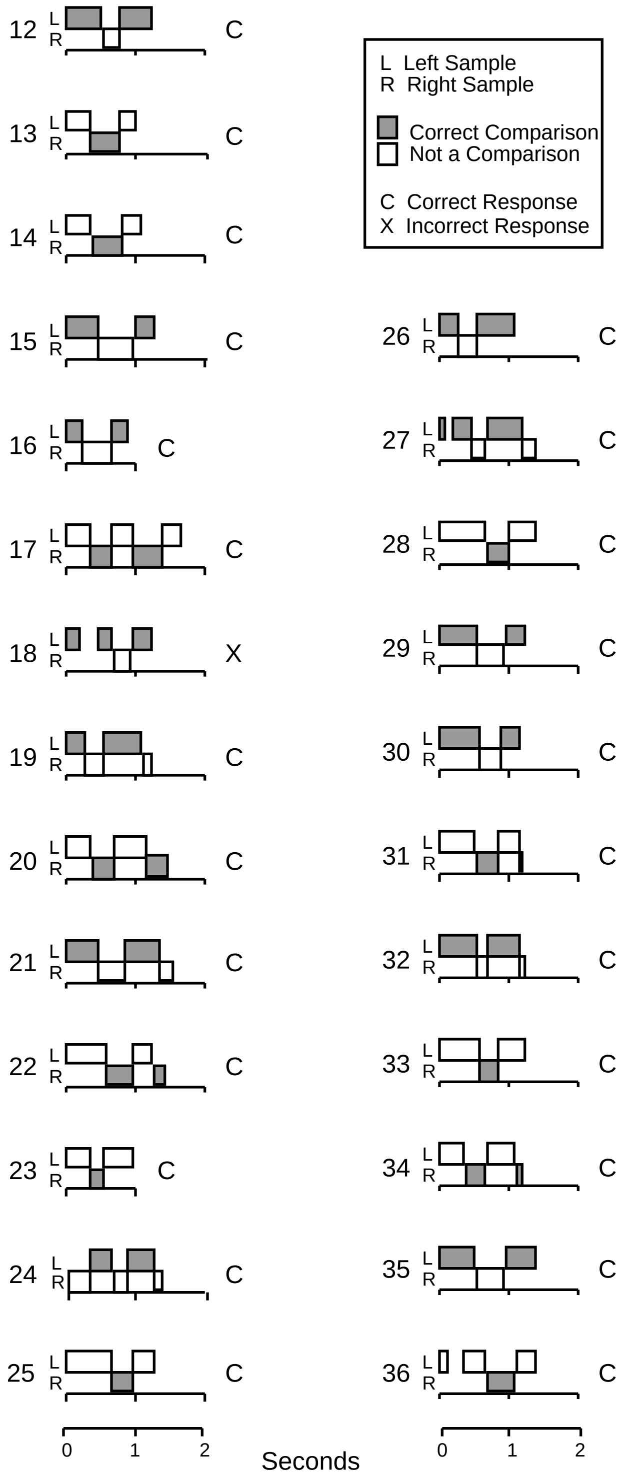

Figure 4

task. Trial numbers appear to the left of each plot. To allow some time for performance to stabilize, the analyses began with the twelfth DMTS trial of the session. In each plot, the upper and lower horizontal bars show the duration of each observation of the left and right sample stimuli, respectively (the bars are labeled L and R in the figures). Durations are shown according to the scale (seconds) at the bottom of the figure. Each plot begins with the first observation of a sample (latency to the first observation is not shown) and continues to the end of the last observation. Gaps between bars indicate that neither stimulus was observed. Bars for the sample stimulus that subsequently appeared as the correct comparison are shown in gray, and bars for the sample that did not appear in the comparison array are white. (While observing the samples, the participant could not predict which one would appear as the correct comparison; the distinction is made in this presentation to assist in the interpretation of DTM's results.) Letters to the right of each plot indicate whether the participant's response to the comparison array was correct (C) or an error (X). For example, in Figure 4, Trial 12 began with an observation of the left sample stimulus for 0.50 s, then the right sample for 0.27 s, and then back to the left sample for 0.47 s. Total observing duration was 1.24 s (the reader's estimation of approximate durations will be sufficient for the present discussion). When the comparisons were displayed, the stimulus that had been the left sample was the correct comparison (gray bars), and the participant selected it (C).

Figure 4 shows LCN's data from a session in which overall accuracy was 96%. Her observing behavior is typical of eight nonclinical adults we have studied. Observing patterns were highly regular; nearly every trial began with a left-right-left sequence. Every sample stimulus was observed at least one time on every trial, and only two trials (16 and 23) had total observing durations of less than 1 s.

Figure 5 shows DTM's data from a session in which overall accuracy was 61%. Observing patterns were more irregular than LCN's, with substantial variation from trial to trial. There were 12 trials on which he observed only one of the sample stimuli. On 4 of these trials (17, 19, 30, 31), the observed stimulus was the correct comparison, and DTM was correct on all of these trials; on the other 8 trials (12, 13, 14, 16, 22, 24, 33, and 36), the observed stimulus did not appear in the comparison array, and he made errors on 6 of these 8 trials. Observing durations were often irregularly distributed between the two sample stimuli and generally shorter than LCN's. There were 15 trials on which total observing duration

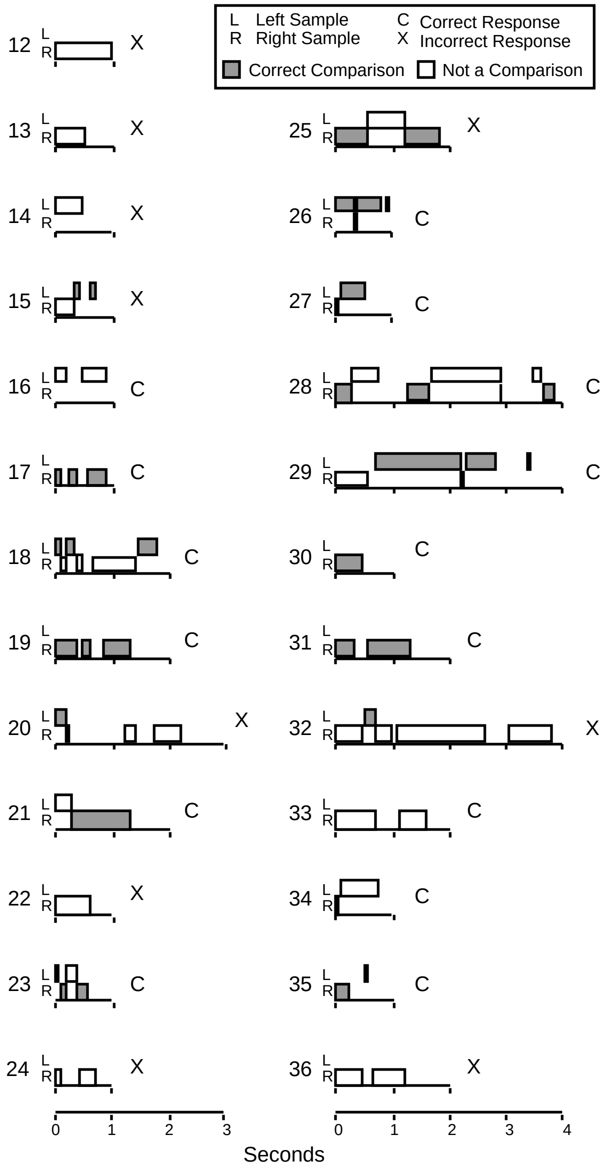

Figure 5

was 1 s or less. There were four trials on which DTM observed both sample stimuli and still made errors, and observing durations for the sample that was the correct comparison on three of these trials were relatively brief, 0.19 to 0.26 s (gray bars in Trials 15, 20, and 32). Taken together, observing failures and brief observing durations occurred on 9 of the 10 trials with errors.

Discussion

Results show that eye tracking with a head-mounted system is feasible with at least some individuals with moderate mental retardation who display stimulus overselectivity. Because the head-mounted apparatus allows unrestricted head movements, it makes eye tracking possible with individuals unlikely to participate in sessions involving mechanical head restraints. In addition to cooperation issues, head restriction may introduce concerns that participants do not perform tasks in the same ways that they do when given free head movement; for example, Creedon (1999) recently reported that children with autism tended to move the head and eyes together when fixating on changing target locations. Another potential advantage is that the eyetracking signal is not lost if a participant turns his or her head to look away from the screen; in such instances the apparatus can record the source of the distraction. This feature also makes the head-mounted apparatus appropriate for analyses of observing behavior in other applications with tasks that require some head movements (sorting, assembly, etc.).

The eye tracking data from DTM's session show that stimulus overselectivity may be accompanied by failure to observe all of the relevant stimuli. On trials where he observed only one sample stimulus, he was always correct if that stimulus was the correct comparison, but he was correct only at chance levels if it was not. Because observing behavior is open to modification by manipulating its consequences (Schroeder & Holland, 1968a,b, 1969; Rosenberger, 1973), these results raise the question of whether overselectivity could be remediated by modifying observing behavior. Because the eye tracking apparatus produces a real-time video image, it provides information that could be used to arrange contingencies for observing responses. In our ongoing research, we are beginning to examine this possibility. The results will help determine to what extent the role of eye tracking can be expanded from assessment to remediation.

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