Available online at www.sciencedirect.com
SCIENCE DIRECT®
Research in Developmental Disabilities
25 (2004) 155–181

Research in Developmental Disabilities

Assessing visual attention in young children and adolescents with severe mental retardation utilizing conditional-discrimination tasks and multiple testing procedures

Nancy H. Huguenin*

Behavior Analysis & Technology, Inc., 61 Long Hill Road, P.O. Box 327, Groton, MA 01450-0327, USA

Abstract

To effectively reduce overselective attention, a fine-grained analysis of the control exhibited by compound training cues is first needed. Computer software was developed in this study to administer two different stimulus control-testing procedures to assess how three young children of normal development and three adolescents with severe mental retardation attended to stimulus compounds when conditional-discrimination tasks were provided. One test assessed stimulus control by determining response accuracy for each component of the S+ compounds. The other testing procedure measured the response topographies of the compound stimuli using a touch screen attached to a computer monitor screen. After pretraining each stimulus component, all three children attended simultaneously to two elements in a conditional-discrimination task with few errors occurring. The adolescents with mental retardation eventually attended to both elements simultaneously but required more pretraining and exposure to the conditional-discrimination tasks before simultaneous attention occurred. Since the adolescents with severe mental retardation learned to simultaneously attend to multiple cues in the conditional-discrimination tasks, this demonstrated that restricted attention is not an unmodifiable perceptual characteristic among individuals with developmental disabilities. Recording response topographies with a touch screen was also discovered to be a sensitive measure of stimulus preferences for both groups. Utilizing touch-screen technology may prove to be critical for accurately identifying stimulus preferences and

* Tel.: +1-978-448-6262.
E-mail address: nhuguenin@ba-and-t.com (N.H. Huguenin).

0891-4222/$ – see front matter
doi:10.1016/j.ridd.2004.01.001

contribute to the understanding and treatment of overselective attention in students with attentional deficits.

Keywords: visual attention; mental retardation; touch-screen technology

1. Introduction

The intent of this investigation was to utilize computer touch-screen technology for assessing visual attention. The specific computer instructional program involved procedures which determined how young children of normal development and adolescents with severe mental retardation, both groups having comparable mental age, attended to compound visual cues when conditional-discrimination tasks were provided. This kind of assessment is important because it can reveal perceptual abnormalities that prevent or delay acquisition of essential skills. One type of attentional deficit, for example, that can interfere with a child's development is overselective attention in which the child attends only to restricted portions of complex stimulus displays. Children with overselective visual attention demonstrate a type of ''tunnel vision'' in which they attend to only a limited number of elements in a visual compound. Overselective attention has been reported in students with developmental disabilities (Bailey, 1981; Koegel & Wilhelm, 1973; Lovaas & Schreibman, 1971; Lovaas, Schreibman, Koegel, & Rehm, 1971; Rincover & Ducharme, 1987; Schreibman & Lovaas, 1973; Schreibman, Kohlenberg, & Britten, 1986; Stromer, McIlvane, Dube, & Mackay, 1993; Ullman, 1974; Whiteley, Zaparniuk, & Asmundson, 1987; Wilhelm & Lovaas, 1976), and this attentional deficit can be very extreme among individuals with autism and severe levels of mental retardation (Rincover & Ducharme, 1987; Whiteley et al., 1987; Wilhelm & Lovaas, 1976). Stimulus overselectivity may explain the difficulty in acquiring appropriate social, language, play, and emotional behaviors commonly demonstrated by children with developmental disabilities (Burke, 1991; Dunlap, Koegel, & Burke, 1981).

The current study used conditional-discrimination tasks requiring simultaneous attention to multiple cues to assess the presence of overselective attention in young children of normal development and adolescents with severe mental retardation. The stimulus compounds were composed of letters and symbols, and conditional-discrimination tasks were presented, which required simultaneous attention to two elements of the training compounds to maintain continuous reinforcement. An advantage of using a conditional-discrimination paradigm requiring simultaneous attention to multiple cues is that it tests directly whether or not overselective attention is evident. Since responding to only one component would produce errors and prevent the student from achieving continuous reinforcement, selective attention is immediately revealed. In contrast, tests which consist of presenting individual components alone after the acquisition of compound discriminations can only infer attentional patterns produced by the compound training cues. Despite the greater reliability of conditional-discrimination procedures for revealing overselective attention, most investigations reporting the presence of overselective attention have not employed this stimulus control procedure.

Since remediating stimulus overselectivity should be an important part of educational programs for teaching essential skills to students with attentional deficits, a fine-grained analysis of the control exhibited by the stimulus elements of compound training cues is first needed in order to design effective treatment (Bickel, Richmond, Bell, & Brown, 1986). Utilizing computer touch-screen technology can permit greater precision in identifying overselective attention in students and assist in understanding conditions responsible for its occurrence. Computer software was developed in this study to administer two different stimulus control testing procedures in order to assess how young children of normal development and adolescents with mental retardation attended to stimulus compounds when conditional-discrimination tasks were provided. One test assessed stimulus control by determining response accuracy for each component of the S+ compounds during the conditional-discrimination tests. The other testing procedure measured the response topographies of the compound stimuli. This goal was achieved by using a touch screen attached to a computer monitor screen, which automatically recorded which stimuli the students touched in the compounds.

Investigations have shown the necessity of multiple test conditions for accurately assessing stimulus control (Danforth, Chase, Dolan, & Joyce, 1990; Fields, 1985; Huguenin, 1987, 1997; Huguenin & Touchette, 1980; Merrill & Peacock, 1994; Newman & Benefield, 1968; Smeets, Hoogeveen, Striefel, & Lancioni, 1985; Wilkie & Masson, 1976). Multiple stimulus control tests are needed since only one stimulus control test cannot rule out possible contamination by test variables. Misleading conclusions can be made about control exerted by components of compound cues when accuracy scores across probe trials, for example, are summarized. Past research has shown separate controlling stimulus-response relations can be hidden when such accuracy scores are averaged together (Bickel et al., 1986; Bickel, Stella, & Etzel, 1984; Stromer et al., 1993). More than one testing procedure has been used infrequently to assess how stimulus compounds are attended to, however, due to equipment limitations.

Computer touch-screen technology was utilized in this study to automatically administer multiple stimulus control tests and to record response topographies while presenting stimulus displays. Computer touch-screen technology is ideal for measuring visual attention, as many different response parameters can be simultaneously recorded whenever compound stimuli appear on the computer screen. Recording spatial locations of responses, for example, can be accurately determined with a touch screen and can identify features of compound visual stimuli which students are attending to (Huguenin, 1997, 2000). In addition, touch screens can provide this detailed analysis of stimulus control without requiring the sophisticated eye–hand coordination required by a mouse or track ball which young children and many students with developmental disabilities may lack. Other investigations have used touch screens for training visual discriminations (e.g., Bhatt & Wright, 1992; Huguenin, 1987; Lynch & Green, 1991; Markham, Butt, & Dougher, 1996; Stromer et al., 1993). Only a few investigations, however, have used touch screens to record spatial locations of responses to identify stimulus elements attended to in visual compounds (Huguenin, 1997, 2000). Recording response topographies with a touch screen in addition to determining the response accuracy of stimulus elements should permit a more fine-grained analysis of how students attend to compound visual cues when conditional-discrimination tasks are provided. As a result of a more detailed assessment by recording response topographies, individual differences in the visual attention of students might be discovered which could not be revealed by accuracy scores alone. Utilizing touch-screen technology in this manner may prove to be beneficial for accurately identifying overselective attention and contribute to the development of procedures for reducing this attentional deficit.

Another purpose of this study was to determine the similarities and differences in the visual attention of young children of normal development and adolescents with severe mental retardation of comparable mental age when conditional-discrimination tasks were provided. Past research demonstrated differences between these two groups when visual compounds were presented whose stimulus components had conflicting prior reinforcement histories (Huguenin, 1997). In the current investigation, computer touch-screen technology was utilized to administer conditional-discrimination tasks requiring simultaneous attention to multiple cues to both young children of normal development and students with mental retardation to determine attentional deficits which could interfere with learning. It was wondered if utilizing computer touch-screen technology to administer this type of test to assess visual attention might prove to be an effective diagnostic technique for identifying attentional problems which could prevent or delay acquisition of essential skills. As a result of identifying attentional problems at an early age, treatment and educational programs designed to diminish the effects of attentional deficits on later development could be provided.

The amount of single-stimulus pretraining and exposure to the conditional-discrimination tasks required before simultaneous attention to multiple cues occurred for the two groups was also examined. In a previous investigation, manipulating prior reinforcement histories was effective in controlling what aspects of stimulus compounds adolescents with mental retardation selectively attended to when extended training was provided (Huguenin, 2000). If extended training was omitted, prior reinforcement histories failed to control their selective attention. In the current study, it was determined whether extended single-stimulus pretraining and repeated exposure to conditional-discrimination tasks would permit students with severe mental retardation to acquire conditional discriminations requiring simultaneous attention to multiple cues. As a result of additional pretraining, the durability of previously taught visual discriminations could be enhanced and become less susceptible to disruption when the conditional-discrimination tasks were presented. Computer touch-screen technology was utilized in this study to examine whether overselective attention is an unmodifiable attentional problem or if administering conditional-discrimination procedures could eliminate overselective attention in students with severe mental retardation.

2. Method

2.1. Subjects

Three young children of normal development and three adolescents with severe mental retardation with comparable mental age participated. The three young children had no sensory or motor impairments. The chronological ages and gender of the young children were 5.5 (female), 6.0 (female), and 6.5 years (female), respectively. They were of normal intelligence. Two of the subjects were children of acquaintances of the author. The third child was enlisted through an ad placed in a local newspaper. The chronological ages and gender of the adolescents with mental retardation were 17 (female), 20 (female), and 21 years (female), respectively. They were enlisted through material describing the study. All three adolescents attended the same special-education program consisting of a self-contained classroom which was located in an elementary school building. Their mental ages were assessed to be approximately 4–6 years in age. Diagnostic tests included the Stanford-Binet (4th edition), Beery Test of Visual Motor Integration, Goodenough-Harris Draw a Person Test, and Brigance Diagnostic Inventory of Early Development. All of the adolescents were diagnosed within the severe range of mental retardation.

2.2. Apparatus

The experimental sessions were automated by an Apple Power Macintosh 7500/100 desk-top computer with a 40 GB internal hard disk, 128 MB RAM, and System 8.6. A MicroTouch 14-in. monitor was used. The code was generated to be fully System 8.x compatible, using Macintosh-standard graphical user interface dialog boxes to initialize the sessions, fully automated event-driven procedure implementation and data acquisition, and automatic output file generation.

The computer presented stimuli and recorded responses. When stimuli appeared on the display screen, the computer decoded the correct position for each trial. In addition, the computer also kept a running account of trials, stimuli presented, the location on the display screen where the subject touched during each compound trial, as well as response accuracy. A report was provided following each experimental session that supplied this information. A BCI, Inc., token/coin dispenser was located to the left of each student. This device was operated after each correct response, and pennies dropped into a $9.6\,\text{cm} \times 14\,\text{cm} \times 9.6\,\text{cm}$ receptacle at the base of the dispenser.

2.3. Experimental design

A within-subject reversal design was utilized to determine whether single stimulus pretraining influenced conditional-discrimination performance. A within-subject reversal design was also used to assess if original treatment effects generalized to transfer compounds.

2.4. General procedure

Each student sat in a chair facing a computer display screen. The experimenter sat beside the student. Sessions consisted of 80–100 trials in length. A trial began when letters and symbols, centered on two white illuminated backgrounds, appeared on the computer screen. The trial ended when the student touched either illuminated area. A 3-s intertrial interval followed in which the computer screen was dark, and then the next trial began. Correct choices produced the delivery of pennies, a flashing computer screen, and verbal praise. Following an incorrect choice, reinforcement was not delivered. At the end of each session, the children and adolescents traded their accumulated pennies for favorite snacks and recreational items. The stimuli were presented in an unpredictable sequence with the restriction that no stimulus appeared more than twice in succession in the same location. The stimuli also occurred an equal number of times on the left and right portions of the computer screen.

2.5. Conditional-discrimination tasks

Each student was presented two conditional-discrimination tasks. The S+ and S− compound stimuli were presented simultaneously, and they were composed of letters and symbols. One conditional discrimination required selecting the stimulus compound containing the letter F and the symbol for flower to obtain reinforcement. If stimulus compounds displaying either the letter W and the flower symbol or the letter F and a house symbol were selected, reinforcement was not provided (see Fig. 2). In another conditional-discrimination task presented to the students, a stimulus compound containing the letter T and the symbol for tree was consistently paired with reinforcement. The S− stimulus compounds were either the letter R appearing with the tree symbol or the letter T appearing with a cup symbol (see Fig. 2). The two S− conditions for each conditional-discrimination task were successively presented in a random sequence with the S+ compound with the restriction that the same S− condition could not appear more than three times in succession. This procedure insured sustained attention to both aspects of the S+ compounds had occurred when errorless or near errorless performance was demonstrated, as selective responding to only one of the stimulus elements would have prevented continuous reinforcement. Both conditional-discrimination tasks were administered for 20 trials to determine baseline performance. The two conditional-discrimination tasks also continued to be presented for 20 trials after varying amounts of single-stimulus pretraining were provided to the children and adolescents.

2.6. Single-component training and conditional-discrimination testing

Single-stimulus pretraining was accomplished for both conditional-discrimination tasks by presenting only one S− condition at a time with the S+ compound until criterion accuracy was reached for each discrimination (see Fig. 1). One of the training compounds was the letter F appearing with a flower symbol. Stimulus control by the letter component was achieved by making the flower symbol common to both the S+ and S− compounds and consistently pairing the letter F with reinforcement. The letter W was always paired with extinction. A prompt was provided during the first two trials which consisted of the experimenter, who sat beside the students during the sessions, pointing to the letter F for a few seconds and indicating it was the correct choice. Following criterion accuracy (29/30 trials correct), stimulus control by the symbol component of the F-Flower compound was next obtained. Now, the letter F appeared in both of the S+ and S− compounds, and only the flower and house symbols were consistently paired with reinforcement and extinction, respectively. A prompt was again provided during the first two trials in which the experimenter pointed to the flower symbol and indicated at this point it was the correct choice. Symbol pretraining continued until criterion accuracy (29/30 trials correct) was achieved. Single-stimulus pretraining was repeated at the beginning of the next session. After criterion accuracy was again achieved for each component of the training compounds, the

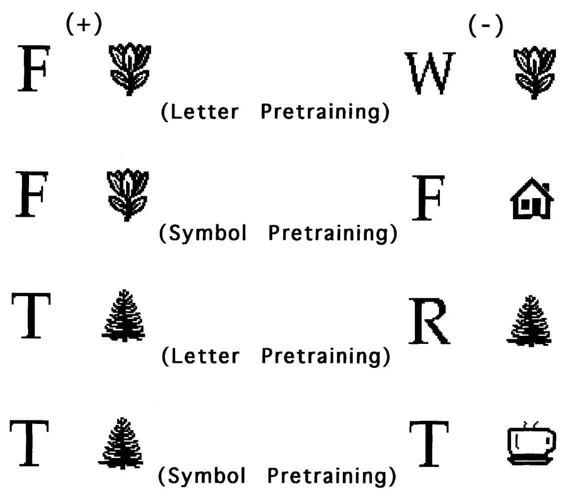

Fig. 1. Diagram of four separate visual discriminations established prior to presentation of the conditional-discrimination tests. Plus (+) indicates stimulus compounds paired with reinforcement and minus (−) denotes stimulus compounds paired with nonreinforcement. The S+ and S− compounds were presented simultaneously and were composed of letter and symbol components.

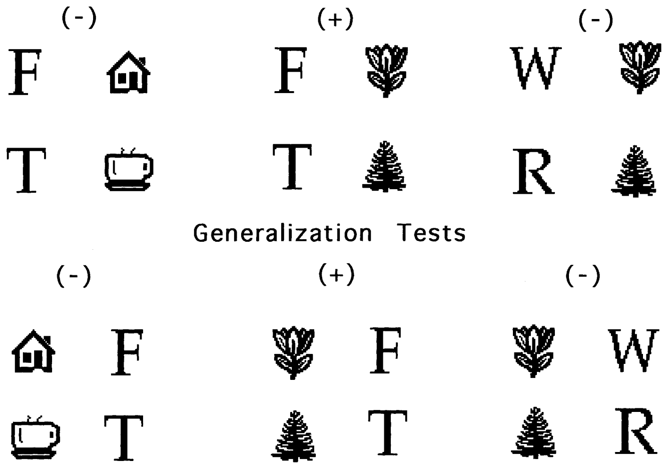

Fig. 2. Diagram of the conditional-discrimination tasks. Plus (+) indicates stimulus compounds paired with reinforcement and minus (−) denotes stimulus compounds paired with nonreinforcement. The S+ and S− compounds were presented simultaneously and were each composed of letter and symbol components.

conditional-discrimination test described above was presented a second time for 20 trials. During the conditional-discrimination test, the two S− compounds (W-Flower and F-House) were successively presented in a random sequence with the F-Flower S+ compound with the restriction that either S− compound could not appear more than three times in succession (see Fig. 2). At the beginning of the third session, single-stimulus pretraining was repeated, and the conditional-discrimination test was again presented a third time for another 20 trials.

The same single-stimulus pretraining procedures were applied to another training compound, the letter T appearing with a tree symbol (see Fig. 1). Stimulus control by the letter component was also obtained by making the tree symbol common to both the S+ and S− compounds and consistently pairing the letter T and the letter R with reinforcement and extinction, respectively. The experimenter also pointed to the correct letter, the letter T, during the first two trials. After criterion accuracy occurred, control by the symbol component of the T-Tree compound was established. The letter T appeared now in both of the S+ and S− compounds, and tree and cup symbols were consistently paired with reinforcement and extinction, respectively. A gestural prompt was again provided during the first two trials to designate tree at this point as the correct choice. This step continued until criterion accuracy was achieved. Single-stimulus pretraining was also repeated at the beginning of the next session. Following criterion accuracy for each stimulus component of the training compound, the other conditional-discrimination test was presented a second time for 20 trials as described above. At this point, the two S− compounds (R-Tree and T-Cup) were successively presented in a random sequence with the T-Tree S+ compound with the restriction that either S− compound could not appear more than three times in succession (see Fig. 2). Single-stimulus pretraining was repeated at the beginning of the following session, and then the conditional-discrimination test was presented again for a third time.

2.7. Generalization tests

Two generalization tests were also provided to the students. Two conditional-discrimination tasks were presented for 20 trials each during the generalization tests. Although each of the conditional discriminations involved the same letters and symbols as the original tasks, the positions of the letters and symbols in the S+ and S− compounds were reversed during the generalization tests (see Fig. 2). The corresponding generalization tests were presented immediately following the original conditional-discrimination tests.

2.8. Data collection

Data collection for the conditional-discrimination tests consisted of overall response accuracy and response accuracy for the letter and symbol components of the S+ compounds. Response accuracies for each component of the S+ compounds were determined from trials in which that component predicted reinforcement and the remaining component appeared in both the S+ and S− compounds. Because a touch screen was utilized, it was also recorded where the children and adolescents touched each time the stimulus compounds appeared on the screen. This permitted a direct comparison of accuracy scores with stimuli touched in the stimulus compounds during the 20-trial conditional-discrimination tests.

Table 1 lists the sequence of stimuli and procedures provided to the three young children and the three adolescents with mental retardation.

3. Results

3.1. Conditional-discrimination (overall) accuracy scores

When the overall accuracy scores of the conditional-discrimination tests were determined, the young children all achieved high accuracy for the first conditional-discrimination task following initial pretraining and continued to achieve high accuracy (80% or higher) during the following two test sessions (see Fig. 3). They also demonstrated high accuracy scores throughout all of the test sessions, with one exception, when the second conditional-discrimination task was presented.

For the adolescents with mental retardation, variable performance was observed during the test sessions of the first conditional-discrimination task when overall accuracy scores were examined (see Fig. 4). More uniform test performance was observed, however, for the adolescents with mental retardation when overall accuracy scores of the second conditional-discrimination task were determined. Following initial pretraining, all three adolescents displayed high

Table 1
Sequence of stimuli and procedures

Child 1, Adolescent 1	Child 2, Adolescent 2	Child 3, Adolescent 3
Conditional discrimination, F-Flower (+)	Conditional discrimination, T-Tree (+)	Conditional discrimination, F-Flower (+)
Letter pretraining (F)	Letter pretraining (T)	Letter pretraining (F)
Symbol pretraining (Flower)	Symbol pretraining (Tree)	Symbol pretraining (Flower)
Letter pretraining (F)	Letter pretraining (T)	Letter pretraining (F)
Symbol pretraining (Flower)	Symbol pretraining (Tree)	Symbol pretraining (Flower)
Conditional discrimination, F-Flower (+)	Conditional discrimination, T-Tree (+)	Conditional discrimination, F-Flower (+)
Letter pretraining (F)	Letter pretraining (T)	Letter pretraining (F)
Symbol pretraining (Flower)	Symbol pretraining (Tree)	Symbol pretraining (Flower)
Conditional discrimination, F-Flower (+)	Conditional discrimination, T-Tree (+)	Conditional discrimination, F-Flower (+)
Generalization test, Flower-F (+)	Generalization test, Tree-T (+)	Generalization test, Flower-F (+)
Conditional discrimination, T-Tree (+)	Conditional discrimination, F-Flower (+)	Conditional discrimination, T-Tree (+)
Letter pretraining (T)	Letter pretraining (F)	Letter pretraining (T)
Symbol pretraining (Tree)	Symbol pretraining (Flower)	Symbol pretraining (Tree)
Letter pretraining (T)	Letter pretraining (F)	Letter pretraining (T)
Symbol pretraining (Tree)	Symbol pretraining (Flower)	Symbol pretraining (Tree)
Condititional discrimination, T-Tree (+)	Conditional discrimination, F-Flower (+)	Conditional discrimination, T-Tree (+)
Letter pretraining (T)	Letter pretraining (F)	Letter pretraining (T)
Symbol pretraining (Tree)	Symbol pretraining (Flower)	Symbol pretraining (Tree)
Condititional discrimination, T-Tree (+)	Conditional discrimination, F-Flower (+)	Conditional discrimination, T-Tree (+)
Generalization test, Tree-T (+)	Generalization test, Flower-F (+)	Generalization test, Tree-T (+)

overall accuracy scores (80% or higher) and maintained high accuracy during the subsequent two test sessions of the second conditional-discrimination task.

In summary, although differences were noted for the young children of normal development and the adolescents with mental retardation when the first conditional-discrimination task was presented, differences were less apparent for the two groups during the second conditional-discrimination task when overall accuracy scores were evaluated.

3.2. Stimulus component accuracy scores (conditional-discrimination tasks)

When the separate accuracy scores of both the letter and symbol components of the conditional-discrimination tasks were examined, the young children of normal development displayed greater variability in performance compared to their overall accuracy scores (see Figs. 5 and 6). Following initial pretraining, all three children of normal development demonstrated simultaneous control by both elements during the conditional-discrimination test session that followed as both

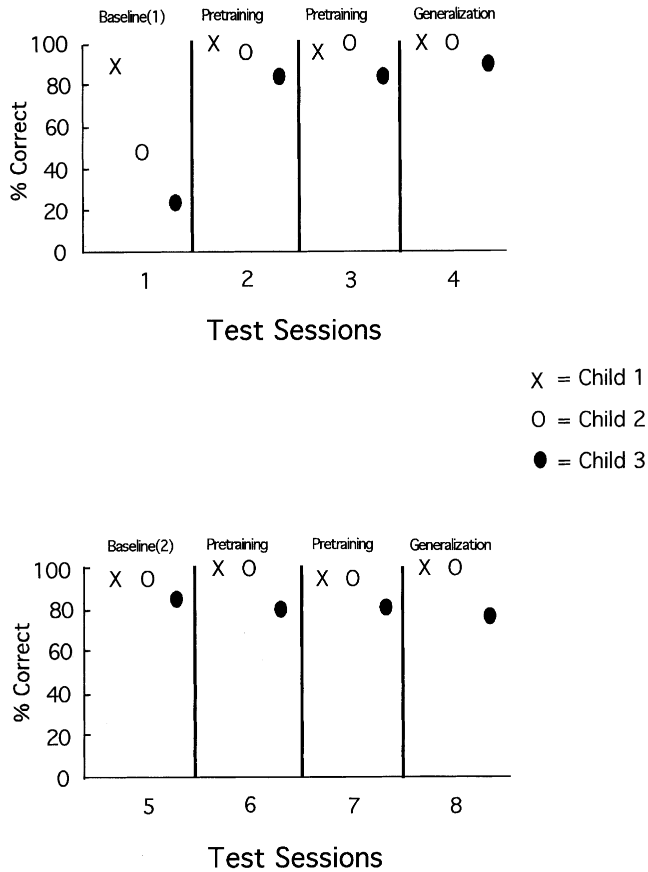

Fig. 3. The overall accuracy of responses for the first conditional-discrimination task (top graph) and the second conditional-discrimination task (bottom graph) in the different test conditions for the young children of normal development. Test results for each child appear in the order in which the different testing conditions were administered.

stimulus elements were associated with high accuracy scores (80% or higher). For two of the children (C1 and C2), simultaneous control by both the letter and symbol components continued to be revealed in the following six test sessions. For one of the three children (C3), however, simultaneous control by both elements was revealed in only one of the subsequent test sessions in contrast to the other two children of normal development. The third child (C3) demonstrated, instead, selective attention in five of the test sessions following initial pretraining where only one of the stimulus elements was associated with a high accuracy score (80% or higher). The overall accuracy scores did not reveal this changing attentional pattern by the third child with continued exposure to the conditional-discrimination tests and would have led to the false conclusion that she was attending to both elements when in fact she was attending selectively to only one (see Fig. 3).

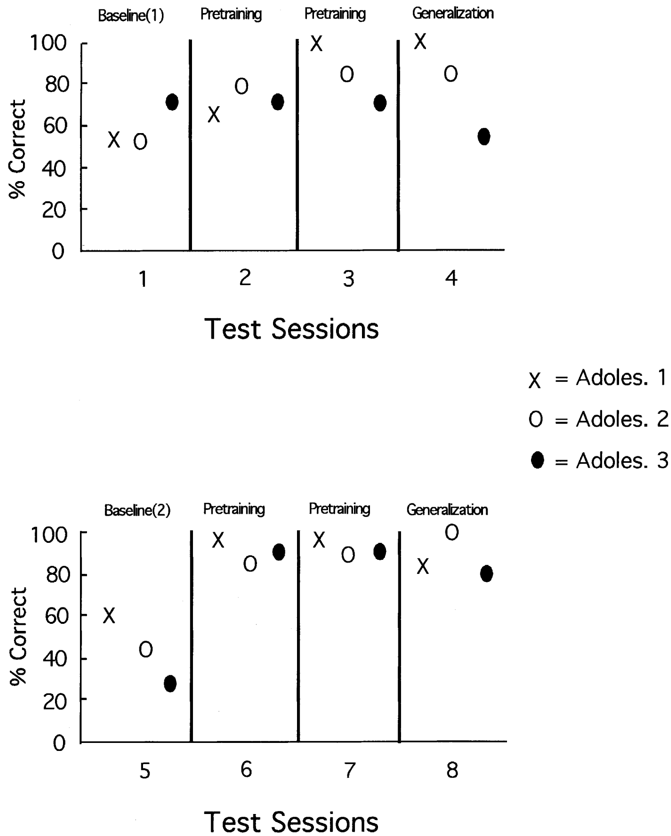

Fig. 4. The overall accuracy of responses for the first conditional-discrimination task (top graph) and the second conditional-discrimination task (bottom graph) in the different test conditions for the adolescents with mental retardation. Test results for each adolescent appear in the order in which the different testing conditions were administered.

The overall accuracy scores of the conditional-discrimination test sessions were also found to be misleading for the adolescents with mental retardation in some cases when compared to the accuracy scores of the separate stimulus components (see Figs. 7 and 8). Although for two of the adolescents (A1 and A3) simultaneous control by both the letter and symbol components was consistently associated with high overall accuracy scores in the conditional-discrimination test sessions, this was not the case for the remaining adolescent. The third adolescent (A2), in contrast, achieved high overall accuracy scores throughout testing with the exception of the baseline test session of both conditional-discrimination tasks (see Fig. 4). When the response accuracy of the separate stimulus components in the conditional-discrimination test sessions were determined for the third adolescent (A2), however, simultaneous control by both the letter and symbol components was revealed in only the final two test sessions (see Figs. 7 and 8). Prior to this,

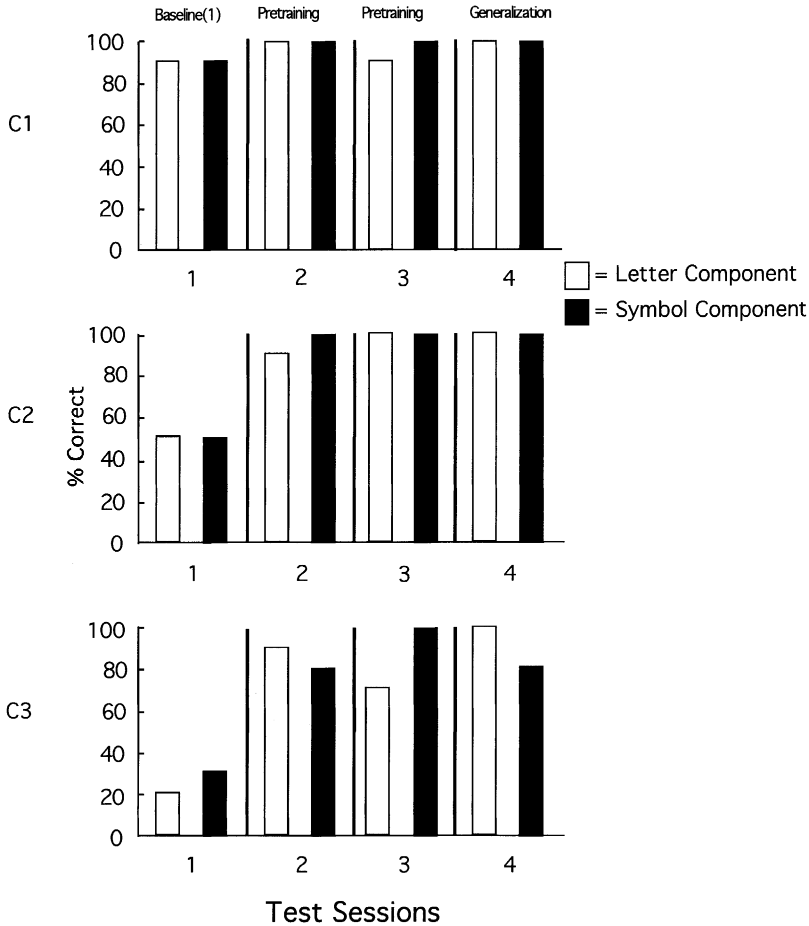

Fig. 5. Percent accuracy of responses for the letter (white bars) and symbol (black bars) components of the S+ compound of the first conditional-discrimination task in the different test conditions for the young children of normal development. Percent response accuracies for each component of the S+ compound were determined from trials where that component predicted reinforcement and the remaining component appeared in both the S+ and S− compounds. Test results for each child appear in the order in which the different testing conditions were administered.

Adolescent 2 was selectively attending to only the symbol component although the overall accuracy scores would have mistakenly indicated that she was attending simultaneously to both elements.

3.3. Stimulus-component response topographies (conditional-discrimination tasks)

The response topographies measured by the touch screen provided a fine grain analysis of stimulus preferences during the conditional-discrimination test trials.

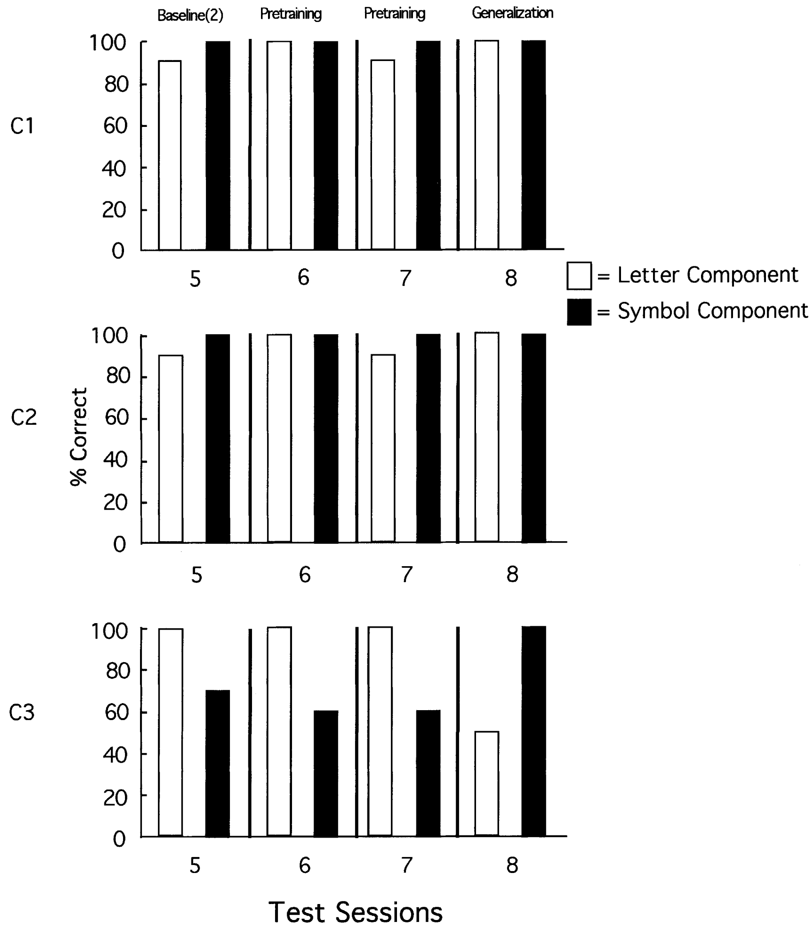

Fig. 6. Percent accuracy of responses for the letter (white bars) and symbol (black bars) components of the S+ compound of the second conditional-discrimination task in the different test conditions for the young children of normal development. Percent response accuracies for each component of the S+ compound were determined from trials where that component predicted reinforcement and the remaining component appeared in both the S+ and S− compounds. Test results for each child appear in the order in which the different testing conditions were administered.

This was shown for the young children as response topographies recorded with a touch screen were discovered to be a more sensitive measure of stimulus preferences than response accuracy when the conditional-discrimination tasks requiring attention to multiple cues were presented. For the young children of normal development when response accuracy of the individual stimulus elements were examined, only one child (C3) gave evidence of a stimulus preference occurring (see Figs. 5 and 6). She demonstrated this in five test sessions when response accuracies of the individual stimulus elements revealed a stimulus preference where only one of the stimulus elements was associated with high

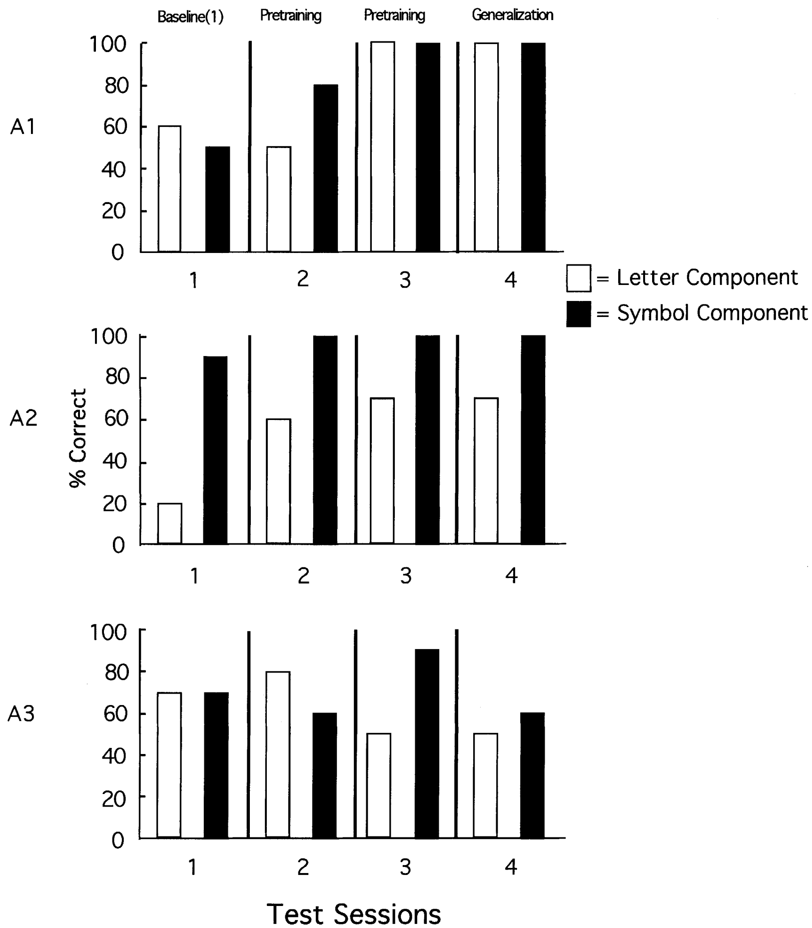

Fig. 7. Percent accuracy of responses for the letter (white bars) and symbol (black bars) components of the S+ compound of the first conditional-discrimination task in the different test conditions for the adolescents with mental retardation. Percent response accuracies for each component of the S+ compound were determined from trials where that component predicted reinforcement and the remaining component appeared in both the S+ and S− compounds. Test results for each adolescent appear in the order in which the different testing conditions were administered.

accuracy (80% or higher). When response topographies were examined, however, stimulus preferences were evident for all three children throughout the conditional-discrimination tests (see Figs. 9 and 10). The response topographies demonstrated a stimulus preference during the conditional-discrimination test trials whenever the child selectively touched the same stimulus element in 80% or more of the trials. In summary, accuracy scores of the individual stimulus components revealed stimulus preferences in five instances for the young children. Recording response topographies with a touch screen was a more sensitive measurement technique as stimulus preferences were demonstrated

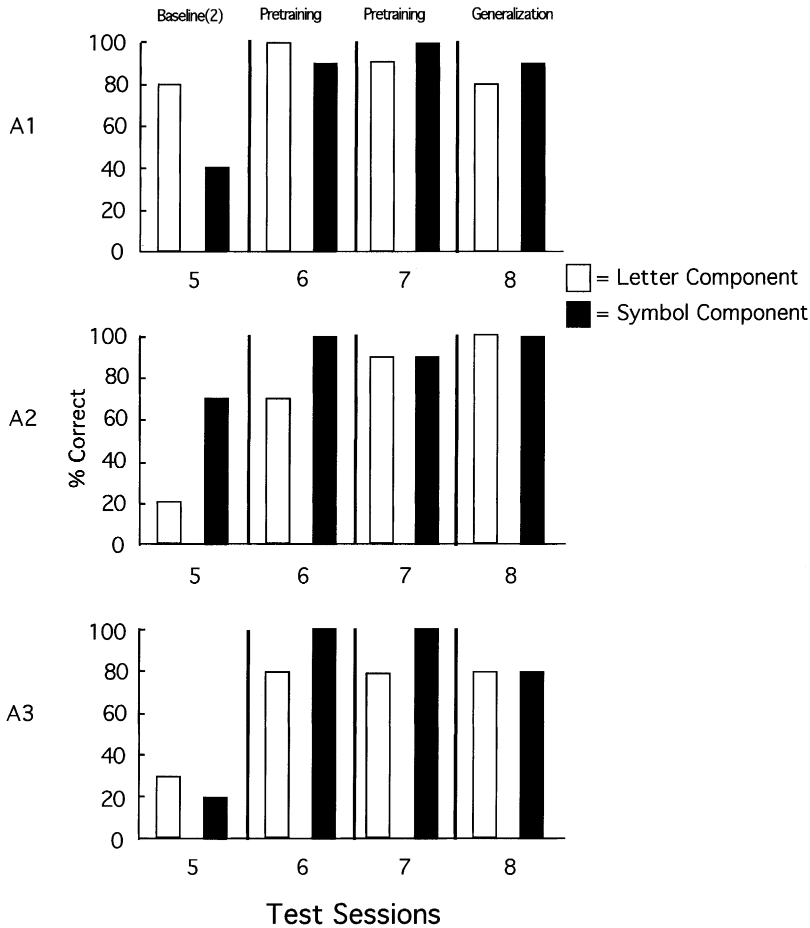

Fig. 8. Percent accuracy of responses for the letter (white bars) and symbol (black bars) components of the S+ compound of the second conditional-discrimination task in the different test conditions for the adolescents with mental retardation. Percent response accuracies for each component of the S+ compound were determined from trials where that component predicted reinforcement and the remaining component appeared in both the S+ and S− compounds. Test results for each adolescent appear in the order in which the different testing conditions were administered.

in 21 instances. In 16 of these test sessions, response topographies recorded by the touch screen revealed stimulus preferences which were not indicated by the accuracy scores of the stimulus components.

Response topographies recorded by the touch screen also proved to be a more sensitive measure of stimulus preferences than response accuracy for the adolescents with mental retardation. When response accuracy of the individual stimulus elements was examined, stimulus preferences were revealed in nine cases in which only one of the stimulus elements was associated with an accuracy score of 80% or higher (see Figs. 7 and 8). In contrast, stimulus preferences were

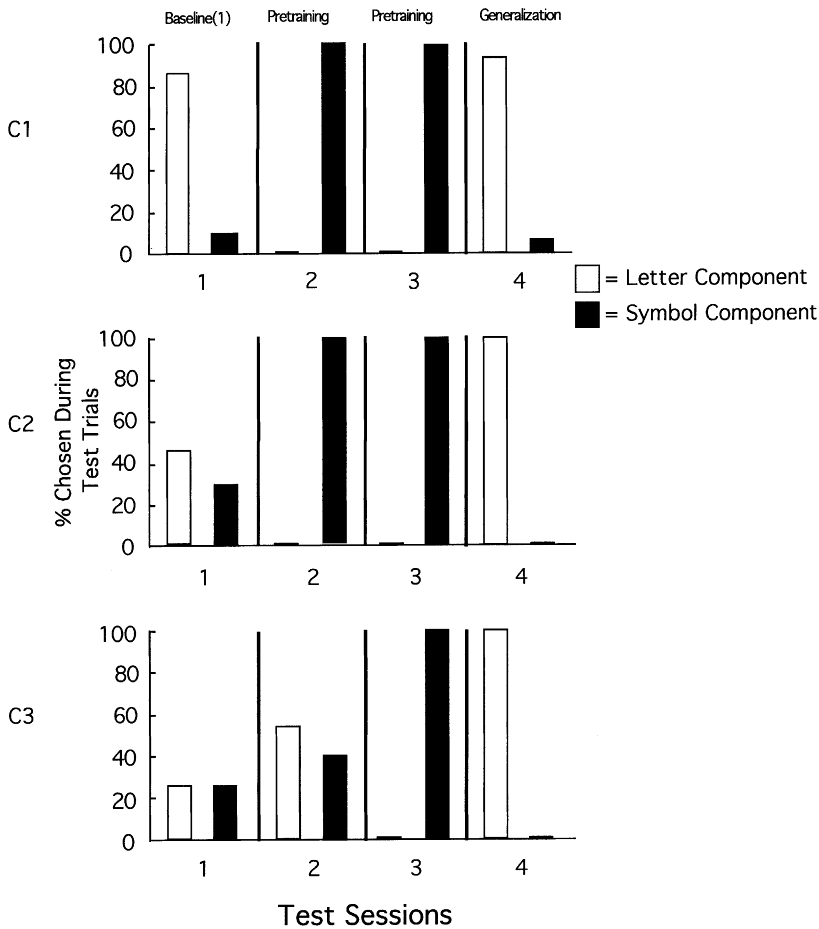

Fig. 9. Percentage letter component (white bars) and symbol component (black bars) of the S+ compound of the first conditional-discrimination task were chosen in the different test conditions for the young children of normal development. Test results for each child appear in the order in which the different testing conditions were administered.

demonstrated in 16 instances when the adolescents' response topographies were analyzed where the adolescent selectively touched the same stimulus element in 80% or more of the trials (see Figs. 11 and 12). Although their response topographies demonstrated in seven instances stimulus preferences which were also revealed by the accuracy scores of the stimulus components, the two different testing procedures did not both confirm the occurrence of stimulus preferences in 11 test sessions. This disagreement between testing procedures occurred in most cases when accuracy scores of the stimulus components indicated the absence of a stimulus preference. The response topographies recorded by the touch screen revealed, instead, the three adolescents did demonstrate stimulus preferences when the training compounds were presented.

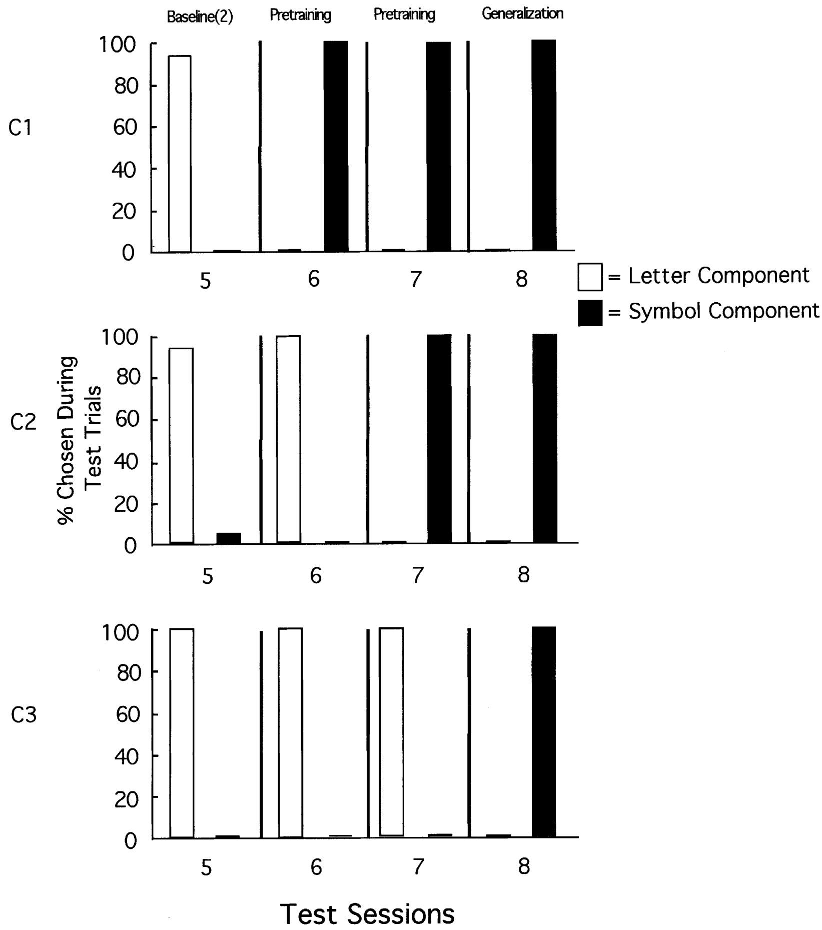

Fig. 10. Percentage letter component (white bars) and symbol component (black bars) of the S+ compound of the second conditional-discrimination task were chosen in the different test conditions for the young children of normal development. Test results for each child appear in the order in which the different testing conditions were administered.

3.4. Simultaneous attention

Baseline accuracy showed that single-stimulus pretraining was effective in producing simultaneous attention to both stimulus elements in the first conditional discrimination for two of the children (see Fig. 5). Simultaneous attention occurred for Child 2 and Child 3 immediately following initial pretraining where both children now achieved high levels of response accuracy for both stimulus components. The third child, in contrast, simultaneously attended to both stimulus elements in the initial baseline test session before any pretraining was provided. Simultaneous attention to both stimulus elements also continued to be revealed by two of the children (C1 and C2) during the second conditional-discrimination task

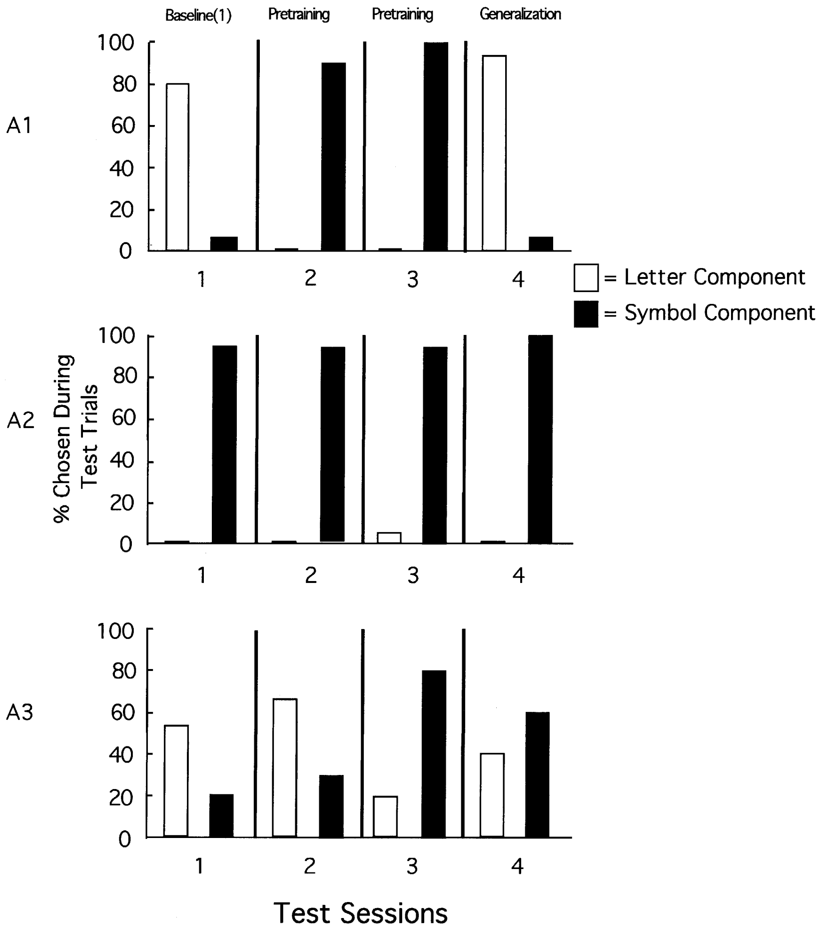

Fig. 11. Percentage letter component (white bars) and symbol component (black bars) of the S+ compound of the first conditional-discrimination task were chosen in the different test conditions for the adolescents with mental retardation. Test results for each adolescent appear in the order in which the different testing conditions were administered.

in all of the test sessions where high levels of accuracy (80% or higher) were achieved for both the letter and symbol components (see Fig. 6). Pretraining was not necessary, however, during the second conditional-discrimination task for simultaneous attention to occur for either child. Although one of these children (C2) had previously required pretraining in order to simultaneously attend to both stimulus components in the first conditional-discrimination task, pretraining was not needed in the second conditional-discrimination due to transfer effects from the original conditional discrimination. In addition, although following initial pretraining all three children simultaneously attended to both components, each of the children continued to demonstrate stimulus preferences as revealed by their response topographies (see Figs. 9 and 10).

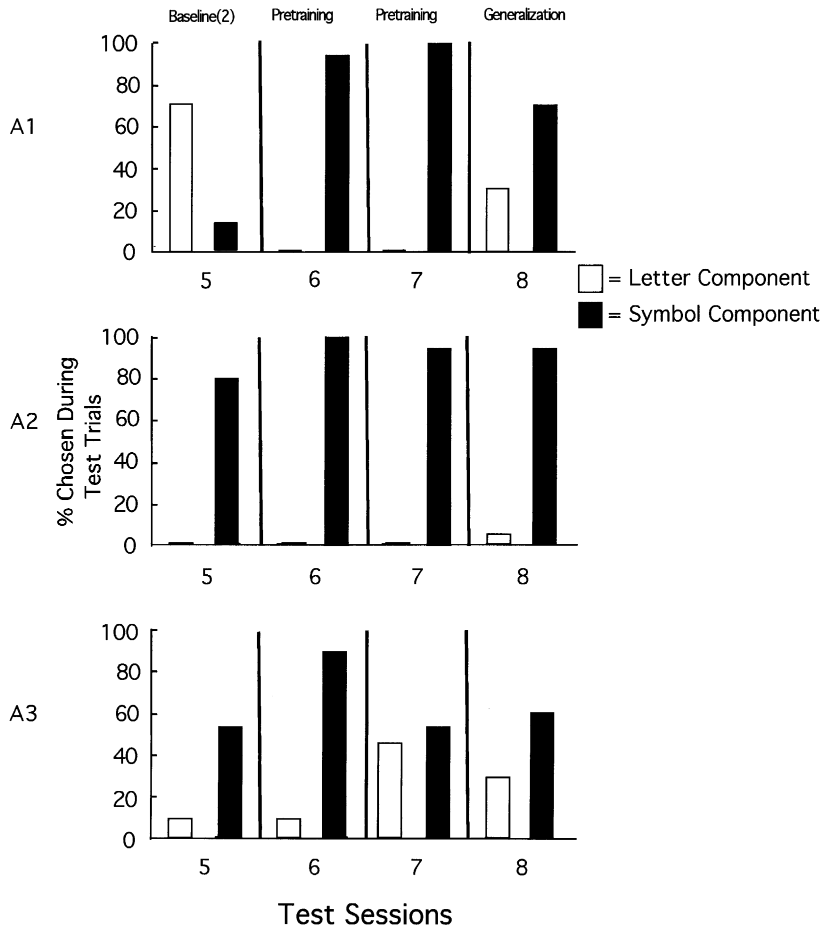

Fig. 12. Percentage letter component (white bars) and symbol component (black bars) of the S+ compound of the second conditional-discrimination task were chosen in the different test conditions for the adolescents with mental retardation. Test results for each adolescent appear in the order in which the different testing conditions were administered.

Single-stimulus pretraining and exposure to the conditional-discrimination tasks were also successful in teaching each of the adolescents with mental retardation to attend simultaneously to both stimulus elements. More pretraining and exposure to the conditional-discrimination tests were needed for the adolescents, however, than was required for the young children (see Figs. 7 and 8). Pretraining was effective when the first conditional-discrimination task was presented in establishing simultaneous attention to both the letter and symbol features of the training compound for only one of the adolescents (A1). In contrast, pretraining was effective in producing simultaneous attention to both stimulus elements for all three adolescents during the second conditional-discrimination task.

The three adolescents differed, however, in the amount of pretraining and exposure to the conditional-discrimination tasks required before simultaneous attention occurred to both the letter and symbol elements (see Figs. 7 and 8). Adolescent 1 (A1) required the least amount of pretraining and exposure as she demonstrated simultaneous attention by achieving high response accuracy (80% or higher) for both elements after pretraining was repeated for the first conditional-discrimination task. Following the initial pretraining for the second conditional-discrimination task, she continued to reveal simultaneous attention to both stimulus elements in all of the subsequent test sessions. Although Adolescent 3 (A3) did not demonstrate simultaneous attention to both elements in the test sessions of the first conditional-discrimination task, simultaneous attention was evident immediately after pretraining was initially provided for the second conditional-discrimination task. She continued to display simultaneous attention during the following two test sessions. Adolescent 2 (A2) also did not simultaneously attend to both stimulus elements during any of the test sessions of the first conditional-discrimination task, but she achieved high levels of accuracy for both stimulus elements after pretraining was repeated for the second conditional-discrimination task. Adolescent 2 persisted in displaying simultaneous attention during the following test session. Finally, after extended pretraining and exposure to the conditional-discrimination tests were provided, the adolescents maintained simultaneous attention to both elements despite the occurrence of stimulus preferences as revealed by their response topographies (see Figs. 11 and 12).

3.5. Generalization tests

Generalization effects also occurred in five tests where high accuracy scores persisted for both stimulus elements (see Figs. 5 and 6). Although the response topographies recorded with the touch screen demonstrated that the young children continued to display stimulus preferences (see Figs. 9 and 10), their stimulus preferences did not prevent the children from attending to both stimulus elements in the generalization tests, with one exception. Simultaneous attention occurred during the generalization tests even though single-stimulus pretraining was not provided and the positions of the letter and symbol elements were reversed in the stimulus compounds.

The adolescents with mental retardation also displayed generalization as they continued to achieve high accuracy scores for both stimulus elements during four generalization tests when single-stimulus pretraining was omitted and the positions of the letter and symbol components were reversed in the compounds (see Figs. 7 and 8). During the first generalization test, this was shown for only one adolescent (A1). Following exposure to the second conditional-discrimination task, however, all three adolescents exhibited generalization effects. Each adolescent following acquisition of the second conditional discrimination continued to attend simultaneously to both the letter and symbol components in the second generalization test session. Simultaneous attention also persisted for the adolescents with mental retardation in the generalization tests even though in some cases their response topographies revealed stimulus preferences were present (see Figs. 11 and 12).

4. Discussion

Single-component pretraining was effective in establishing simultaneous attention to two elements in a conditional-discrimination task for both young children of normal development and adolescents with severe mental retardation. After pretraining each stimulus component, all three children of normal development attended simultaneously to two elements in a conditional-discrimination task with few errors occurring. Two children, who did not simultaneously attend to both elements in baseline, exhibited high levels of stimulus control for both elements following pretraining. The adolescents with mental retardation also eventually attended to both stimulus elements simultaneously although it took more pretraining and exposure to the conditional-discrimination tests than was required for the young children. Pretraining was shown to be effective when the first conditional-discrimination task was presented for only one of the adolescents in establishing simultaneous attention to both the letter and symbol features of the training compound. In contrast, pretraining was effective in producing simultaneous attention to both stimulus elements for all three adolescents during the second conditional-discrimination task. The three adolescents with mental retardation also differed in the amount of pretraining and exposure to the conditional-discrimination tasks needed before simultaneous attention occurred to both the letter and symbol elements in contrast to the young children of normal development.

The finding of this study that extended single-component pretraining and repeated exposure to visual compounds determined how individuals with severe mental retardation attended to stimulus compounds supports past research (Huguenin, 2000). In a previous investigation (Huguenin, 2000), extended training was effective in determining how adolescents with severe mental retardation selectively attended to visual compounds when the prior reinforcement histories of individual stimulus elements were manipulated. The results of the current investigation demonstrate the effectiveness of extended pretraining and repeated exposure to visual compounds for controlling how students with mental retardation respond to conditional-discrimination tasks requiring simultaneous attention to multiple cues. Although the three adolescents initially displayed overselective attention when visual compounds were presented, extended single-component pretraining and additional exposure to the conditional-discrimination tasks eventually taught all three adolescents to attend simultaneously to multiple stimulus elements. Following extended training, the adolescents with mental retardation also maintained simultaneous attention to two stimulus elements despite the occurrence of stimulus preferences as shown by their response topographies. Extended training not only successfully taught all three adolescents with mental retardation to attend simultaneously to multiple stimulus elements, but their broadened visual attention persisted even when single-stimulus pretraining was omitted and the positions of the stimulus elements were reversed in the generalization tests. Although initially the visual attention of the adolescents was disrupted in most cases during the first conditional-discrimination test sessions, their broadened visual attention proved to be as durable as the visual attention of young children of normal development after extended training was provided.

The three adolescents' simultaneous attention to both the letter and symbol components of the training compounds following extended single-element training and repeated exposure to the conditional-discrimination tasks may have been due to several factors. Extended stimulus-component pretraining may have increased the durability of the individually trained stimulus-response relations. As a result, when the two S− conditions were subsequently combined during the conditional-discrimination task and simultaneous attention to two elements was now required, the pretrained stimulus-response relations were less susceptible to disruption. Students with developmental disabilities may not only differ from students of normal development in the rate at which they acquire stimulus control but they may also differ in the susceptibility of stimulus-response relations to disruption. Extended single-stimulus pretraining was demonstrated and repeated exposure to compound stimuli on reducing the disruption of previously taught visual discriminations to permit students with mental retardation to acquire conditional discriminations requiring simultaneous attention to multiple cues.

The results of this study also indicate that overselective attention is not an unmodifiable perceptual characteristic among individuals with severe developmental disabilities. Although many investigations have reported the presence of stimulus overselectivity among students with developmental disabilities, few studies have found treatment procedures effective in reducing this attentional deficit (Allen & Fuqua, 1985; Dube & McIlvane, 1999; Huguenin, 1985; Koegel & Schreibman, 1977; Schreibman, Charlop, & Koegel, 1982). Extended single-stimulus pretraining and repeated exposure to conditional-discrimination tasks requiring simultaneous attention to multiple cues may prove to be an effective manipulation for eliminating overselective attention and broadening the visual attentional skills of students with developmental disabilities. More research is needed to determine the generality of this finding with other students with special needs and with different educational tasks.

Recording response topographies with a touch screen provided a fine grain analysis of stimulus preferences for both young children of normal development and adolescents with mental retardation. When response accuracy was examined for the young children, only one child gave evidence of a stimulus preference occurring in some of the test sessions where only one of the stimulus elements was associated with high accuracy. When response topographies recorded with the touch screen were examined, however, stimulus preferences were evident for all three children throughout the conditional-discrimination tests where the children touched the same stimulus element in most of the test trials. Response topographies recorded with a touch screen were a more sensitive measure of stimulus preferences than response accuracy when conditional-discrimination tasks requiring attention to multiple cues were presented.

Response topographies recorded by the touch screen again proved to be a more sensitive measure of stimulus preferences for the adolescents than response accuracy as had occurred for the young children. Stimulus preferences were demonstrated in almost twice the number of test sessions when the adolescents' response topographies measured by the touch screen were analyzed as compared to the response accuracies of the individual stimulus elements. Recording response topographies revealed that following extended pretraining and repeated exposure to the conditional-discrimination tasks, the adolescents with mental retardation maintained simultaneous attention to two elements, despite the occurrence of stimulus preferences. Simultaneous attention had also persisted for the young children in most instances even though their response topographies had shown the occurrence of stimulus preferences as well. Before extended training was provided to the adolescents with mental retardation, however, stimulus preferences had resulted in overselective attention.

The finding that recording response topographies with a touch screen provides a sensitive and fine grain analysis of stimulus control supports the results of previous investigations (Huguenin, 1997, 2000). In the current investigation, response topographies recorded with a touch screen demonstrated that both young children of normal development and eventually adolescents with mental retardation learned to simultaneously attend to two elements in a conditional-discrimination task while stimulus preferences were still present. These stimulus preferences were not revealed by the response accuracy of the individual stimulus elements. Recording response topographies showed that even though two elements exhibited high levels of response accuracy, they did not necessarily exercise the same level of stimulus control.

Both the young children of normal development and the adolescents with mental retardation displayed stimulus preferences, but the stimulus preferences of the adolescents appeared to have a greater effect in most instances on hindering simultaneous attention to multiple cues from developing. More single-component pretraining and exposure to the conditional-discrimination tasks were needed before simultaneous attention to multiple cues occurred as compared to the young children. The fact that stimulus preferences can be sufficiently intense to prevent simultaneous attention to multiple cues from occurring in children of normal development was also shown in this investigation. Even though one of the children learned to simultaneously attend to two stimulus elements after pretraining was initially provided, she could not maintain simultaneous attention with repeated exposure to the conditional-discrimination tasks. Stimulus preferences were consistently demonstrated in this case.

The presence of stimulus preferences does not appear to differentiate students with or without overselective attention. The critical distinction seems to be the intensity of the stimulus preferences which distinguishes individuals with attentional deficits. Recording response topographies with a touch screen showed the presence of stimulus preferences. The accuracy scores of the individual stimulus elements during the conditional-discrimination tests revealed the intensity of the stimulus preference by determining how quickly simultaneous attention to two elements in conditional-discrimination tasks developed. The results of this study indicate stimulus preferences are a typical occurrence among children of normal development and are not only present among students with developmental disabilities. For many students with developmental disabilities and some children of normal development, however, stimulus preferences may be so intense that they block attention to other features of educational tasks and, thus, result in stimulus overselectivity. The findings of this study do not indicate, in spite of this, that students with severe developmental disabilities are incapable of attending to multiple cues or that stimulus overselectivity cannot be eliminated in this population. These results rather suggest that frequently students with developmental disabilities have intense stimulus preferences which postpone the development of simultaneous attention to multiple cues until extended single-component pretraining is provided.

These findings further indicate utilizing touch-screen technology is particularly advantageous when presenting complex educational material in order to quickly determine stimulus features which are controlling the student's behavior. As a result, when errors occur in educational tasks, recording response topographies with a touch screen can permit the teacher to determine efficiently the source of the errors. Recording response topographies can also be used to corroborate other testing procedures. Touch-screen technology would be especially beneficial in reading and spelling instruction in identifying sources of errors and where instruction needs to be modified to permit students to reach their educational objectives.

The present study also shows that students with severe mental retardation can learn to discriminate individual letters while attending simultaneously to corresponding symbols when extended pretraining and repeated exposure to visual compounds are administered. Previous research has shown that attending to individual letters within training compounds is more difficult than attending to individual letters presented alone (Saunders, Johnston, & Brady, 2000). Attending to individual letters within whole words is a basic skill which is a prerequisite for reading instruction. The results of this investigation suggest that individuals with severe developmental disabilities could learn this basic attentional skill if extended pretraining of individual letters and repeated exposure to written words are administered. Future research is needed to address this issue.

In summary, recording response topographies in addition to response accuracy of stimulus elements provides a more complete and thorough analysis of how students respond to visual compounds. Recording response topographies permits the visual attention of students to be more precisely specified and to determine individual differences across students which are not revealed by accuracy scores alone. By monitoring stimulus preferences with touch-screen technology, potential factors contributing to the emergence or re-emergence of overselective attention can be discovered.

Acknowledgments

The author wishes to thank the children's families and the educational staff of the Bi-County Collaborative for their cooperation and to acknowledge the technical assistance of Robert Huguenin.

References

Allen, K. D., & Fuqua, R. W. (1985). Eliminating selective stimulus control: A comparison of two procedures for teaching mentally retarded children to respond to compound stimuli. *Journal of Experimental Child Psychology*, *39*, 55–71.

Bailey, S. (1981). Stimulus overselectivity in learning disabled children. *Journal of Applied Behavior Analysis*, *14*, 239–248.

Bhatt, R. S., & Wright, A. A. (1992). Concept learning by monkeys with video picture images and a touch screen. *Journal of the Experimental Analysis of Behavior*, *57*, 219–225.

Bickel, W. K., Richmond, G., Bell, J., & Brown, K. (1986). A microanalysis of the controlling stimulus-response relations engendered during the assessment of stimulus overselectivity. *The Psychological Record*, *36*, 225–238.

Bickel, W. K., Stella, M. E., & Etzel, B. C. (1984). A reevaluation of stimulus overselectivity: Restricted stimulus control or stimulus control hierarchies. *Journal of Autism and Developmental Disorders*, *14*, 137–157.

Burke, J. C. (1991). Some developmental implications of a disturbance in responding to complex environmental stimuli. *American Journal on Mental Retardation*, *96*, 37–52.

Danforth, J. S., Chase, P. N., Dolan, M., & Joyce, J. H. (1990). The establishment of stimulus control by instructions and by differential reinforcement. *Journal of the Experimental Analysis of Behavior*, *54*, 97–112.

Dube, W. V., & McIlvane, W. J. (1999). Reduction of stimulus overselectivity with nonverbal differential observing responses. *Journal of Applied Behavior Analysis*, *32*, 25–33.

Dunlap, G., Koegel, R. L., & Burke, J. C. (1981). Educational implications of stimulus overselectivity in autistic children. *Exceptional Education Quarterly*, *2*, 37–49.

Fields, L. (1985). Reinforcement of probe responses and acquisition of stimulus control in fading procedures. *Journal of the Experimental Analysis of Behavior*, *43*, 235–241.

Huguenin, N. H. (1985). Attention to multiple cues by severely retarded adults: Effects of single-component pretraining. *Applied Research in Mental Retardation*, *6*, 319–335.

Huguenin, N. H. (1987). Assessment of attention to complex cues in young children: Manipulating prior reinforcement histories of stimulus components. *Journal of Experimental Child Psychology*, *44*, 283–303.

Huguenin, N. H. (1997). Employing computer technology to assess visual attention in young children and adolescents with severe mental retardation. *Journal of Experimental Child Psychology*, *65*, 141–170.

Huguenin, N. H. (2000). Reducing overselective attention to compound visual cues with extended training in adolescents with severe mental retardation. *Research in Developmental Disabilities*, *21*, 93–113.

Huguenin, N. H., & Touchette, P. E. (1980). Visual attention in retarded adults: Combining stimuli which control incompatible behavior. *Journal of the Experimental Analysis of Behavior*, *33*, 77–86.

Koegel, R. L., & Schreibman, L. (1977). Teaching autistic children to respond to simultaneous multiple cues. *Journal of Experimental Child Psychology*, *24*, 299–311.

Koegel, R. L., & Wilhelm, H. (1973). Selective responding to the components of multiple visual cues by autistic children. *Journal of Experimental Child Psychology*, *15*, 442–453.

Lovaas, O. I., & Schreibman, L. (1971). Stimulus overselectivity of autistic children in a two stimulus situation. *Behavior Research and Therapy*, *9*, 305–310.

Lovaas, O. I., Schreibman, L., Koegel, R. L., & Rehm, R. (1971). Selective responding by autistic children to multiple sensory input. *Journal of Abnormal Psychology*, *77*, 211–222.

Lynch, D. C., & Green, G. (1991). Development and crossmodal transfer of contextual control of emergent stimulus relations. *Journal of the Experimental Analysis of Behavior*, *56*, 139–154.

Markham, M. R., Butt, A. E., & Dougher, M. J. (1996). A computer touch-screen apparatus for training visual discriminations in rats. *Journal of the Experimental Analysis of Behavior*, *65*, 173–182.

Merrill, E. C., & Peacock, M. (1994). Allocation of attention and task difficulty. *American Journal on Mental Retardation*, *98*, 588–593.

Newman, F. L., & Benefield, R. L. (1968). Stimulus control, cue utilization, and attention: Effects of discrimination training. *Journal of Comparative and Physiological Psychology*, *66*, 101–104.

Rincover, A., & Ducharme, J. M. (1987). Variables influencing stimulus overselectivity and "tunnel vision" in developmentally delayed children. *American Journal of Mental Deficiency*, *91*, 422–430.

Saunders, K. J., Johnston, M. D., & Brady, N. C. (2000). Identity matching of consonant–vowel–consonant words by preschoolers. *Journal of Applied Behavior Analysis*, *33*, 309–316.

Schreibman, L., Charlop, M. H., & Koegel, R. L. (1982). Teaching autistic children to use extra-stimulus prompts. *Journal of Experimental Child Psychology*, *33*, 475–491.

Schreibman, L., Kohlenberg, B. S., & Britten, K. R. (1986). Differential responding to content and intonation components of a complex auditory stimulus by nonverbal and echolalic autistic children. *Analysis and Intervention in Developmental Disabilities*, *6*, 109–125.

Schreibman, L., & Lovaas, O. I. (1973). Overselective response to social stimuli by autistic children. *Journal of Abnormal Child Psychology*, *1*, 152–168.

Smeets, P. M., Hoogeveen, F. R., Striefel, S., & Lancioni, G. E. (1985). Stimulus overselectivity in TMR children: Establishing functional control of simultaneous multiple stimuli. *Analysis and Intervention in Developmental Disabilities*, *5*, 247–267.

Stromer, R., McIlvane, W. J., Dube, W. V., & Mackay, H. A. (1993). Assessing control by elements of complex stimuli in delayed matching to sample. *Journal of Experimental Analysis of Behavior*, *59*, 83–102.

Ullman, D. G. (1974). Breadth of attention and retention in mentally retarded and intellectually average children. *American Journal of Mental Deficiency*, *78*, 640–648.

Whiteley, J. H., Zaparniuk, J., & Asmundson, G. (1987). Mentally retarded adolescents' breadth of attention and short-term memory processes during matching-to-sample discriminations. *American Journal of Mental Deficiency*, *92*, 207–212.

Wilhelm, H., & Lovaas, O. I. (1976). Stimulus overselectivity: A common feature in autism and mental retardation. *American Journal of Mental Deficiency*, *81*, 26–31.

Wilkie, D. M., & Masson, M. E. (1976). Attention in the pigeon: A re-evaluation. *Journal of the Experimental Analysis of Behavior*, *26*, 207–212.