Behavior Analysis & Technology

Monograph 080415

Assessing Visual Attention to Letters and Words in Young Children

Nancy H. Huguenin, Ph.D.
Behavior Analysis & Technology, Inc.
Groton, MA, USA
www.ba-and-t.com

Abstract

Assessing visual attention in children can identify attentional deficits that interfere with academic performance. Computer technology was employed in this investigation to provide a detailed analysis of how young children visually attended to letters and words. During pretraining, the children were taught to respond to each letter of a consonant-vowel compound. The two pretrained letters subsequently appeared in four word-discriminations. During the word-discrimination task, the children were required to discriminate words containing both pretrained letters from words containing only one of the pretrained letters. The children were required, therefore, to attend to both pretrained letters in the word discriminations to maintain continuous reinforcement. Two different stimulus-control tests were administered. One test assessed stimulus control by determining response accuracy when the letter compounds and word discriminations were presented. The other stimulus-control test measured the response topographies of the pretrained letters and test words using a touch screen attached to a computer monitor screen. While the children responded identically to individual letters during pretraining, they displayed a variety of attentional patterns when the same letters predicted reinforcement in the word-discrimination task. Although accuracy scores revealed variability in how young children attended to word discriminations, recording response topographies was a more sensitive stimulus-control test in revealing individual differences. Utilizing multiple stimulus-control assessment techniques administered by a computer provided a fine-grained analysis and revealed differences in how children of similar age attended to words, which is critical information for developing effective reading instruction.

Key Words: Visual Attention, Word Discriminations, Young Children, Computer Assessment

(Full text follows)

The intent of this investigation was to utilize computer touch-screen technology for assessing how young children visually attended to letters and words. Assessing the visual attention of young children when letters and words are presented is important because it can identify attentional deficits, which are interfering with the child's academic performance. One perceptual problem, for example, that can interfere with a child's learning and development is overselective attention. Students with overselective attention respond to only restricted portions of complex stimulus displays. They demonstrate a type of "tunnel vision", as they attend to only a limited number of elements in a visual compound. Overselective attention is frequently reported in students with developmental disabilities (Bailey, 1981; Huguenin, 1997, 2004; 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), but it can also occur in young children with learning disabilities (Bailey, 1981) as well as young children of typical development (Huguenin, 2006). Chronic restricted attention affects many areas of a child's development (Burke, 1991; Dunlap, Koegel, & Burke, 1981), and it can especially interfere with reading acquisition if a child is attending to only a limited number of letters when training words are presented. By utilizing computer touch-screen technology to administer tests designed to assess how children attend to words, it can be determined whether children are attending to individual letters within whole words, which is critical for word identification.

In the current investigation, young children were taught to respond to each letter of a consonant-vowel stimulus compound. The two letters subsequently appeared in four CVC word-discriminations. During the word-discrimination task, the children were required to discriminate words containing both previously trained letters from words containing only one of the letters. The children were required, therefore, to attend to both letters in the word discriminations to maintain continuous reinforcement as attending to only one of the letters would have produced errors. An advantage of using this type of word-discrimination procedure, which requires simultaneous attention to multiple letters, is that it tests directly whether or not selective attention is evident when words are presented. Since responding to only one of the pretrained letters in the word discriminations would produce errors and prevent the child from achieving continuous reinforcement, selective attention is immediately revealed when the word-test is administered. If on the other hand, the child achieves high levels of accuracy throughout the word-discrimination test, simultaneous attention to both pretrained letters in the word discriminations would be shown. Other investigations have found administering conditional-discrimination tasks requiring simultaneous attention to multiple cues effective in assessing how young children of typical development (Huguenin, 2004, 2006) and students with severe mental retardation (Huguenin, 1985, 2004) attended to visual compounds composed of two elements. It was determined in this investigation if a procedure requiring simultaneous attention to multiple letters might prove effective in assessing how young children attended to words.

Two different stimulus-control testing procedures were automatically administered with computer technology to measure how the young children responded to the consonant-vowel letter compounds and CVC words. One test assessed stimulus control by determining response accuracy when the letter compounds and word discriminations were presented. The other stimulus-control test measured the response topographies of the letter compounds and test words using a touch screen attached to a computer monitor screen. Multiple stimulus-control tests were utilized to verify and confirm the children's test performance. Without more than one test condition, false assumptions can occur concerning which stimulus elements control responding in stimulus compounds. Misleading conclusions have been made, for example, about the control exerted by components of stimulus compounds when accuracy scores across probe trials were summarized. Separate controlling stimulus-response relations can be hidden when accuracy scores are averaged together (Bickel, Richmond, Bell, & Brown, 1986; Bickel, Stella, & Etzel, 1984; Stromer et al., 1993). Other test variables may contaminate test results. Huguenin and Touchette (1980) demonstrated how easily test performance can be altered by the reinforcement contingency in effect during the test trials. Numerous studies have also shown the need for multiple test conditions for accurately assessing stimulus control (Danforth, Chase, Dolan, & Joyce, 1990; Fields, 1985; Huguenin, 1997, 2004; Huguenin & Touchette, 1980; Merrill & Peacock, 1994; Newman & Benefield, 1968; Sloutsky & Napolitano, 2003; Smeets, Hoogeveen, Striefel, & Lancioni, 1985; Van Laarhoven, Johnson, Repp, Karsh, & Lenz, 2003; Wilkie & Masson, 1976). More than one testing procedure has been used infrequently, however, due to equipment limitations.

The visual attention of young children was assessed in this investigation using computer technology to administer different test conditions to provide a more reliable and complete assessment of how they attended to letters and words. It was wondered how consistently children would attend to individual letters when they appeared in letter compounds and whole words. By assessing the visual attention of children under multiple test conditions, differences across children in terms of their attentional patterns could be detected which might not be evident if only one stimulus-control test was utilized.

Computer touch-screen technology was employed in this study due to its precision in measuring visual attention. Many different response parameters can be simultaneously recorded whenever visual stimuli appear on the computer screen. Recording spatial location of responses, for example, can be accurately determined with a touch screen and can identify features of compound visual stimuli students are attending to. Although other studies have employed touch screens for training visual discriminations (e.g., Bhatt & Wright, 1992; Dube & McIlvane, 1999; Huguenin, 1987; Lynch & Green, 1991; Markham, Butt, & Dougher, 1996; Saunders, Johnston, & Brady, 2000; Stromer et al., 1993), only a few investigations have used touch screens to record spatial locations of responses for identifying stimulus elements attended to in visual compounds (Huguenin, 1997, 2004). In these investigations (Huguenin, 1997, 2004), stimulus preferences were discovered for both young children of typical development and adolescents with developmental disabilities when their response topographies were recorded with a touch screen, which were not evident when their accuracy scores were analyzed. Recording response topographies with a touch screen, in addition to determining response accuracy, would permit a more fine-grained analysis of how young children attend to individual letters when word discriminations are provided. As a result of a more detailed assessment by recording response topographies, individual differences in how children attend to words could be discovered which might not be revealed by accuracy scores alone. It is quite likely that even children of the same age may vary in how they attend to words as researchers have discovered considerable variability in the learning strategies of children both within and across children of similar ages (Siegler, 2005). Determining how children attend to words by employing computer technology to administer multiple assessment procedures has practical importance, as it could result in more individualized and effective programs for reading instruction. In addition, attentional disorders, which interfere with the child's academic performance, could be identified with this sensitive assessment tool.

The present investigation also examined the effect of single-letter pretraining and repeated exposure to word-discrimination tests requiring simultaneous attention to multiple letters on how young children attended to whole words. Past research has demonstrated providing compatible single-element training is effective in teaching conditional discriminations requiring simultaneous attention to multiple cues (Huguenin, 1985, 2004, 2006). The amount of single-stimulus pretraining and exposure to conditional-discrimination tasks that is needed before simultaneous attention occurs to multiple elements in a visual compound can vary, however, across students. This was demonstrated in two investigations where both young children of typical development (Huguenin, 2006) and adolescents with developmental disabilities (Huguenin, 2004) differed in the amount of single-component pretraining and repeated exposure to visual compounds required before they simultaneously attended to two elements in a conditional-discrimination task. As a result of this variability in the visual attention of students, determining the amount of single-letter pretraining and repeated exposure to word-discrimination tests that is necessary before a child simultaneously attends to multiple letters in word discriminations could be another parameter for assessing a child's attentional skills. It could assist in identifying whether a child has the prerequisite behaviors for reading instruction. Finally, computer touch-screen technology could be employed to monitor how children respond to word discriminations over extended time periods, which would permit the visual-attentional skills of children to be precisely specified and potential factors contributing to the elimination or the emergence of reading or spelling difficulties determined.

Method

Subjects

Four young children of typical development participated in the study. Their chronological ages and gender were 6.1 (female), 7.1 (male), 7.7 (male), and 7.8 years (female), respectively. The children

had no sensory, motor, or cognitive impairments, and all of the children were enlisted as a result of an ad placed in a local newspaper. The four children came from similar socioeconomic backgrounds and attended schools in the same school district.

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. The computer also kept a running account of trials, stimuli presented, the location on the display screen where the student touched during each trial, as well as response accuracy. A report was provided following each 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- by 14- by 9.6-cm receptacle at the base of the dispenser.

Experimental Design

A within-subject reversal design was utilized to determine word-discrimination test performance before and after single-letter pretraining was administered and to assess if original treatment effects generalized to transfer word-discriminations.

General Procedure

Each student sat in a chair facing a computer display screen, and the author sat beside the student. Sessions consisted of 80 or 100 trials in length, and a trial began when letters or words appeared on two illuminated areas on the computer screen. The trial ended when the student touched either illuminated area. A 3-second intertrial interval followed in which the computer screen was dark, and then the next trial began. Each time the child made the correct choice, he was reinforced with the delivery of a penny, a flashing computer screen, and verbal praise. If the child made an incorrect choice, however, reinforcement was not provided. The children traded their accumulated pennies for recreational items at the end of each session. 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. An individual session consisted of approximately 60 letter-compound pretraining trials and 20 or 40 word-discrimination test trials.

Word-Discrimination Test

Each child was presented a word-discrimination task composed of four CVC word-discriminations in which the S+ and S- words were presented simultaneously (see Fig. 1). The children had to select words containing both the letters C and A to obtain reinforcement. If they selected words containing only the letter C or only the letter A, no reinforcement was given. In the first word discrimination, for instance, the children were reinforced whenever they touched the S+ word, CAT, but did not receive reinforcement if they selected the S- word, CUT. After this word discrimination was presented for five trials, the words CAN and MAN appeared on the computer screen. CAN was now the S+ word and MAN was the S- word, and this word pair was presented for the next five trials. The third word pair provided for five trials consisted of CAB vs. COB in which touching CAB (S+) produced reinforcement while touching COB (S-) did not. The final word pair presented for five trials was CAP (S+) vs. SAP (S-).

Since the children were required to select words containing the letters C and A to obtain reinforcement, the children had to attend to both letters (C and A) in the word-discrimination task to maintain continuous reinforcement. Attending to only one of the letters would have produced errors. The word-discrimination task was initially presented for 20 trials in order to determine baseline performance.

The word-discrimination task continued to be presented for 20 trials after differing amounts of single-letter pretraining were provided to the children.

Word-Discrimination Test

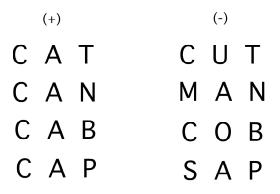| (+)	(-)
C A T	C U T
C A N	M A N
C A B	C O B
C A P	S A P

Figure 1. Diagram of the word-discrimination test, which was composed of four CVC word-discriminations. Plus (+) indicates words paired with reinforcement and minus (-) denotes words paired with nonreinforcement. Each word-discrimination was presented for five trials, and the S+ and S- words were presented simultaneously.

Single-Letter Training and Word-Discrimination Testing

Single-letter pretraining was provided for the letters C and A since these were the letters that predicted reinforcement in the word discriminations. During pretraining, the children were taught to attend to the letter C and the letter A when both letters were combined to form a compound (C-A). Selective attention to the letter C in the C-A compound was first obtained by making the letter A common to both the S+ and S- letter compounds, and only the letter C was consistently paired with reinforcement. The letter K was always paired with extinction (See Fig. 2). A prompt was provided during the first two trials when the author, who sat beside the children during the sessions, pointed to the letter C for a few seconds and indicated it was the correct choice.

After criterion accuracy (29/30 trials correct) was achieved for the first discrimination, the children were next taught to selectively attend to the letter A in the C-A compound by making the letter C common to both the S+ and S- letter compounds. Only the letter A in the second discrimination was consistently paired with reinforcement, while the letter E was consistently paired with extinction (See Fig. 2). The author again provided a prompt during the first two trials by pointing to the letter A and indicating it was the correct choice. Letter A pretraining continued until criterion accuracy (29/30 trials correct) was achieved.

Single-letter pretraining was repeated at the beginning of the next session until criterion accuracy was again achieved for each letter of the C-A compound. The two pretrained letters subsequently appeared in four word-discriminations when the word-discrimination test described previously was presented a second time for 20 trials. Single-letter pretraining and the word-discrimination test were presented in additional sessions until the word-discrimination test was provided six times to each of the children. Finally, a generalization test was administered as described below.
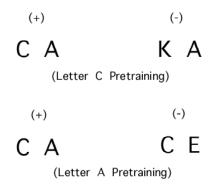
(+)   (-)

C A   K A

(Letter C Pretraining)

(+)   (-)

C A   C E

(Letter A Pretraining)

Figure 2. Diagram of two separate letter discriminations established prior to presentation of the word-discrimination test. Plus (+) indicates letter compounds paired with reinforcement and minus (-) denotes letter compounds paired with nonreinforcement. The S+ and S- compounds were presented simultaneously and were composed of two letter components.

Word-Discrimination Generalization Test

A word-discrimination generalization test was also presented for 20 trials to each of the children, which consisted of four novel word-discriminations (See Fig. 3). During the generalization test, the children were required to select words containing both the letters B and O to obtain reinforcement. If the children selected words containing only the letter B or only the letter O, however, they did not receive reinforcement. Single-letter pretraining was not administered prior to the generalization test.

Word-Discrimination
Generalization Test

(+)   (-)

B O G   B A G
B O X   F O X
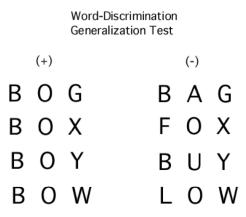B O Y   B U Y
B O W   L O W

Figure 3. Diagram of the word-discrimination generalization test, which was composed of four novel CVC word-discriminations. Plus (+) indicates words paired with reinforcement and minus (-) denotes words paired with nonreinforcement. Each word-discrimination was presented for five trials, and the S+ and S- words were presented simultaneously.

Data Collection

Two different stimulus-control tests were administered with computer technology. One test assessed stimulus control by determining response accuracy when the letter compounds and four word-discriminations were presented. Response accuracy for each letter component of the letter compound (C-A) was calculated from trials in which each letter (C or A) predicted reinforcement while the remaining letter appeared in both of the S+ and S- letter compounds. Response accuracy was also determined from trials when each of the same two letters (C or A) predicted reinforcement in the word-discrimination task while the remaining letter appeared in both of the S+ and S- words.

Because a touch screen was employed, it was also recorded where the children touched each time the letter compounds and word pairs appeared on the computer screen. This permitted a direct comparison of accuracy scores with letters touched in the letter compounds during pretraining and during the 20-trial word-discrimination tests.

Table 1 lists the sequence of stimuli and procedures provided to each of the four children.

Table 1

Sequence of Stimuli and Procedures
_____

Word-Discrimination Test
Letter Pretraining (C)
Letter Pretraining (A)
Letter Pretraining (C)
Letter Pretraining (A)
Word-Discrimination Test
Letter Pretraining (C)
Letter Pretraining (A)
Word-Discrimination Test
Letter Pretraining (C)
Letter Pretraining (A)
Word-Discrimination Test
Letter Pretraining (C)
Letter Pretraining (A)
Word-Discrimination Test
Letter Pretraining (C)
Letter Pretraining (A)
Word-Discrimination Test
Generalization Test

Results

Letter-Compound Pretraining: Accuracy Scores

When the separate accuracy scores of both letter components of the C-A compound were examined during pretraining, each of the young children consistently achieved 100% or near 100% accuracy. This occurred regardless of whether the letter C or the letter A predicted reinforcement in the letter-compound discriminations. Child 1, for example, achieved 100% accuracy in all six pretraining sessions for each letter (C and A) of the S+ compound (See Fig. 4). Child 2, Child 3, and Child 4 also achieved 100% accuracy in pretraining when each letter predicted reinforcement, with the exception of one or two sessions when they achieved 100% accuracy for one letter and near 100% accuracy for the remaining letter of the C-A compound (See Figs. 5-7).

Letter-Compound Pretraining: Response Topographies

In addition, the children revealed identical response topographies throughout pretraining. Each child selectively responded to the letter C and the letter A in the letter-compound discriminations. This was revealed as all four children selectively touched both the letter C and the letter A in 100% or near 100% of the pretraining trials when each letter predicted reinforcement in the C-A compound (See Figs. 8-11).
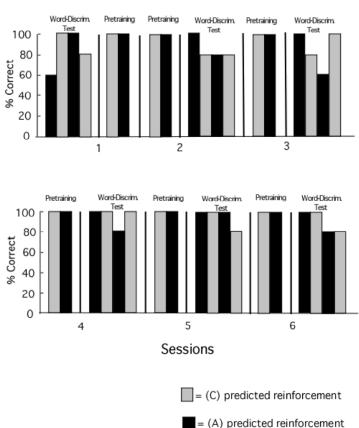
In summary, both stimulus-control tests confirmed that all of the young children selectively attended to each individual letter that predicted reinforcement in the letter compound. Both the accuracy scores and the response topographies of the young children demonstrated that they consistently responded

to both the letters C and A when each letter predicted reinforcement in the compound discriminations in all of the pretraining sessions.

Word-Discrimination Test: Accuracy Scores

While the children achieved response accuracy at or near 100% in pretraining for both the letters C and A, stimulus control was disrupted in some cases when the pretrained letters appeared in four word-discriminations. The degree of disruption of control by the individual letters (C and A) in the word discriminations differed, however, across the four children.

Child 3, for instance, showed some disruption in stimulus control by the individual pretrained letters (C and A) when they appeared in words. Although he achieved high accuracy scores for all four word-discriminations following pretraining, which did not occur in baseline, Child 3 did not maintain the pretraining accuracy in three of the word-discrimination test sessions. His accuracy decreased to 80%, when the letter C predicted reinforcement, in one of the word discriminations in these three test sessions compared to 100% or near 100% pretraining accuracy (See Fig. 6). As a result, Child 3 maintained pretraining accuracy for all four word-discriminations in only two of the word-discrimination test sessions.

Figure 4. For Child 1, percent accuracy of responses when the letter C (gray bars) and the letter A (black bars) predicted reinforcement in pretraining and in the word-discrimination test, which was composed of four word-discriminations. Percent-accuracy results for Child 1 appear in the order in which the different conditions were administered.
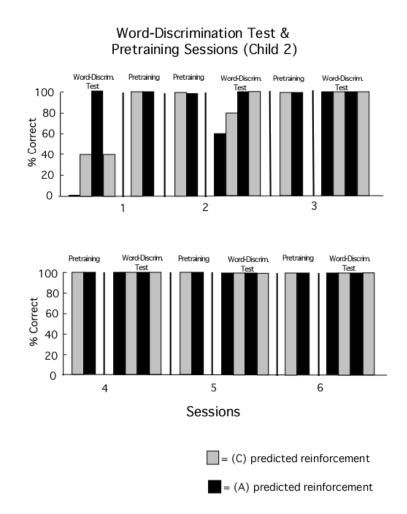
Word-Discrimination Test & Pretraining Sessions (Child 2)

= (C) predicted reinforcement
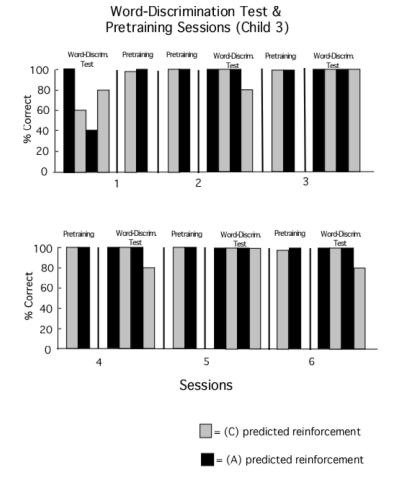
= (A) predicted reinforcement

Figure 5. For Child 2, percent accuracy of responses when the letter C (gray bars) and the letter A (black bars) predicted reinforcement in pretraining and in the word-discrimination test, which was composed of four word-discriminations. Percent-accuracy results for Child 2 appear in the order in which the different conditions were administered.

Prior to initial pretraining Child 1 failed to achieve high accuracy (80% or higher) for all four word-discriminations, but he too obtained high accuracy for each of the word discriminations following pretraining, with one exception. Child 1 demonstrated, however, some disruption in stimulus control of the pretrained letters whenever the word-discrimination task was presented. Although Child 1 consistently achieved 100% accuracy during pretraining, his accuracy decreased to 80% in some of the word discriminations, when the pretrained letters C and A predicted reinforcement, in five of the word-discrimination test sessions. In one test session following pretraining, his response accuracy decreased to 60% in a word discrimination when the letter A predicted reinforcement (See Fig. 4). Child 1 did not maintain, therefore, pretraining accuracy for all four word-discriminations in any of the word-discrimination test sessions.

Child 2, in opposition to Child 3 and Child 1, required extended pretraining before she achieved high levels of accuracy throughout the word-discrimination test. Although her response accuracy increased during the word-discrimination test following initial pretraining compared to baseline, she did not maintain high levels of accuracy for each of the four word discriminations until additional pretraining was provided (See Fig. 5). Child 2, however, exhibited disruption in stimulus control of the individually pretrained

letters (C and A) when they appeared in word discriminations in only one test session in contrast to the other three children (See Fig. 5). Her response accuracy during the second word-discrimination test session decreased to 80% for one of the word discriminations when the letter C predicted reinforcement and decreased to 60% for another word discrimination when the letter A predicted reinforcement compared to 100% or near 100% pretraining accuracy.   Child 2 achieved 100% accuracy for all four word-discriminations during four subsequent word-discrimination test sessions, however, which was identical to her response accuracy in the preceding pretraining trials (See Fig. 5).

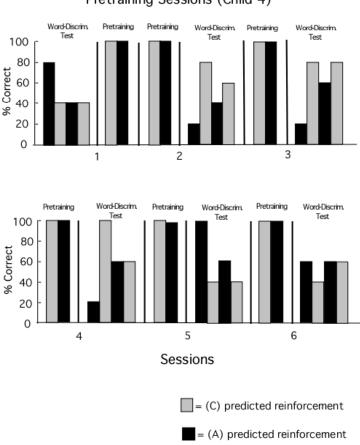### Word-Discrimination Test & Pretraining Sessions (Child 3)

Figure 6. For Child 3, percent accuracy of responses when the letter C (gray bars) and the letter A (black bars) predicted reinforcement in pretraining and in the word-discrimination test, which was composed of four word-discriminations. Percent-accuracy results for Child 3 appear in the order in which the different conditions were administered.

Finally, Child 4 did not maintain high levels of accuracy throughout any of the word-discrimination test sessions, in contrast to the other three children. Although Child 4 achieved 100% or near 100% accuracy for each letter (C and A) during pretraining, she did not maintain high accuracy (80% or higher) for all four word-discriminations during any of the test sessions, when each pretrained letter predicted reinforcement (See Fig. 7). Instead, the stimulus control of the two pretrained letters (C and A) was disrupted whenever the pretrained letters appeared in the word discriminations as revealed by a decrease in response accuracy that occurred in all of the test sessions compared to 100% or near 100% pretraining accuracy. When the letter C predicted reinforcement in the word discriminations, her response accuracy decreased, with one exception, to between 80% and 40% accuracy, and in most instances her response accuracy was below 80%. When the letter A predicted reinforcement in the word discriminations,

her response accuracy decreased, with one exception, to between 60% and 20% accuracy compared to 100% or near 100% pretraining accuracy. Although Child 4 attended consistently to both the letters C and A when each letter predicted reinforcement in pretraining, she did not attend consistently to either letter when they predicted reinforcement in the word discriminations (See Fig. 7).

Figure 7.   For Child 4, percent accuracy of responses when the letter C (gray bars) and the letter A (black bars) predicted reinforcement in pretraining and in the word-discrimination test, which was composed of four word-discriminations. Percent-accuracy results for Child 4 appear in the order in which the different conditions were administered.

Word-Discrimination Test: Response Topographies

Although three children achieved high accuracy scores for all four word-discriminations following pretraining, their response topographies revealed individual differences in how they responded to the words. By recording which letters the children touched during the word-discrimination tests, all of the children were discovered to attend to the word discriminations differently even though the accuracy scores of three of the children were similar.

The response topographies of Child 1, compared to the other three children, revealed less disruption in stimulus control when the pretrained letters appeared in the word discriminations, with one exception (See Fig. 8). When the letter C predicted reinforcement, the percentage that Child 1 selectively touched the letter C decreased to 80% in some of the word discriminations in four test sessions compared to 100% or near 100% pretraining levels. The percentage that Child 1 selectively touched the letter A, when

the letter A predicted reinforcement, decreased to 80% in one of the word discriminations in three test sessions and decreased to 60% in another test session from 100% pretraining levels. Although the response topographies of Child 1 for some of the word discriminations were disrupted in every test session, in almost every case the disruption of stimulus control was small.
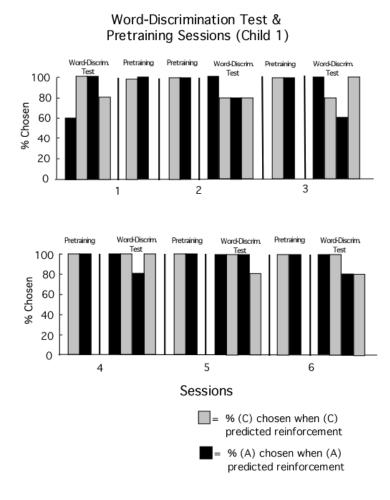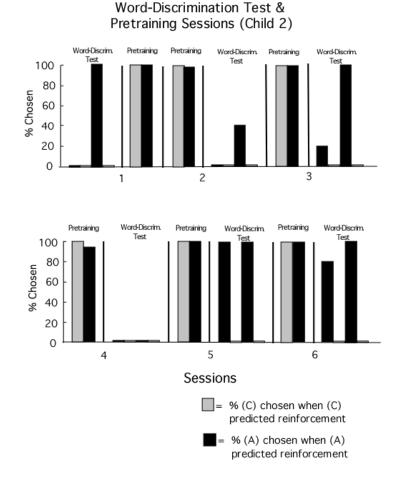

Figure 8. For Child 1, the percent the letter C (gray bars) was chosen when the letter C predicted reinforcement in pretraining and in the word-discrimination test, which was composed of four word-discriminations, and the percent the letter A (black bars) was chosen when the letter A predicted reinforcement in pretraining and in the word-discrimination test. Percent-chosen results for Child 1 appear in the order in which the different conditions were administered.

In addition, Child 1 did not exhibit letter preferences in any of the test sessions when letters selected in the word-discrimination tests were examined, regardless of whether or not they predicted reinforcement. A letter preference was evident whenever the child selectively touched the same letter in 80% or more of the test trials. Child 1 chose both pretrained letters in the word-discrimination task at approximately equal levels throughout all six tests (See Fig. 12). `

Child 2 revealed a different pattern of responding when her response topographies were examined during the word-discrimination tests. Although Child 2 selectively touched each individual letter (C and A) when it predicted reinforcement at 100% or near 100% levels in pretraining, she did not consistently touch the same letters when they predicted reinforcement in the word-discrimination tests (See Fig. 9). Child 2 always touched the letter C when it predicted reinforcement in pretraining, but she never selected the letter C when it predicted reinforcement in any of the word-discrimination test sessions.   The response topography of the pretrained letter A was also disrupted when the word-discrimination test was provided.
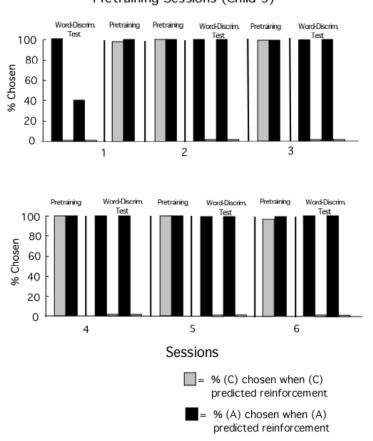
Although Child 2 consistently selected the letter A when it predicted reinforcement in pretraining, she did not consistently select the letter A, when it predicted reinforcement in the word discriminations, in three of the test sessions. In the final two test sessions, however, Child 2 touched the letter A, when it predicted reinforcement in the word discriminations, at levels of 80% or higher.   In summary, the response topography of Child 2 for one of the pretrained letters never occurred whenever the word-discrimination test was presented, and the response topography of the remaining pretrained letter was only evident in the final two word-discrimination test sessions.

Figure 9. For Child 2, the percent the letter C (gray bars) was chosen when the letter C predicted reinforcement in pretraining and in the word-discrimination test, which was composed of four word-discriminations, and the percent the letter A (black bars) was chosen when the letter A predicted reinforcement in pretraining and in the word-discrimination test. Percent-chosen results for Child 2 appear in the order in which the different conditions were administered.

        In contrast to Child 1, Child 2 exhibited letter preferences in four of the six test sessions when letters selected in the word-discrimination tests were examined, regardless of whether or not they predicted reinforcement. Child 2 exhibited letter preferences in four of the six test sessions. Child 2 failed to touch either pretrained letter, with a few exceptions, in the word discriminations in two test sessions. She demonstrated, instead, a preference for the novel third letter in the word discriminations in the second and fourth test sessions when she selected the novel third letter at levels of 85% and 100%, respectively (See Fig. 12). In the final two word-discrimination test sessions, however, Child 2 demonstrated a preference for the letter A as she selectively touched the letter A in the word discriminations at levels of 100% and 95%, respectively. Although Child 2 achieved high accuracy scores for all four word-discriminations,

recording her response topographies revealed letter preferences with repeated testing that her accuracy scores did not indicate.

Figure 10. For Child 3, the percent the letter C (gray bars) was chosen when the letter C predicted reinforcement in pretraining and in the word-discrimination test, which was composed of four word-discriminations, and the percent the letter A (black bars) was chosen when the letter A predicted reinforcement in pretraining and in the word-discrimination test. Percent-chosen results for Child 3 appear in the order in which the different conditions were administered.

Child 3 also consistently selected both the letters C and A when each letter predicted reinforcement during pretraining. The response topography of one of the pretrained letters was disrupted, however, whenever the pretrained letters appeared in the word-discrimination test. Although Child 3 continued to selectively touch the letter A when it predicted reinforcement in the word-discrimination tests following pretraining, he never selected the letter C (See Fig. 10). Child 3 selected the letter C at or near 100% levels during pretraining when it predicted reinforcement, but he did not touch the letter C when it predicted reinforcement in any of the word-discrimination test sessions. Although Child 3 maintained the

response topography of one of the pretrained letters in all of the word-discrimination test sessions, the response topography of the other pretrained letter never occurred in any of the test sessions.
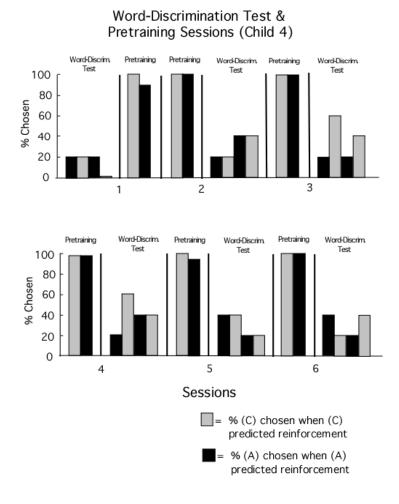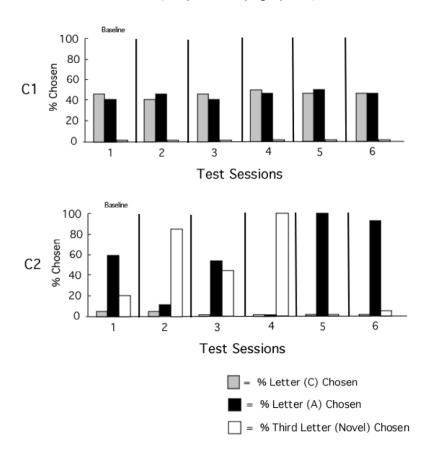

Figure 11. For Child 4, the percent the letter C (gray bars) was chosen when the letter C predicted reinforcement in pretraining and in the word-discrimination test, which was composed of four word-discriminations, and the percent the letter A (black bars) was chosen when the letter A predicted reinforcement in pretraining and in the word-discrimination test. Percent-chosen results for Child 4 appear in the order in which the different conditions were administered.

Child 3 exhibited a letter preference in all of the word-discrimination test sessions when letters selected were determined regardless of whether or not they predicted reinforcement. Child 3 failed to selectively touch the letter C in the word discriminations because he always selected the letter A in the test sessions regardless of whether or not it predicted reinforcement (See Fig. 13). Although Child 3 maintained high accuracy scores throughout the word-discrimination test sessions following pretraining, his response topographies revealed a preference for the letter A. His letter preference, shown by his response topographies, indicated both pretrained letters did not exercise the same level of stimulus control in the word discriminations even though both letters were associated with high response accuracy in all of the test sessions following pretraining.
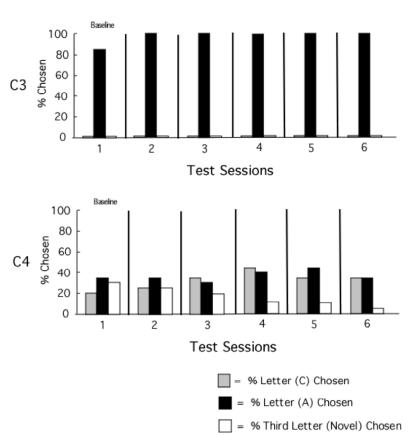
Child 4, in opposition to the other three children, did not exhibit the response topographies of either pretrained letter when both letters appeared in the word discriminations. Child 4 selectively touched both the letter C and the letter A at or near 100% levels when each letter predicted reinforcement in pretraining. She failed, however, to reliably select either pretrained letter, when they predicted reinforcement, in any of the word-discrimination test sessions (See Fig. 11). When the letter C predicted reinforcement in the word discriminations, for instance, Child 4 selected the letter C in the word discriminations following pretraining at levels ranging from 20% to 60%. She selectively touched the letter A in the word discriminations following pretraining, when it predicted reinforcement, at levels ranging from 20% to 40%. These low levels of selecting the pretrained letters in the word discriminations demonstrated the response topographies of both pretrained letters were disrupted whenever the word-discrimination test was presented to Child 4. Although her response topographies revealed Child 4 responded reliably to both the letter C and the letter A in pretraining, she did not consistently respond to either letter in the word-discrimination tests which was also demonstrated by her accuracy scores.

When letters selected in the word-discrimination tests were determined, regardless of whether or not they predicted reinforcement, Child 4 did not exhibit letter preferences in any of the test sessions (See Fig. 13). Although Child 4 touched both pretrained letters and novel letters in all of the test sessions, she did not selectively touch any of the letters in the word discriminations at levels of 80% or higher, which would have indicated a letter preference. She chose both pretrained letters and novel letters, instead, in the word-discrimination tests at levels of 45% or lower.

Figure 12. For Child 1 and Child 2, the percent the letter C (gray bars), the letter A (black bars), and the novel third letter (white bars) were chosen in the word-discrimination test, which was composed of four word-discriminations. Percent-chosen results for Child 1 and Child 2 appear in the order in which the word-discrimination test sessions were administered.

Figure 13. For Child 3 and Child 4, the percent the letter C (gray bars), the letter A (black bars), and the novel third letter (white bars) were chosen in the word-discrimination test, which was composed of four word-discriminations. Percent-chosen results for Child 3 and Child 4 appear in the order in which the word-discrimination test sessions were administered.

Word-Discrimination Generalization Test

During the word-discrimination generalization test, only one of the four children achieved high levels of response accuracy for all four novel word-discriminations. Child 2 displayed generalization as she achieved accuracy scores of 100% for three of the word discriminations and 80% accuracy for the remaining word discrimination in the generalization test (See Fig 14, upper graph). Child 2 maintained high levels of accuracy (80% or higher) for all four word-discriminations even though single-letter pretraining was not provided prior to the word-discrimination test. Although the accuracy scores of Child 2 indicated both letters (B and O), which predicted reinforcement in the generalization test, exercised comparable levels of stimulus control, her response topographies revealed a preference for the letter O which was not shown by her accuracy scores (See Fig. 14, lower graph).
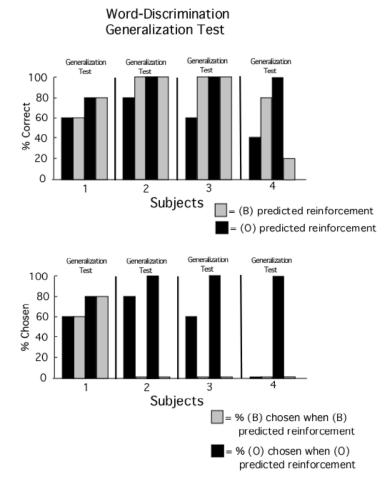
Word-Discrimination Generalization Test

Figure 14. In the top graph, percent accuracy of responses for all four children when the letter B (gray bars) and the letter O (black bars) predicted reinforcement in the word-discrimination generalization test, which was composed of four novel word-discriminations. In the bottom graph, for all four children, the percent the letter B (gray bars) was chosen when the letter B predicted reinforcement in the word-discrimination generalization test and the percent the letter O (black bars) was chosen when the letter O predicted reinforcement in the word-discrimination generalization test.

Discussion

The young children responded identically to individual letters in pretraining, but they did not respond identically to the same letters when they predicted reinforcement in word discriminations. Their accuracy scores revealed the stimulus control of the individual letters, established in pretraining, was disrupted in some cases when the pretrained letters appeared in a word-discrimination task. The degree of disruption in stimulus control varied, however, across the children. One child showed only a minor

disruption in stimulus control whenever the pretrained letters appeared in the word discriminations when his accuracy scores were examined. Only a small decrease in response accuracy occurred during the word-discrimination task compared to his pretraining levels, and he maintained high accuracy levels (80% or higher) throughout all of the word-discrimination test sessions following pretraining. Two children also achieved high accuracy scores that showed minimal disruption in the stimulus control of the pretrained letters when they predicted reinforcement in the word-discrimination task. In one word-discrimination test session, however, both children exhibited accuracy scores at chance levels, demonstrating a loss of stimulus control when a pretrained letter predicted reinforcement in one of the word discriminations. The remaining child did not maintain high accuracy levels whenever either pretrained letter predicted reinforcement in the word-discrimination task. She never achieved high accuracy scores for all four word-discriminations in any of the word-discrimination test sessions following pretraining in contrast to the other three children. Her accuracy scores revealed a loss of stimulus control when the pretrained letters appeared in the word-discrimination task.

The accuracy scores of the young children demonstrated some variability in how they attended to word discriminations. Recording their response topographies, however, was a more sensitive stimulus-control test in demonstrating individual differences. Although the four children reliably touched each letter when it predicted reinforcement in the letter compounds during pretraining, their response topographies revealed a variety of attentional patterns when the same letters predicted reinforcement in the word-discrimination task. By recording the letters the four children were touching in the word-discrimination test, they were discovered to attend to the word discriminations differently even though three of the children eventually achieved high accuracy for all four word-discriminations. The response topographies of one child, for example, demonstrated high levels of stimulus control, with one exception, whenever the two pretrained letters appeared in the word discriminations. His attention to both pretrained letters in the word discriminations was revealed by both his response accuracy and the response topographies of the individual letters in the word-discrimination test sessions. While two other children also learned to maintain high levels of response accuracy when each pretrained letter predicted reinforcement in the word discriminations, their response topographies demonstrated neither child responded reliably to both pretrained letters in the word discriminations. Although both children responded consistently to one of the pretrained letters in some or all of the word-discrimination test sessions following pretraining, they never responded to the remaining pretrained letter in any of the word-discrimination test sessions. Their accuracy scores indicated they simultaneously attended to both pretrained letters in the word discriminations, but their response topographies, in contrast, revealed letter preferences indicating unequal levels of stimulus control. Finally, the fourth child also reliably touched both pretrained letters, when each letter predicted reinforcement, in all of the pretraining sessions. She never consistently touched, however, either pretrained letter in any of the word-discrimination test sessions when each letter predicted reinforcement. Both her accuracy scores and her response topographies indicated neither pretrained letter exercised stimulus control when the word-discrimination task was presented.

In summary, although all four children responded consistently to individual letters in pretraining as revealed by both their response accuracy and their response topographies, the stimulus control of the individual letters was disrupted when they appeared in a word-discrimination task. Only one child showed only a minor disruption in stimulus control as demonstrated by both his response accuracy and the response topographies of the pretrained letters in the word discriminations. While two children eventually maintained high response accuracy when the pretrained letters predicted reinforcement in the word-discrimination task, the response topographies of the pretrained letters were disrupted as shown by the occurrence of letter preferences when the word discriminations were presented. Both the response accuracy and the response topographies of the pretrained letters were disrupted when the word-discrimination task was presented to a fourth child demonstrating a loss of stimulus control as revealed by both response measures. Even though all of the children responded in the same manner to individual letters in pretraining, they demonstrated varied attentional patterns when the same letters predicted reinforcement in word discriminations.

Utilizing multiple stimulus-control assessment techniques administered by a computer provided a detailed analysis and demonstrated differences in how young children attended to words that accuracy scores alone wouldn't have revealed. By recording the response topographies of the children with a touch

screen, individual differences were shown in their attention to words, which were not evident from the accuracy scores of the word-discrimination test sessions. Recording response topographies revealed letter preferences for some of the children that demonstrated pretrained letters did not exercise comparable levels of stimulus control in the word discriminations despite the occurrence of high accuracy levels throughout the word-discrimination test sessions. These results support past research which also discovered recording response topographies in addition to response accuracy provided a more complete and thorough analysis of the attention of young children of typical development and adolescents with developmental disabilities when visual compounds were presented (e.g., Huguenin, 1997, 2004). The present study further demonstrates the utility of touch-screen technology in assessing stimulus control and revealing stimulus preferences and shows its practical application in providing a fine-grained and reliable analysis of how young children attend to letters and words.

Previous studies have shown the difficulty of teaching young children to attend to individual letters within whole words (e.g., Saunders, Johnston, & Brady, 2000), which is necessary for word identification. Single-letter pretraining and repeated exposure to word discriminations were effective in this investigation in teaching young children to attend to multiple letters in a word-discrimination task, which required them to simultaneously attend to two letters to maintain continuous reinforcement. None of the children attended to both letters throughout the word-discrimination task before single-letter pretraining was provided. Following single-letter pretraining, however, two children achieved high accuracy scores for all four word-discriminations when the word-discrimination task was repeated, indicating they were now attending to both pretrained letters that predicted reinforcement in the word discriminations. After pretraining was repeated, a third child also achieved high accuracy for all four word-discriminations. In addition, the three children persisted, with one exception, in maintaining high accuracy levels for both pretrained letters when they predicted reinforcement in the subsequent word-discrimination test sessions while also maintaining high accuracy scores for both letters in pretraining. Their test performance revealed that the majority of the children learned to attend simultaneously to two letters in a series of word discriminations when single-letter pretraining was provided. These findings support the results of other investigations that demonstrated the effectiveness of single-stimulus pretraining in controlling which features of visual compounds young children of typical development (Huguenin, 1987, 1997) and students with developmental disabilities responded to (Huguenin, 2000, Huguenin & Touchette, 1980). Previous studies have also shown the utility of single-stimulus pretraining and extended training in teaching young children of typical development (Huguenin, 2004, 2006) and students with developmental disabilities (Huguenin, 1985, 2004) to attend simultaneously to two stimulus elements in conditional-discrimination tasks. The current investigation extends the practical implications of this teaching technique by employing single-letter pretraining and extended training to teach children to attend simultaneously to multiple letters in a word-discrimination task.

Employing computer technology to administer procedures similar to those described in this study to assess how children attend to words could improve reading instruction by providing more individualized programs. Ensuring children are attending to individual letters in training words would facilitate word identification and spelling. Attentional disorders, which are interfering with the child's reading instruction, could also be specified by utilizing touch-screen technology to administer the multiple testing procedures of this study. Children who can attend to individual letters when presented alone but repeatedly show difficulty in attending to the same letters when presented in words, as was the case for one of the children in this investigation, could be identified. Overselective attention can occur in young children (e.g., Huguenin, 2006), and investigators have found overselective attention to be a contributing factor in why some children have difficulty in attending to the individual letters of training words (Birnie-Selwyn & Guerin, 1997). Such children could be monitored over time using touch-screen technology to determine the success of instructional programs designed to improve their attention to individual letters in words or whether clinical treatment and educational programs are needed for a chronic attentional disorder. Early signs of attentional problems should be discovered as soon as possible as inattentive behavior has been shown to disrupt the acquisition of early reading skills in young children (Dally, 2006).

Researchers have found that children who can identify letters when they are presented individually does not guarantee the same children will attend to the individual letters of words when words are presented (Saunders et al., 2000). The findings of the current investigation indicate single-letter pretraining

of critical letters alternating with repeated exposure to word discriminations could be effective in teaching this attentional skill, which is essential to reading acquisition. Investigators have discovered, for instance, teaching children a matching-to-sample task, which emphasized individual letters in whole words, improved their subsequent spelling performance (Birnie-Selwyn & Guerin, 1997). Another study demonstrated that teaching an adolescent diagnosed with autism differential observing responses involving letters improved her matching of whole words (Walpole, Roscoe, & Dube, 2007). In addition, using computer touch-screen technology to administer multiple testing procedures, as shown in this study, can provide a detailed analysis of how young children attend to the individual letters of whole words. This would assist in determining if a child has the necessary attentional skills before reading instruction begins or whether attentional-skills instruction is first needed. Finally, if the error patterns of children were analyzed using touch-screen technology, which recorded not only response accuracy but also their response topographies, this could assist teachers in understanding why particular children have difficulties in identifying words. Teachers could also predict where errors are likely to occur.

In summary, although accuracy scores revealed variability in how young children attended to word discriminations, recording response topographies with a touch screen was a more sensitive stimulus-control test in revealing individual differences. Utilizing multiple stimulus-control assessment techniques administered by a computer provided a fine-grain analysis and demonstrated differences in how children attended to words that wouldn't have been revealed by accuracy scores alone. Determining how children attend to words utilizing computer technology to administer multiple testing procedures could also result in reading instruction more individualized to the attentional skills of a particular student and, thus, improve reading acquisition.

Footnotes

References

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, 1986, 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.

Birnie-Selwyn, B., & Guerin, B. (1997). Teaching children to spell: Decreasing consonant cluster errors by eliminating selective stimulus control. Journal of Applied Behavior Analysis, 30, 69-91.

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

Dally, K. (2006). The influence of phonological processing and inattentive behavior on reading acquisition. Journal of Educational Psychology, 98, 420-436.

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 mentally 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. (2004). Assessing visual attention in young children and adolescents with severe mental retardation utilizing conditional-discrimination tasks and multiple testing procedures. Research in Developmental Disabilities, 25, 155-181.

Huguenin, N.H. (2006). Computer assessment of overselective visual attention in six-year and nine-year old boys. Behavior Analysis and Technology Monograph (060701), 1-22. (www.ba-and-t.com).

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., & 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 prereaders. Journal of Applied Behavior Analysis, 33, 309-312.

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

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.

Siegler, R.S. (2005). Children's learning. American Psychologist, 60, 769-778.

Sloutsky, V. M., & Napolitano, A.C. (2003). Is a picture worth a thousand words? Preference for auditory modality in young children. Child Development, 74, 822-833.

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.

Van Laarhoven, T., Johnson, J.W., Repp, A.C., Karsh, K.G., & Lenz, M. (2003). Discrimination training: A comparison of two procedures for presenting multiple examples within a fading and non-fading paradigm. Research in Developmental Disabilities, 24, 1-18.

Walpole, C.W., Roscoe, E.M., & Dube, W.V. (2007). Use of a differential observing response to expand restricted stimulus control. Journal of Applied Behavior Analysis, 40, 707-712.

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.