Behavior Analysis & Technology

Monograph 170410

Employing Multiple Tests to Assess Visual Attention in Young Children and Individuals with Developmental Disabilities: A Review of Research Investigations at Behavior Analysis & Technology, Inc.

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Abstract

Research investigations conducted at Behavior Analysis & Technology, Inc. have expanded our knowledge and understanding of visual attention in young children of typical development and students with developmental disabilities. In early investigations, the effect of prior reinforcement histories on how students with developmental disabilities and young children of typical development attended to stimulus compounds was investigated. Manipulating prior reinforcement histories was effective in determining which stimulus elements they attended to and which stimulus elements they ignored. Multiple tests administered with computer technology, which included not only recording response accuracy but also recording with a touch screen which stimulus features were touched in the stimulus compound, validated the reliability of this manipulation. We also discovered that a critical distinction between students with developmental disabilities and students of typical development may be the efficiency with which they shift attention among elements of stimulus compounds depending upon prior reinforcement histories. The effect of the amount of single-stimulus pretraining on attention to stimulus compounds was also investigated. In one of our studies prior reinforcement contingencies failed to control how students with developmental disabilities initially responded to stimulus compounds. After additional training, the students with developmental disabilities now selectively attended to stimulus elements whose prior reinforcement history was unchanged in the compound.

In addition, we found that the amount of single-stimulus pretraining affected the response accuracy of two intermixed conditional discriminations requiring attention to multiple cues for four adults with developmental disabilities. The adults attended to both elements of two intermixed S+ compounds if all of the individual components were pretrained, but their attention was reduced if only partial pretraining was given. Conditional-discrimination tasks requiring simultaneous attention to multiple cues were again employed in a later investigation to assess the presence of overselective attention in young children of typical development and adolescents with severe intellectual disabilities. Single-stimulus pretraining resulted in simultaneous attention to two stimulus elements in a conditional-discrimination task for both young children of typical development and adolescents with severe intellectual disabilities, but the adolescents with intellectual disabilities required more pretraining and exposure to the conditional-discrimination tasks. Although all three adolescents initially displayed overselective attention, extended single-stimulus pretraining and repeated exposure to the conditional-discrimination tasks eliminated their overselective attention.

Stimulus compounds composed of letters and symbols and all letters were administered in another investigation to see if overselective attention occurred in young children of typical development when more complex stimuli were presented. Overselective attention occurred in young boys, but following extended training, they eventually attended simultaneously to two stimulus elements. Restricted attention in young boys of typical development appears to be temporary, however, since overselective attention was not observed in older boys of typical development. In contrast, restricted attention in children with developmental disabilities is often chronic and doesn't diminish as the child advances in age. Computer technology was also employed in a later study 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. 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. The majority of the children did learn to attend simultaneously to two letters in word discriminations when single-letter pretraining was provided.

In a more recent investigation, we determined if overselective attention occurred in young children when word discriminations were presented. Multiple stimulus-control tests were administered. One test assessed how many letters of word discriminations were attended to by recording response choice when the letters comprising the S+ and S- words were presented separately. In a second test, word choice was determined when the S+ word appeared with three comparison words that differed from the S+ word by only one letter. Another stimulus-control test measured the response topographies of the children using a touch screen. Both nondifferential and differential-reinforcement contingencies were also employed during the stimulus-control tests. Although three of the four children demonstrated overselective attention when word discriminations were presented, they differed in the degree of their overselective attention. In addition, the effect of repeated testing on whether the children learned to attend to all three letters of training words depended on the type of reinforcement contingency utilized during the test trials. In a subsequent study, the amount of single-letter pretraining required before four young children simultaneously attended to each letter of a consonant-vowel-consonant (CVC) word discrimination was also employed to assess the intensity of their overselective attention to words. Multiple stimulus-control tests were employed. In one test, word choice was determined when the S+ word appeared with three comparison words that differed by only one letter. Because a touch screen was employed, which of the letters the children touched each time word pairs appeared on the computer screen was recorded. All four young children displayed overselective attention to words, but the children differed in the intensity of their overselective attention. The prevalence of overselective attention also depended on the type of response measurement.

Key Words: Visual Attention, Overselective Attention, Attention to Words,
Stimulus Overselectivity, Young Children

Behavior Analysis& Technology Monograph 170410, 1 – 23, 2017
Publication Date: 10 April 20178

(Full text follows)

BA&T Monographs is published by *BA&T, Inc.*, Groton, Massachusetts, USA,
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Our research at Behavior Analysis & Technology, Inc. has involved discovering manipulations that determine how children of typical development and individuals with developmental disabilities attend to complex cues, which has significant educational applications. Attending to irrelevant aspects of instructional materials can prevent or postpone the acquisition of essential skills. Skills may also fail to generalize if students attend to irrelevant features of educational tasks. Increasing the student's likelihood of attending to the relevant features, however, can minimize errors and enhance generalization.

Prior Reinforcement Histories and Attention to Stimulus Compounds

Adults with Intellectual Disabilities

One manipulation we have found that affects which components of stimulus compounds young children and individuals with developmental disabilities attend to is prior reinforcement histories associated with individual stimuli. An early investigation (Huguenin & Touchette, 1980), which was based on the doctoral dissertation of the president of Behavior Analysis & Technology, Inc., provided a foundation for much of our later research investigating the influence of prior reinforcement histories on visual attention to compound stimuli. This investigation demonstrated that prior reinforcement histories paired with color and line-orientation stimuli controlled the attention of adults with severe intellectual disabilities when these stimuli were combined. Eight young men with severe intellectual disabilities initially learned color and line-orientation discriminations. After 95% accuracy was achieved for both discriminations, they were combined to form "conflict-compound" stimuli in which the prior reinforcement history was reversed for one element of the compound while the prior reinforcement history remained unchanged for the other element. Following criterion accuracy for the conflict-compound discrimination, test trials were administered to determine the level of stimulus control for each element. During the test trials, both nondifferential and differential-reinforcement contingencies were employed. Multiple test conditions were utilized since only one type of stimulus-control test could not rule out possible contamination by test variables. Misleading conclusions could be made, as a result, about how the stimulus compounds were attended to.

Ray (1969) found in an earlier study that only the unchanged element of the conflict compound controlled the responding of rhesus monkeys in agreement with the reinforcement contingencies of the conflict compound. Her test consisted of presenting the unchanged elements and reversed elements separately with a differential- reinforcement contingency in effect during the test trials. The test results of Huguenin and Touchette (1980) for adults with intellectual disabilities, in contrast, collected with identical differential-reinforcement contingencies revealed control in agreement with the reinforcement contingencies of the conflict compound by both the unchanged and reversed elements. When the tests were conducted with nondifferential reinforcement in effect, however, selective responding to the unchanged element was revealed. Only the unchanged element exercised control in agreement with the reinforcement contingencies of the compound, regardless of whether it was color or line orientation, with few exceptions. The reversed element, which had a conflicting prior history of reinforcement, most often exerted control associated with original training or no control, indicating that it had been ignored in the compound.

These findings demonstrated that individuals with intellectual disabilities selectively attended to compound visual stimuli as a function of the prior reinforcement history of the individual stimuli. The discovery that differential reinforcement during the test sessions modified the stimulus-response relations also illustrated the danger of assessing stimulus control with only one test. In contrast, when the opportunity was reduced for conditioning new stimulus control during testing by applying nondifferential reinforcement, individuals with intellectual disabilities selectively responded to the unchanged element with rare evidence of control in agreement with the conflict compound by the reversed element. By employing more than one stimulus-control test, it was demonstrated that prior reinforcement histories of individual stimuli did control how adults with severe intellectual disabilities attended to stimulus compounds.

Children of Typical Development

In another investigation (Huguenin, 1987), our company president extended these earlier findings to include an analysis of the effects of prior reinforcement histories on attention to compound displays in young children of typical development. Although attentional deficits interfere with the cognitive and social development of children, environmental factors that influence how they attend to complex cues had not been thoroughly investigated. To address this issue, three separate visual discriminations composed of six symbols were first conditioned utilizing computer technology with one of the earliest touch screens fitted to the monitor screen. The stimuli were next combined to form conflict compounds by keeping prior reinforcement contingencies unchanged for two symbols and reversing them for the remaining four symbols. After criterion accuracy for the conflict-compound discriminations was achieved, test trials were administered. During these test trials, the three original symbol pairs appeared alone in a mixed sequence, and whichever symbol the child touched produced reinforcement to prevent conditioning from occurring during the test. The purpose of the test was to determine which elements of the compound stimuli the children were attending to when criterion accuracy was achieved. In addition, test results were supported by comparing them with symbols touched in the conflict compound. This was accomplished by recording with the touch screen exactly which symbols the child touched each time conflict compounds were presented on the computer screen.

Prior reinforcement histories of separate components controlled how the young children attended to complex cues. The children always selectively responded to stimulus elements whose prior reinforcement history was unchanged in the conflict compounds while simultaneously ignoring stimulus elements with reversed prior reinforcement histories. These results confirmed the findings of our earlier investigation with young adults with intellectual disabilities (Huguenin & Touchette, 1980) and extended the effect of this manipulation to young children of typical development. Prior reinforcement histories were also a determining factor of the attention of children in this investigation (Huguenin, 1987) when more complex stimulus compounds were presented and where stimulus elements were not superimposed upon each other in the compound in contrast to the previous investigation (Huguenin & Touchette, 1980).

Multiple stimulus-control tests administered by computer technology confirmed the reliable effect of the experimental manipulation for each child. In one stimulus-control test, unchanged and reversed symbols were presented individually following acquisition of the conflict compounds. Only symbols with unchanged prior reinforcement histories controlled responding in agreement with the conflict compound's contingencies indicating selective attention to the unchanged symbols in the compound. Response topographies recorded with the touch screen supported this conclusion. With one exception, the children touched only unchanged symbols and did not touch reversed symbols in the conflict compounds on all or nearly all reinforced trials when criterion accuracy was achieved. Both stimulus-control tests confirmed that prior reinforcement histories determined which stimulus features young children selectively attended to in a stimulus compound.

In addition, the consistency in how the children attended to stimulus compounds was affected by the extent of single-stimulus pretraining. If each component was previously conditioned and prior contingencies reversed for some of the stimulus elements in the compound while remaining unchanged for the remaining stimulus elements, all of the children responded to only unchanged elements in the compound. Variable test performance was noted, however, both within and across children when compounds were presented containing some or all novel components. These results supported an earlier investigation conducted by our company president (Huguenin, 1985) where total pretraining also generated the same attentional response to compound stimuli in adults with intellectual disabilities, which did not occur when only partial pretraining was provided. Manipulating whether the prior reinforcement history of each individual component was either reversed or unchanged in the compound was the most reliable procedure in this investigation (Huguenin, 1987) for controlling the attention of the young children.

Children of Typical Development and Adolescents with Intellectual Disabilities

In a later investigation (Huguenin, 1997), we examined at Behavior Analysis & Technology, Inc. the similarities and differences in how prior reinforcement histories affected attention to compound visual cues for both young children of typical development and adolescents with intellectual disabilities, both groups having comparable mental age. Computer technology was again employed to present a series of identical conflict-compound tasks, composed of six symbols, to both groups, and generalization effects were examined. Multiple stimulus-control tests were presented. One test assessed stimulus control by presenting stimulus components separately following acquisition of the conflict-compound discriminations. The other test measured the response topographies of the compound stimuli through the use of a touch screen attached to a computer monitor screen, which automatically recorded which stimuli the students touched in the compounds.

When prior reinforcement histories were manipulated, the young children of typical development in most instances selectively attended to stimulus elements whose prior reinforcement history was unchanged in the conflict compound. Selective attention to the unchanged elements occurred when unchanged elements were in the left portion, right portion, or middle portion of the compound visual stimuli. Stimulus elements with a reversed prior reinforcement contingency, in contrast, were usually ignored. The reliability of the effect of prior reinforcement histories on the attention of the young children to stimulus compounds was validated by both assessment procedures. When unchanged elements and reversed elements were presented separately following acquisition of the conflict compounds, only unchanged elements exhibited a high level of control in agreement with the conflict compound’s reinforcement contingencies, with few exceptions, indicating selective attention to the unchanged elements. Response topographies recorded with a touch screen also confirmed that the young children of typical development selectively responded to only the unchanged elements of the conflict compounds when they achieved criterion accuracy. With one exception, the young children touched only unchanged symbols in the compounds and did not touch reversed symbols.

The adolescents with intellectual disabilities were less sensitive, however, to the initial effects of prior reinforcement histories. In contrast to the young children’s test performance, the adolescents did not selectively attend to the unchanged elements in most cases when criterion accuracy for the conflict compounds was obtained. They demonstrated, instead, greater variability in test performance following acquisition of the conflict compounds compared to the young children. Their response topographies recorded with a touch screen also revealed that two of the three adolescents selectively responded to the same symbol pair in all of the conflict compounds regardless of whether the prior contingencies of the symbol pair were unchanged or reversed in the compound. These findings (Huguenin, 1997) indicated that a critical distinction between students with developmental disabilities and students of typical development of comparable mental age could be the efficiency with which they shift their attention among elements of stimulus compounds depending upon prior reinforcement histories. The manner in which students initially respond to compounds with conflicting prior reinforcement histories could prove to be an effective technique for identifying students with developmental disabilities and attentional deficits.

Prior Reinforcement Histories and Extended Training

In another investigation at Behavior Analysis & Technology, Inc. (Huguenin, 2000), the effect of prior reinforcement histories on attention to compound visual cues for adolescents with intellectual disabilities was examined when extended training was given. Because prior reinforcement contingencies of individual stimuli failed to control how the adolescents initially attended to conflict compounds, longer single-stimulus pretraining and additional exposure to the conflict-compound discriminations were provided. After additional training was administered, the adolescents now attended to only stimulus elements whose prior reinforcement history was unchanged in the compound while ignoring stimulus elements with a reversed prior reinforcement contingency. The adolescents demonstrated selective attention to the unchanged elements because only unchanged elements exhibited a high level of control in agreement with the conflict compound’s reinforcement contingencies after extended training was provided. Following additional training, the adolescents also touched, which was recorded with a touch screen, only unchanged elements in the conflict compounds on most reinforced trials when criterion accuracy was achieved and did not touch reversed elements, with one exception.

By manipulating whether prior reinforcement histories associated with individual stimulus elements were unchanged or reversed in the compounds, multiple stimulus-control tests revealed that the adolescents selectively attended to the unchanged elements of the conflict compounds if extended training was provided. After additional training, prior reinforcement histories of individual stimuli affected how adolescents with intellectual disabilities attended to visual compounds in essentially the same way as their initial effect on the attention of young children of typical development of comparable mental age (Huguenin, 1997).

Two of the three adolescents with intellectual disabilities in our investigation (Huguenin, 2000) initially displayed stimulus overselectivity when their response topographies were recorded and analyzed, as they responded to only restricted portions of the compound stimulus displays. Stimulus overselectivity was not revealed by any of the adolescents, however, after longer single-stimulus pretraining was provided. All three adolescents now responded to unchanged elements when unchanged elements were in the left portions, right portions, or middle portions of the conflict compounds, with one exception, following additional training. By manipulating which of the individual stimulus elements were paired with unchanged or reversed prior reinforcement contingencies in the compound, the adolescents responded to each component of the conflict compounds after additional training was given.

Utilizing a touch screen in our investigation (Huguenin, 2000) to record response topographies also provided greater precision in identifying overselective attention. Presenting stimulus elements separately following initial acquisition of the conflict compounds did not reveal overselective attention for the adolescents with intellectual disabilities. Responding to a restricted portion of the compound was only demonstrated when their response topographies, recorded with a touch screen, were analyzed. Employing touch-screen technology proved to be a more sensitive technique for identifying overselective attention and provided greater precision in evaluating treatment procedures for reducing overselective attention among adolescents with intellectual disabilities.

Single-Element Pretraining and Simultaneous Attention to Multiple Stimuli

<u>Adults with Intellectual Disabilities</u>

Another area of research that we have been involved in at Behavior Analysis & Technology, Inc. has involved utilizing conditional-discrimination tasks involving multiple cues to assess visual attention in individuals with developmental disabilities and young children of typical development. In an early investigation (Huguenin, 1985), our company president examined whether the amount of single-element pretraining affected response accuracy for conditional-discrimination tasks requiring attention to multiple cues. Children with autism and intellectual disabilities have a particularly difficult time acquiring conditional discriminations, and stimulus overselectivity is often responsible for their high percentage of errors. One purpose of this investigation (Huguenin, 1985) was to discover whether adults with severe intellectual disabilities could learn a conditional discrimination requiring simultaneous attention to multiple components of stimulus compounds with few errors occurring if separate control by each stimulus component was first established. It was wondered if pretraining each component to exercise compatible stimulus control to prevent stimulus overselectivity from occurring might facilitate the acquisition of conditional discriminations requiring attention to multiple cues. The performance on three transfer conditional-discrimination tasks was also examined in which the extent of prior single-element training provided to individuals with intellectual disabilities was manipulated.

Four adults with severe intellectual disabilities participated, and a multiple baseline across subjects and reversal design were employed. The S+ and S- stimuli were composed of animal pictures on colored backgrounds. Following acquisition of the conditional discriminations after first pretraining each stimulus element, transfer tests were administered. Two intermixed conditional-discrimination tasks were presented in the first transfer condition, which contained identical stimuli to those individually trained. In the second transfer condition, two intermixed conditional-discrimination tasks composed of novel S- stimuli and pretrained S+ stimuli were presented. A control procedure was provided in which conditional-discrimination tasks contained all novel cues.

When single-component pretraining was initially provided, the adults with severe intellectual disabilities acquired the conditional discriminations with few errors. By having first the color component and next the animal component of the S+ compound (lion on red background) common to both the S+ and S- compounds, the adults learned to selectively attend to each stimulus element while the S+ compound was present throughout pretraining. Stimuli paired with extinction in pretraining were also S- stimuli during the conditional-discrimination task. The same procedures were applied to the second S+ compound (seal on green background). Employing identical S+ and S- stimuli during single-component and conditional-discrimination training facilitated errorless acquisition of the conditional discriminations.

In addition, the response accuracy of transfer tasks involving two intermixed conditional discriminations was affected by the amount of single-stimulus pretraining. The adults attended to both elements of the two intermixed S+ compounds if all of the individual components were pretrained, but their attention was reduced if only partial pretraining was given. Establishing stimulus control for each component of the S+ compounds in pretraining did not produce attention to both stimulus elements of two intermixed conditional-discrimination tasks if novel S- cues were presented. Stimulus overselectivity or a lack of control by each stimulus element occurred for half of the S+ compounds. When none of the stimuli were previously trained, neither S+ compound of the two intermixed conditional-discrimination tasks demonstrated control by both stimulus elements. The degree of similarity between training and transfer conditional-discrimination tasks determined the extent to which the attention to multiple cues of adults with intellectual disabilities generalized to transfer conditions. The greater the number of stimuli in common between training and transfer conditions, the less their simultaneous attention to multiple stimuli was disrupted.

The results of this investigation (Huguenin, 1985) demonstrated that adults with severe intellectual disabilities could learn to attend simultaneously to multiple cues with few errors occurring if separate control by individual components of S+ compounds was initially established. This procedure proved successful, because it prevented stimulus overselectivity from occurring when the multi-stimulus tasks were presented. Another advantage of using the conditional-discrimination procedure of this study to evaluate the effects of single-stimulus pretraining was that it directly tested whether or not simultaneous attention to multiple elements occurred. Overselective attention was immediately revealed, since responding to only one stimulus component typically created chance performance on trials when that stimulus appeared in both the S+ and S- compounds. In contrast, tests provided by presenting individual components alone after the acquisition of compound discriminations can only infer attentional patterns produced by compound training cues.

In summary, adults with severe intellectual disabilities quickly learned conditional discriminations that required attention to multiple cues by maintaining compatible prior reinforcement contingencies of separate stimuli in conditional-discrimination tasks. This proved to be an effective technique for broadening the attentional skills of individuals with intellectual disabilities. This has important educational implications, since the ability to respond to multiple cues is a prerequisite skill for learning to occur in classroom settings.

Children of Typical Development and Adolescents with Intellectual Disabilities

Conditional-discrimination tasks requiring simultaneous attention to multiple cues were again employed in a later investigation at Behavior Analysis & Technology, Inc. (Huguenin, 2004) to assess the presence of overselective attention in young children of typical development and adolescents with severe intellectual disabilities. Conditional-discrimination tasks were presented, which required simultaneous attention to both letter and symbol elements of the stimulus compounds to maintain continuous reinforcement. Responding to only one of the components produced errors and prevented the student from achieving continuous reinforcement.

Computer software administered two different stimulus-control tests to determine how the stimulus compounds were attended to when the 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 by automatically recording with a touch screen which stimuli the students touched in the compounds. By recording response topographies with a touch screen in addition to determining the response accuracy of the stimulus elements, a fine-grained analysis of how students attended to the compound visual cues was achieved.

Another purpose of our study (Huguenin, 2004) was to determine the similarities and differences in the visual attention of young children of typical development and adolescents with severe intellectual disabilities of comparable mental age. It was investigated if utilizing computer technology to administer conditional-discrimination tasks requiring simultaneous attention to multiple cues might prove to be effective for identifying overselective attention. As a result, treatment and educational programs designed to diminish the effects of overselective attention on later development could be provided. In our study at Behavior Analysis & Technology, Inc. (Huguenin, 2004), 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. We determined whether single-stimulus pretraining and repeated exposure to the conditional-discrimination tasks eliminated overselective attention and if students needed differing amounts of pretraining before they acquired conditional discriminations requiring simultaneous attention to multiple cues.

Single-component pretraining did result in simultaneous attention to two stimulus elements in a conditional-discrimination task for both young children of typical development and adolescents with severe intellectual disabilities. All three children of typical development attended simultaneously to both the letter and symbol elements in the conditional-discrimination task with few errors occurring. Two of the children, who did not simultaneously attend to both elements in baseline, exhibited high levels of stimulus control for both elements after pretraining was provided. The adolescents with intellectual disabilities also eventually attended simultaneously to both the letter and symbol elements, but they required more pretraining and exposure to the conditional-discrimination tasks than the young children required. When the first conditional-discrimination task was presented, only one of the adolescents simultaneously attended to both the letter and symbol features of the S+ compound following pretraining. After pretraining was provided for the second conditional-discrimination task, however, all three adolescents now attended simultaneously to both stimulus elements. Although the three adolescents eventually attended simultaneously to both the letter and symbol elements, they differed in the amount of pretraining needed before simultaneous attention occurred.

All three adolescents with intellectual disabilities displayed, initially, overselective attention when the visual compounds were presented. Extended single-component pretraining and repeated exposure to the conditional-discrimination tasks, however, eventually eliminated their overselective attention. The adolescents also maintained simultaneous attention to two stimulus elements following extended training despite the occurrence of stimulus preferences, which their response topographies revealed. In addition, extended training not only taught the three adolescents to attend simultaneously to multiple stimulus elements, but their broadened visual attention persisted when single-stimulus pretraining was omitted and the positions of the stimulus elements were reversed in the generalization test. Our study (Huguenin, 2004) indicated that overselective attention was not an unmodifiable perceptual characteristic of individuals with severe developmental disabilities. Many investigations have reported the presence of stimulus overselectivity among students with developmental disabilities, but few studies have found treatment procedures for eliminating this attentional deficit. Extended single-stimulus pretraining and repeated exposure to conditional-discrimination tasks requiring simultaneous attention to multiple cues were effective in our investigation (Huguenin, 2004) in eliminating overselective attention for three adolescents with intellectual disabilities.

Recording response topographies with a touch screen in our investigation (Huguenin, 2004) also provided a more fine grain analysis of stimulus preferences for both the young children of typical development and the adolescents with intellectual disabilities than their response accuracy. When response accuracy was examined, only one child revealed stimulus preferences in the test sessions where only one of the stimulus elements was associated with high accuracy. All three children demonstrated stimulus preferences, in contrast, when their response topographies were examined, as all three children touched only one of the stimulus elements in the test trials, with few exceptions. Response topographies recorded with a touch screen were also a more sensitive measure of stimulus preferences for the adolescents with intellectual disabilities than their response accuracy. The adolescents demonstrated stimulus preferences in almost twice the number of test sessions when their response topographies were compared to their response accuracies for the individual stimulus elements.

The finding that recording response topographies with a touch screen provided a sensitive and detailed analysis of stimulus control supported the results of our previous investigations (Huguenin, 1987, 1997, 2000). In this investigation (Huguenin, 2004), even though the accuracy scores of both young children of typical development and eventually adolescents with intellectual disabilities revealed simultaneous attention to two stimulus elements, their response topographies continued to demonstrate stimulus preferences. Recording response topographies showed that even when two elements exhibited high levels of response accuracy, differences in stimulus control still existed.

The presence of stimulus preferences in this study (Huguenin, 2004) did not, however, differentiate students with or without overselective attention. The critical distinction was the intensity of their stimulus preferences. While recording response topographies with a touch screen identified the presence of stimulus preferences, it was the accuracy scores of the individual stimulus elements during the conditional-discrimination tasks, which revealed their intensity. The intensity of the stimulus preferences was shown by how quickly simultaneous attention to both elements developed in the conditional-discrimination tasks. Stimulus preferences were a typical occurrence among children of typical development in this study (Huguenin, 2004) and were not only present among the students with developmental disabilities. The stimulus preferences of the adolescents were more intense, however, as in most instances, their stimulus preferences hindered simultaneous attention to multiple cues from developing. The adolescents required more single-component pretraining and exposure to the conditional-discrimination tasks before they simultaneously attended to multiple cues compared to the young children. The findings of this study did not indicate, however, that students with severe developmental disabilities were incapable of attending to multiple cues or that their stimulus overselectivity could not be eliminated. These results rather suggested that frequently students with developmental disabilities have such intense stimulus preferences that they postpone the development of simultaneous attention to multiple cues until extended single-component pretraining is provided.

Stimulus preferences can also be sufficiently intense to prevent simultaneous attention to multiple cues from occurring in children of typical development. One of the children in our investigation (Huguenin, 2004) learned to simultaneously attend to both stimulus elements after pretraining was initially provided, but she could not maintain simultaneous attention with repeated exposure to the conditional-discrimination tasks. Her stimulus preferences, revealed by the touch screen, were sufficiently intense to result in overselective attention.

In summary, recording both response topographies and response accuracy provided a more complete analysis of how young children and adolescents with intellectual disabilities responded to visual compounds. Recording response topographies permitted their visual attention to be more precisely specified and revealed individual differences that their accuracy scores did not show. Using touch screen technology to monitor stimulus preferences could permit potential factors contributing to the emergence of overselective attention to be discovered.

Six-Year and Nine-Year-Old Children

Although overselective attention is frequently reported in students with developmental disabilities, it has typically not been observed in children of typical development six years of age or older. In another study at Behavior Analysis & Technology, Inc. (Huguenin, 2006), computer software administered stimulus compounds composed of letters and symbols or all letters to determine if overselective attention occurred in four boys of typical development of approximately six years of age when more complex stimuli were presented. Conditional-discrimination tests were employed where responding was only reinforced when two visual cues (a letter and a symbol or two letters) appeared together in the same stimulus compound. If the student responded when either visual cue appeared without the other visual cue in a stimulus compound, extinction resulted. Overselective attention was directly assessed, because if the child responded to only one component of the S+ compound, errors immediately occurred, which prevented continuous reinforcement.

Two different stimulus-control tests were again administered. One test assessed stimulus control by determining response accuracy for each component of the S+ compounds. The other testing procedure used a touch screen to automatically record which stimuli the children touched in the compounds. Multiple stimulus-control tests were utilized to verify and confirm the children's test performance.

Nine-year old boys were also given the same conditional-discrimination tests. By assessing the visual attention of children of different ages, what constitutes an atypical attentional pattern can be determined. It may not be the presence of overselective attention but how long it persists that determines whether a child has an attentional disorder. In contrast to students with developmental disabilities for whom overselective attention often persists into adolescence and adulthood, it was determined how children of typical development of different ages attended to visual compounds.

This investigation (Huguenin, 2006) also examined the effect of single-stimulus pretraining and repeated exposure to conditional-discriminations on how young children attended to stimulus compounds. Past research has demonstrated single-stimulus pretraining is effective in teaching conditional discriminations requiring simultaneous attention to multiple cues (Huguenin, 1985), but the amount of pretraining and exposure to the conditional discriminations required before simultaneous attention occurs can differ across students (Huguenin, 2004). As a result, the procedure utilized for assessing the intensity of a child's overselective attention in this investigation (Huguenin, 2006) was the amount of extended training that the child required before he simultaneously attended to multiple cues. By monitoring how children respond to visual compounds over extended periods, individual differences in the visual attention of children can also be identified, which has important educational implications.

The young boys (Huguenin, 2006) demonstrated overselective attention for both the conditional-discrimination test that required simultaneous attention to a letter and a symbol as well as the conditional-discrimination test, which required simultaneous attention to two letters. Their overselective attention also persisted despite extended single-stimulus pretraining and repeated exposure to the conditional discriminations. Overselective attention not only occurs in students with developmental disabilities, but our findings revealed overselective attention occurred in children of typical development as old as six years of age. Although previous studies did not find overselective attention in children in this age group, this may have occurred because they employed less complex stimuli than the stimuli used in our investigation (Huguenin, 2006). In addition, previous investigations often tested for overselective attention in young children by presenting stimulus elements separately following the acquisition of compound discriminations. This type of testing procedure can only indirectly infer attentional patterns produced by the compound training cues in contrast to the conditional-discrimination tests used in our investigation, which more directly determined the occurrence of overselective attention.

Both testing procedures of our investigation (Huguenin, 2006), which involved measuring response accuracy during the conditional-discrimination tests and recording response topographies, identified the presence of stimulus preferences in young boys. The intensity of their stimulus preferences was revealed, however, by the accuracy scores of the individual stimulus elements during the conditional-discrimination tests, which determined how quickly simultaneous attention to both elements developed. Stimulus preferences were of sufficient intensity in over half of the conditional-discrimination test sessions to prevent simultaneous attention to both stimulus elements from occurring. The young boys demonstrated, instead, overselective attention during these test sessions, when they achieved a high level of response accuracy for only one of the stimulus elements. Their response topographies confirmed the overselective attention, which their accuracy scores revealed, as the young boys consistently touched the identical preferred stimulus in the compounds, with only a few exceptions.

The three older boys, in contrast, did not display overselective attention for either conditional discrimination. When presented with the conditional discrimination requiring simultaneous attention to both a letter and symbol component, the older boys achieved high response accuracy for both stimulus components in all of the test sessions. They continued to achieve high response accuracy for both stimulus components during the test sessions when the conditional discrimination requiring simultaneous attention to two letters was administered. Single-component pretraining and repeated exposure to the conditional-discrimination tests were not required to establish simultaneous attention to multiple stimulus elements for any of the older boys.

In contrast to their accuracy scores, however, the response topographies of the older boys revealed stimulus preferences, as they selectively touched only one of the stimulus elements in both conditional-discrimination tasks. Even though they achieved high levels of response accuracy for both stimulus elements in all of the test sessions, their response topographies revealed the stimulus elements did not exercise the same level of stimulus control. The conditional-discrimination tests demonstrated, however, the stimulus preferences of the older boys were not intense enough to prevent them from attending simultaneously to multiple cues in opposition to the younger boys. Stimulus preferences may be a common occurrence among children of typical development. The frequency of stimulus preferences may not change as children advance in age, but the results of this investigation (Huguenin, 2006) suggest the intensity of their stimulus preferences is affected by age. Although the response topographies of the older boys revealed stimulus preferences, their accuracy scores showed high levels of stimulus control for both stimulus elements of the S+ compound. The accuracy scores and the response topographies of the younger boys, in contrast, demonstrated overselective attention, revealing their stimulus preferences were sufficiently intense to prevent them from attending simultaneously to multiple cues.

Even though the young boys displayed overselective attention when the compound stimuli were initially presented, extended pretraining and repeated exposure to the conditional-discrimination tests resulted in all four boys eventually attending simultaneously to multiple stimuli. The rate at which simultaneous attention developed differed, however, across the young boys showing the intensity of stimulus preferences also varied even in young children of similar age. Extended pretraining was effective in eliminating their overselective attention and establishing simultaneous attention to multiple elements regardless of the order in which the two conditional-discrimination tests were administered.

Attention to Individual Letters of Word Discriminations

Single-Letter Pretraining and Simultaneous Attention to Two Letters

Computer technology was employed in another investigation at Behavior Analysis & Technology, Inc. (Huguenin, 2008) to provide a detailed analysis of how four young children visually attended to letters and words. Assessing how young children attend to letters and words is important because it can identify attentional deficits, which interfere with the child's reading performance. Using computer technology to assess how children attend to words can also identify whether children are attending to individual letters within whole words, which is critical for word identification.

In our investigation (Huguenin, 2008), young children of typical development were taught to respond to each letter of a consonant-vowel stimulus compound (C-A). The two pretrained letters, the letter C and the letter A, subsequently appeared in four CVC 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 to attend to both pretrained letters in the word discriminations to maintain continuous reinforcement, as attending to only one of the pretrained letters would have produced errors. As a result, simultaneous attention to both pretrained letters was demonstrated if the child achieved high accuracy levels throughout the word test.

Two different testing procedures measured how the young children responded to the letter compounds and test words. One test assessed stimulus control by determining response accuracy when the letter compounds and word discriminations were presented. The other test measured the response topographies of the young children by recording the specific letters the children touched in the letter compounds and test words using a touch screen. Recording response topographies permitted individual differences in how children attended to words to be discovered which accuracy scores alone did not reveal.

Our investigation at Behavior Analysis & Technology, Inc. (Huguenin, 2008) 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 words. Single-stimulus pretraining was effective in our previous research (Huguenin, 1985, 2004, 2006) in teaching young children of typical development and individuals with developmental disabilities to attend simultaneously to multiple cues. The amount of single-stimulus pretraining and exposure to conditional-discrimination tasks required before simultaneous attention to multiple elements occurred, however, varied across students (Huguenin, 2004, 2006). Determining the amount of pretraining and exposure to word-discrimination tests that is necessary before a child simultaneously attends to multiple letters can be another means for assessing if a child has the prerequisite behaviors for reading instruction.

Although the young children in our investigation (Huguenin, 2008) responded identically to individual letters in pretraining, they responded differently to the same letters when they predicted reinforcement in word discriminations. The stimulus control of the individual letters, established in pretraining, was disrupted in many instances when they appeared in a word-discrimination task, but the degree of disruption of the pretrained letters differed across children. While the accuracy scores of the young children demonstrated some variability in how they attended to words, recording their response topographies was a more sensitive stimulus-control test in revealing individual differences.

The four children reliably touched each letter when it predicted reinforcement in the letter compounds during pretraining, but their response topographies exhibited a variety of attentional patterns when the same letters predicted reinforcement in the word-discrimination task. One child, for example, demonstrated high levels of stimulus control, with one exception, whenever the two pretrained letters appeared in the word discriminations. Both his response accuracy and his response topographies revealed he attended simultaneously to both pretrained letters in the word discriminations. Two other children also learned to maintain high levels of response accuracy when each pretrained letter predicted reinforcement in the word discriminations, but their response topographies demonstrated neither child touched both pretrained letters in the S+ words. The two children responded consistently to one of the pretrained letters in the S+ words in some or all of the word-discrimination test sessions following pretraining, but they never touched the remaining pretrained letter. While their accuracy scores showed they simultaneously attended to both pretrained letters in the word discriminations, their response topographies revealed letter preferences indicating unequal levels of stimulus control. Finally, both the accuracy scores and the response topographies of the fourth child indicated neither pretrained letter exercised stimulus control in the word-discrimination task.

Previous studies have shown the difficulty of teaching young children to attend to individual letters within words (e.g., Saunders, Johnston, & Brady, 2000). Single-letter pretraining and repeated exposure to word discriminations were effective, however, in this investigation (Huguenin, 2008) in teaching young children to attend simultaneously to two letters in a word-discrimination task. Before single-letter pretraining was provided, none of the children attended to both letters throughout the word-discrimination task. Following single-letter pretraining, however, two children achieved high accuracy scores for all four word discriminations when the word-discrimination task was repeated. This indicated 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. Their test performance revealed that the majority of the children learned to attend simultaneously to two letters when single-letter pretraining was provided, demonstrating the utility of single-letter pretraining and extended training in teaching young children to attend simultaneously to individual letters in word discriminations.

Overselective Attention to Words: Multiple Testing Procedures

In our next study at Behavior Analysis & Technology, Inc. (Huguenin, 2011), we investigated the occurrence of overselective attention to words in four young children of typical development. Computer software administered multiple stimulus-control tests to more precisely identify the presence and intensity of overselective attention in young children when CVC word discriminations were presented. One stimulus-control test employed in this investigation (Huguenin, 2011) assessed how many letters of word discriminations were attended to, after criterion accuracy was achieved, by recording response choice when the letters comprising the S+ word and S- word were presented separately. The number of letters of the S+ word that the child consistently selected when individual letters of the S+ and S- words were presented assessed whether or not the child attended to only a restricted portion of the S+ word. In a second stimulus-control test, word choice was determined when the S+ word appeared with three comparison words that differed from the S+ word by only one letter. The word test directly determined whether the child attended to each of the individual letters of the S+ word. If the child consistently selected the S+ word despite appearing with comparison words that differed by only one letter, in each spatial position within the comparison word, simultaneous attention to each letter of the S+ word was revealed. A third stimulus-control test measured the response topographies of the training words by using a touch screen that automatically recorded which individual letters the children touched when words appeared on the computer screen.

In addition to employing different stimulus-control tests to assess how young children attended to words, both nondifferential and differential-reinforcement contingencies were used during the single-letter and word test trials. More than one type of reinforcement contingency was utilized during the test trials to confirm which letters of the training words the children were attending to. In this manner, false conclusions were avoided which Huguenin and Touchette (1980) demonstrated could occur if only one type of reinforcement contingency is employed during the test trials.

Utilizing computer software to administer multiple stimulus-control tests in this investigation (Huguenin, 2011) revealed individual differences in how the young children attended to words. The four young children learned word discriminations with few errors occurring, but most of the children did not attend to all the letters of the training words. Although the majority of the children demonstrated overselective attention to words, employing multiple testing procedures revealed differences in the intensity of their restricted attention. This was shown as the children differed in the number of test conditions and test sessions in which overselective attention occurred. One child, for example, exhibited overselective attention in the single-letter and word test trials when a differential-reinforcement contingency was employed but did not reveal overselective attention during the nondifferential-reinforcement test trials. During the nondifferential-reinforcement test trials, none of the letters of the S+ words exhibited stimulus control. Two of the other children exhibited more pervasive overselective attention, as they displayed restricted attention in the single-letter and word test trials when both differential-reinforcement and nondifferential-reinforcement contingencies were provided. The fourth child did not exhibit overselective attention in any of the test sessions. He attended, instead, consistently to each letter of the S+ words regardless of the type of reinforcement condition employed during the test trials. His response topographies recorded with a touch screen, however, revealed selective attention, as he selectively touched the same letter in the S+ words in most of the sessions when he achieved criterion accuracy for the word discriminations.

This investigation (Huguenin, 2011) differed from previous investigations assessing overselective attention, as it used both single-component and conditional-discrimination testing procedures as well as different test reinforcement conditions to determine the presence of overselective attention. Employing more than one type of stimulus-control test made it possible to determine the robustness of overselective attention and whether it was a reliable occurrence. When the single-letter test demonstrated overselective attention for a particular child, the word test also revealed overselective attention with few exceptions. The specific letters exhibiting stimulus control differed, in some instances, as revealed by the two stimulus-control tests, but this may have occurred because of repeated exposure to the word discriminations.

In addition, we discovered in our investigation at Behavior Analysis & Technology, Inc. (Huguenin, 2011) that the effect of repeated testing on whether young children learned to attend to each letter of training words depended on the type of reinforcement contingency utilized during the test trials. If a nondifferential-reinforcement contingency was employed during the single-letter and word test trials, repeated stimulus-control testing did not produce attention to all three letters of the S+ words for three of the four children. One child did not demonstrate stimulus control for any of the letters of the S+ words in all of the nondifferential-reinforcement test sessions. The other two children persisted in exhibiting overselective attention even after repeated testing was provided if nondifferential reinforcement was utilized in the test sessions.

Repeated testing, in contrast, did eliminate the overselective attention the three children initially displayed when a differential-reinforcement contingency was employed in the test trials. Each of the children now attended to all three letters of the S+ words after extended testing with a differential-reinforcement contingency was provided. Repeated testing with a differential-reinforcement contingency eliminated the overselective attention that one child initially exhibited in the single-letter test trials. For the other two children, repeated testing with a differential-reinforcement contingency eliminated the overselective attention that they displayed in both the single-letter and word test trials. The rate at which their overselective attention was eliminated when differential reinforcement was employed in the different test conditions was another means of determining the intensity of their overselective attention.

Although the stimulus-control tests of one child did not reveal overselective attention, the response topographies recorded by a touch screen indicated letter preferences for all four children. A letter preference was demonstrated by the child's response topography whenever the child selectively touched the same letter in the S+ words in 80% or more of the trials when criterion accuracy for the word discriminations was achieved. For two of the children, recording response topographies was more sensitive in revealing letter preferences than their stimulus-control tests where only a single letter of the S+ word exhibited stimulus control. The response topographies of the remaining two children indicated letter preferences comparable in frequency to the letter preferences demonstrated by their stimulus-control tests. Recording response topographies with a touch screen to detect letter preferences further confirmed the effectiveness of employing multiple stimulus-control tests and utilizing touch-screen technology to provide a more complete assessment of how children attend to words.

<u>Overselective Attention to Words: Effect of Single-Letter Pretraining</u>

In another investigation at Behavior Analysis & Technology, Inc. (Huguenin, 2014), we further examined the effect of single-letter pretraining on how young children attended to a word-discrimination task. Determining the amount of single-letter pretraining that was needed before each child simultaneously attended to each of the individual letters of the word discrimination was utilized to assess the intensity of overselective attention to words. The advantage of this type of assessment is that it can assist in identifying if a child has the prerequisite behaviors for reading since attending simultaneously to the individual letters of printed words is a requirement for learning to read. Multiple stimulus-control tests were also employed. In one test, word choice was recorded when the S+ word appeared with three comparison words that differed by only one letter. If the child consistently selected the S+ word despite appearing with comparison words differing by only one letter, in each spatial position within the comparison word, attention to each letter of the S+ word was revealed. Response topographies were measured in a second test by using a touch screen to automatically record which letters the children touched when words were presented on the computer screen.

Four young children participated in the study, and a Macintosh computer, with a touch screen fitted to the monitor screen, automated the sessions. Each child was presented a CVC word discrimination in which the S+ and S- words were presented simultaneously on the computer screen. The word discrimination was initially presented until criterion accuracy was achieved, and the word discrimination continued to be presented after differing amounts of single-letter pretraining were provided. During single-letter pretraining, stimulus control by each letter of the S+ word was obtained by making two letters common to both the S+ word and three comparison S- words and consistently pairing successively each letter of the S+ word with reinforcement. Pretraining trials and the word discrimination were repeated in additional sessions until the word discrimination was presented six times to each child.

Each time criterion accuracy was achieved for the word discrimination, a test was administered. In the test, the S+ word appeared with three comparison words that differed by only one letter. In a generalization test, the S+ word appeared with three comparison words, which differed by one novel letter. During the tests, the three word pairs were presented ten trials each in an unpredictable mixed sequence and nondifferential reinforcement was employed during the test trials. The purpose of the tests was to determine how many letters of the S+ word each child was attending to. Because a touch screen was employed, which of the letters the children touched each time word pairs appeared on the computer screen was also recorded.

All four young children displayed overselective attention to words. The children differed, however, in the intensity of their overselective attention, which was determined by how quickly simultaneous attention to each letter of the S+ word occurred. Although one child did not require single-letter pretraining before he attended simultaneously to all three letters of the S+ word, he did display overselective attention in the generalization test condition when novel letters were introduced. After single-letter pretraining was repeated, however, he now attended simultaneously to each letter of the S+ word in the second generalization test. Another child demonstrated overselective attention in the baseline test session, but she simultaneously attended to each letter of the S+ word after single-letter pretraining was administered. She continued to attend simultaneously to all the letters of the S+ word in the subsequent test sessions. Both children learned to quickly attend to each letter of the S+ word when single-letter pretraining was provided despite the initial occurrence of overselective attention. The remaining two children, however, displayed overselective attention or a loss of stimulus control for the individual letters of the S+ word that persisted even after single-letter pretraining was repeated. Although single-letter pretraining did not eliminate their overselective attention, it did increase the number of letters in the S+ word that one of these children attended to.

The type of response measurement affected the prevalence of the children’s overselective attention to words. When word choice was assessed, only two of the four children persisted in displaying overselective attention. All four children, however, consistently exhibited selective attention to words when their response topographies were recorded. The response topographies of two of the children revealed letter preferences even when their test performance indicated they attended simultaneously to each letter of the S+ word. In contrast, both the response topographies and the test performance of the remaining two children revealed letter preferences. Their test performance revealed letter preferences of sufficient intensity to prevent simultaneous attention to each letter of the S+ word from occurring. While the response topographies of all four children revealed letter preferences when words were presented, the intensity of their letter preferences was the critical factor in whether or not overselective attention to words occurred.

Recording word choice in this investigation provided an incomplete picture of how young children attended to words. While recording words the children chose in the test trials indicated whether they simultaneously attended to each letter of the training word, it did not indicate the relative differences in stimulus control of the individual letters that their response topographies disclosed. Recording individual letters selected in the S+ word with a touch screen provided a direct measurement of letter preferences since exactly which letters the child attended to was determined each time words appeared on the computer screen. Employing word choice in the test trials, on the other hand, to assess stimulus control of the individual letters after criterion accuracy for the word discrimination was achieved, indirectly inferred stimulus control of the individual letters based on later test performance.

In summary, utilizing multiple stimulus-control tests administered by a computer provided a detailed analysis of how young children attended to words. Recording response topographies with a touch screen demonstrated individual differences in the attention of young children to words, which their accuracy scores did not reveal. As a result of recording their response topographies, letter preferences were discovered for the children that showed pretrained letters did not exercise equal levels of stimulus control in word discriminations. Letter preferences were revealed for some of the children by their response topographies even when they achieved high levels of accuracy throughout the word-discrimination tests. Recording response accuracy as well as response topographies provided a more thorough and reliable analysis of how young children attended to words.

Employing computer technology to administer multiple stimulus-control tests to determine how children attend to words could result in improving their reading instruction. Because individual differences were found in the intensity of overselective attention to words in children of typical development, providing similar tests to students with developmental disabilities might also provide a more detailed analysis of how they attend to words. As a result, more individualized and effective reading programs for students with developmental disabilities could be provided. Administering multiple test conditions to assess the visual attention of young children could also serve to identify students with overselective attention of sufficient intensity to prevent simultaneous attention to multiple letters from occurring. This is especially important for children with developmental disabilities where improving their visual attention in their early years is critical in enhancing their later development.

Visual Attention Exercise

In recent years at Behavior Analysis & Technology, Inc., we have been developing innovative web-administered software technologies to provide effective and sensitive attentional skills assessments. Our goal is to provide tools for early identification and remediation of attentional problems in young children. One of these tools is our Visual Attention Exercise, administered from the web. It is designed for 5-7 year old children, and the exercise takes the form of an interactive video that measures and analyzes key characteristics of visual attention.

The exercise takes the form of a sequence of visual displays, and the child is provided a choice. The child makes the choice by selecting one of the two visual displays presented on the screen. Each time a correct choice is made, the screen flashes to provide positive feedback. Throughout the session, the child can also keep track of a posted score (indicating the number of correct choices) as a reward. A sophisticated multiple assessment technique is also employed, which provides an innovative and detailed analysis of several key visual attention characteristics.

The results are automatically analyzed, and a printable report is generated that not only documents and analyzes the findings, but also indicates whether repeating the exercise would be beneficial to improve attentional skills. Included in the report is an assessment of learning efficiency, which determines how quickly the child attends to the relevant features of visual materials. Also included is an assessment of attention durability, which identifies the extent to which attentional skills are disrupted. A third element is an assessment of attention focus, which identifies whether attention can be directed to relevant features in the visual environment, important for learning complex material. The visual attention exercise is an outgrowth of more than thirty years of visual attention research by the president of Behavior Analysis & Technology, Inc. and can be effective in improving attentional skills that enhance learning. Future efforts will involve expanding our web-administered assessment capabilities to identify restricted visual attention that can interfere with acquiring academic skills, especially reading. We also hope to develop web-administered training procedures that would permit individuals with developmental disabilities to acquire essential attentional skills for learning educational and vocational tasks involving complex visual material.

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