Behavior Analysis & Technology

Monograph 250105

Remotely Assessing Visual Attention in Young Children Using Multiple Tests Administered Online

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

Abstract

Discovering manipulations that affect how children attend to complex stimuli is important because of attentional deficits that children can possess which interfere with their development and academic performance. Establishing prior reinforcement histories for separate stimulus components was effective in this study in determining which features of compound visual cues young children attended to. Even when the stimulus-control procedures were administered online at remote sites where the author was not present, prior reinforcement histories determined how the young children attended to a stimulus compound with conflicting prior reinforcement histories. The children selectively attended to the symbol with an unchanged prior reinforcement history in the stimulus compound. Symbols with a reversed prior reinforcement history in the compound were ignored. Individual differences were revealed, however, in how the young children of differing age attended to the conflict compound by employing online multiple testing procedures, which were automatically administered by the software. Neither the response topographies nor the test performance of the younger child indicated that he selectively attended to the symbol with an unchanged prior reinforcement history in the conflict compound when he originally achieved criterion accuracy. After extended training was provided, however, prior reinforcement histories were effective in determining how the younger child attended to the conflict compound. Following extended training, the younger child shifted his attention to the unchanged symbol. The response topographies and the test performance of the older child revealed, in contrast, that he selectively attended to the unchanged symbol in the conflict compound while ignoring the reversed symbols when the conflict compound was originally presented online. This occurred when the older child first achieved criterion accuracy for the conflict-compound discrimination as opposed to the younger child who required extended training. The older child demonstrated, however, a loss of stimulus control for the unchanged symbol when the unchanged symbol initially appeared in the conflict compound. This was because of the initially longer response latencies of the older child for the unchanged symbol in the conflict compound compared to when it was presented alone. While the response topographies and response accuracies of the older child summarized his visual attention, his response latencies demonstrated changes in stimulus control which were not revealed by either his response topographies or response accuracies. Recording response latencies could identify attentional disorders, such as overselective attention and difficulties shifting attention, which have a higher incidence in autistic children that might not be revealed by other types of assessment. Providing similar visual attention assessments online could permit larger numbers of children at risk for developing autism to be identified and enable early interventions to be implemented at a younger age.

Key Words: Visual Attention, Young Children, Overselective Attention, Shifting Attention, Autism, Multiple Tests, Response Latency, Online Assessment

Behavior Analysis& Technology Monograph 250105, 1-27, 2025
Publication Date: 5 January 2025

BA&T Monographs is published by *BA&T, Inc*., Groton, Massachusetts, USA

(Full text follows)

Developing procedures that are effective in assessing how children attend to compound visual displays is important because of the presence of attentional deficits and attentional impairments that many children possess, which can interfere with their learning and development. One attentional impairment that can occur is overselective attention. Overselective attention refers to the situation where the child attends to only a restricted portion of a compound visual display. They might, for example, attend to only the color features of a stimulus compound and ignore the size and shape elements. Overselective attention is frequently reported in individuals with developmental disabilities and autism (Cipani, 2012; Huguenin, 2000; Lovaas & Schreibman, 1971; Lovaas et al, 1971; Ploog & Kim, 2007; Ploog 2010). It can also occur in young children of typical development (Bickel et al, 1984; Eimas, 1969; Hale & Morgan, 1973; Huguenin, 2006, 2011, 2014; Kelly & Reed, 2020; Smith 2005). If overselective attention persists, many areas of a child's development involving the child's language, academic, and social skills can be affected (Burke, 1991; Cipani, 2012; Dunlap et al,1981; Ploog, 2010). Difficulties in shifting attention have also been reported to occur in children with autism compared to children of typical development (Mo et al, 2019; Patten & Watson, 2011). Since attentional impairments are reported to be an early indicator of autism (Keehn et al, 2013; Zwaigenbaum et al, 2005), detecting attentional impairments can permit interventions to be implemented at a younger age, which is critical in enhancing a child's later development (Brown et al, 2022).

Because of restricted attention and other attentional deficits, which occur in children and individuals with developmental disabilities, it is important to discover manipulations that can determine how they attend to stimulus compounds. One manipulation that affects the components of stimulus compounds that young children and individuals with developmental disabilities attend to is prior reinforcement histories associated with individual stimuli (Huguenin & Touchette, 1980: Huguenin, 1987). In one investigation (Huguenin, 1997), 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 developmental disabilities were examined. Both groups had comparable mental age. Computer technology was employed to present stimulus-compound tasks, composed of symbols with conflicting prior reinforcement histories, to both groups. Multiple stimulus-control tests were presented. In most instances, the response topographies and test performance of the young children indicated that they selectively attended to only symbols with an unchanged prior reinforcement history in the compounds when criterion accuracy was achieved. Symbols with a reversed prior reinforcement history in the compounds were usually ignored. The adolescents with intellectual disabilities also eventually learned to selectively attend to unchanged symbols in the compounds. In contrast to the young children of typical development, however, the adolescents required extended training before they selectively attended to the unchanged symbols (Huguenin, 2000).

Another investigation (Huguenin, 2023) assessed if prior reinforcement histories associated with individual stimuli determined how participants attended to a stimulus compound when the procedures were administered online at remote sites. In contrast to the earlier study (Huguenin, 1997), this occurred with laptop computers, where touch screens were not utilized, and where social and monetary reinforcement were not provided. By recording response topographies, it was also determined how quickly they shifted their attention in accordance with prior reinforcement histories when stimulus compounds were presented. Recording response topographies, in addition to response accuracy, revealed some differences in how the participants attended to stimulus compounds. In most cases, however, prior reinforcement histories associated with individual stimuli determined which stimulus elements they attended to and which elements they ignored even when the procedures were administered online at remote sites.

The purpose of the current investigation was to examine if prior reinforcement histories associated with individual stimuli would also determine how young children attended to a stimulus compound when the procedures were administered online at remote sites. Multiple testing procedures were also employed, automatically administered by the software, which permitted a fine-grained analysis of how the children attended to a stimulus compound with conflicting prior reinforcement histories. One test assessed stimulus control by presenting the stimulus elements separately following criterion accuracy for the conflict-compound discrimination and determining their level of agreement with the reinforcement contingencies of the compound. Response topographies were also recorded by the software, which automatically recorded which stimuli the young children selected each time the conflict compound appeared on the computer screen. Recording response topographies permitted attention to the compound to be directly measured instead of inferring attention to the compound after criterion accuracy was achieved when the test trials were administered.

Response latencies were also employed as another assessment of stimulus control in addition to recording response accuracy and response topographies to provide a more complete analysis of how a young child attended to a compound stimulus display. Measuring response latency in a previous investigation (Huguenin, 2024) demonstrated changes in stimulus control within individual sessions for adult participants that were not evident when only response accuracy and response topographies were summarized across sessions. Recording response latencies could also provide a more detailed analysis of changes in stimulus control in how young children attend to a compound with conflicting prior reinforcement histories. Attentional disorders, such as overselective attention or difficulties shifting attention, could be revealed by recording response latency that might not be revealed by other types of assessment. This would be especially beneficial in identifying children at risk for developing autism. Because of the rapid increase in children diagnosed with autism (1 in 36 children), there is now a greater need to identify children with autism at an early age to provide necessary interventions. Recording response latencies could permit early interventions to be implemented at a younger age.

Method

Subjects

Two children (three-years-old and six-years-old) participated in this study.

Apparatus

The stimulus-control procedures were provided online, which were accessible from the author's website (www.ba-and-t.com). The procedures were administered automatically on personal computers at remote sites where the author was not present.

General Procedure

Each session consisted of approximately 100 trials. A trial began when symbols, centered on two white illuminated backgrounds, appeared on the computer screen. The trial ended when the child selected a symbol in either illuminated area. A 3 sec. intertrial interval followed when the computer screen was dark, and then the next trial began. Correct choices during training sessions resulted in a flashing computer screen, and a point was also earned for each correct response. The total number of points accumulated was displayed as a "score" in the upper right corner of the computer screen. Reinforcement was not provided if an incorrect response occurred. During test sessions, reinforcement was provided regardless of which symbol the child selected.

After each step, the results were automatically analyzed by an algorithm, and a printable report was also generated. This was displayed on the computer screen following the session. The report documented and analyzed the findings. It also recommended whether repeating the procedures would be beneficial to improve attentional skills. The report included an assessment of learning efficiency, which determined how quickly the child attended to the relevant features of the visual materials. Also included in the report was an assessment of attention durability. This identified the extent to which attentional skills were disrupted. Finally, the report provided an assessment of attention focus, which identified whether attention could be directed to relevant features in the visual display.

Single Symbol Training

In the first step, each child learned three separate visual discriminations, which were composed of six different symbols (See Fig. 1). The S+ and S- symbols were presented simultaneously. Each of the symbols appeared an equal number of times on the left and right portions of the computer screen in a block of 20 trials, and the S+ symbol never appeared more than twice in succession in the same location. Each of the individual symbol pairs was presented during single symbol training until criterion accuracy was achieved (90% accuracy in a 10-trial sequence).

(+)	(-)
Rabbit	Plum
Scissors	Cane
Grasses	Mule

Figure 1. Diagram of the three separate visual discriminations established prior to formation of the compound stimuli. Plus (+) refers to symbols paired with reinforcement and minus (-) indicates symbols paired with extinction.

In the first discrimination task, rabbit and plum symbols appeared on the computer screen, and reinforcement was provided whenever the child selected the rabbit symbol (S+) on the computer screen. Reinforcement was not provided, however, if the plum symbol (S-) was selected. A prompt was provided on the first trial, which consisted of a cartoon character and an arrow pointing to the correct choice (rabbit) (See Fig. 2). When 90% accuracy was achieved, scissors and cane symbols were presented. Selecting the scissors symbol (S+) now produced reinforcement, but reinforcement was not produced if the child selected the cane symbol (S-). A prompt was also provided on the first trial to indicate the correct choice (scissors). After 90% accuracy occurred, the grasses and mule symbols next appeared on the screen. Selecting the grasses symbol (S+) was reinforced but selecting the mule symbol (S-) was not reinforced. A prompt was again provided on the first trial to designate the correct choice (grasses), and the symbol pair was presented until criterion accuracy was achieved.

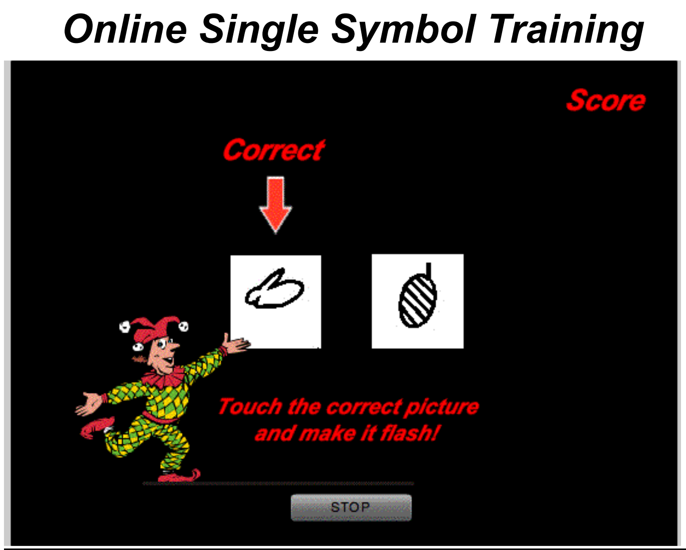

Figure 2. Diagram of the prompt which was provided on the first trial of each of the three visual discriminations, which consisted of a cartoon character and an arrow pointing to the correct choice (S+ symbol).

Mixed-Symbol Sequence

In the second step, the three original symbol pairs were presented in an unpredictable mixed sequence. Each of the three symbol pairs appeared twice in a block of six trials. In addition, no more than two S+ symbols appeared twice in succession in the same location. The individual symbols also occurred an equal number of times on the left and right portions of the computer screen in a block of 18 trials. The mixed-symbol sequence continued until the criterion of 28 out of 30 trials correct was achieved.

Conflict Compound

After criterion accuracy was obtained for the mixed-symbol sequence, the individual symbols were next combined to form a conflict compound. The conflict compound was created by keeping prior reinforcement histories unchanged for one symbol pair in the compound and reversing the prior reinforcement histories for the remaining two symbol pairs (See Fig. 3). The prior reinforcement histories were unchanged for only scissors and cane in the conflict compound. Scissors continued to be paired with reinforcement and cane with extinction, which was unchanged from original single-symbol training. The prior reinforcement histories were reversed, however, for the remaining four symbols. Plum and mule were now paired with reinforcement in the compound and rabbit and grasses with extinction, which was the reverse of original single-symbol training.

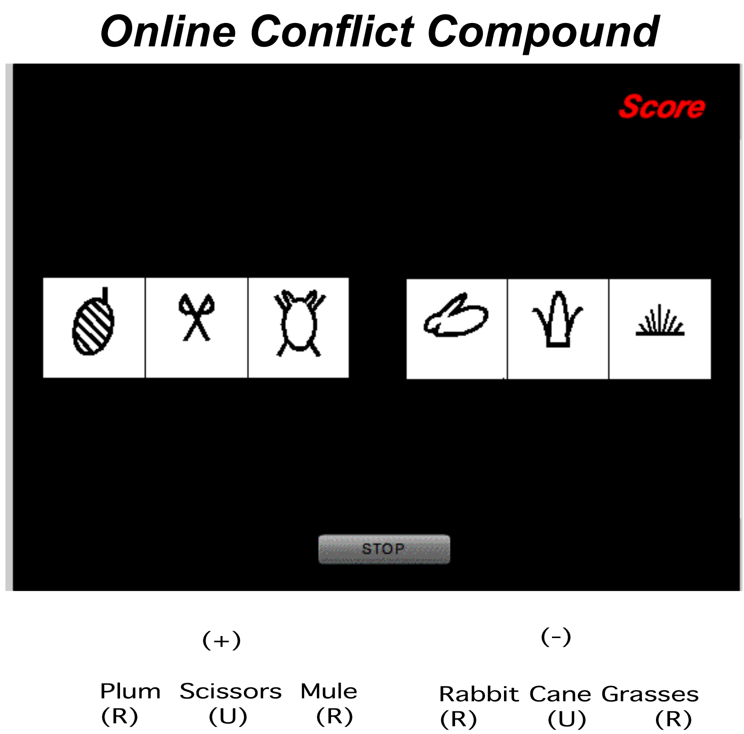

Figure 3. Diagram of the conflict-compound discrimination. Plus (+) indicates stimulus compound paired with reinforcement and minus (-) denotes stimulus compound paired with extinction. The S+ and S- compounds were presented simultaneously and were each composed of three symbols. The positions of the unchanged symbols (U) and reversed symbols (R) within the compounds are shown in the diagram and remained constant across trials.

.

Test Conditions

After criterion accuracy (90% accuracy in a 20-trial sequence) was achieved for the conflict compound, test trials were presented. This consisted of thirty-six test trials in which the three symbol pairs were presented 12 times each in a mixed sequence. Reinforcement was provided during the test trials regardless of which symbol the child selected. The purpose of the test was to assess which symbols the child was attending to when criterion accuracy was obtained for the compound discrimination. The percentages of responses during the unchanged-symbol and reversed-symbol test trials that were in agreement with the reinforcement contingencies of the conflict compound were calculated. Symbols associated with high percent agreement scores (80% or greater) were concluded to control responding in the conflict compound when criterion accuracy was attained.

The symbol the children selected each time the conflict compound appeared on the screen was also recorded with software. This provided a direct comparison of test session results with symbols selected in the conflict compound when compound criterion accuracy was met.

Response latencies were also recorded for the six-year-old child in the different steps of the procedure. Response latency was defined as the amount of time that elapsed between the presentation of symbol pairs on the child's computer screen and his symbol selection.

Extended Training

Additional exposure to the initial stimulus-control procedures was given to the younger child (3 yrs), who participated in this study. The stimulus-control procedures were repeated to determine how prior reinforcement histories affected which symbols of the compound stimuli the younger child attended to when additional training was provided. The three visual discriminations, composed of six different symbols, were presented a second time, and mixed-symbol training was also presented again until criterion accuracy was achieved. Following criterion accuracy, the individual symbols were combined a second time to form the conflict compound, in which the prior reinforcement histories were unchanged for scissors and cane in the compound but were reversed for the remaining four symbols. Plum and mule were again paired with reinforcement in the compound and rabbit and grasses with extinction, which was the reverse of original single-symbol training. After 90% accuracy was met for the conflict compound, 36 test trials were administered a second time. The three symbol pairs were again presented 12 times each in a mixed sequence, and software also recorded as before which symbol the younger child selected each time the conflict compound appeared on the screen.

Results

Younger Child (3 yrs)

Single-symbol training. In the first phase, the younger child learned the three separate single-symbol discriminations online and the prompts and reinforcement were provided by the software (See Fig. 4). When the first single-symbol discrimination (rabbit+ vs. plum-) was presented, the younger child made eight errors (69% accuracy) and required 26 trials before achieving criterion accuracy. The younger child made only one error (90% accuracy) when the second single-symbol discrimination (scissors+ vs, cane-) was presented and achieved criterion accuracy in the first ten trials. He also made only one error (90% accuracy) when the third single-symbol discrimination (grasses+ vs. mule-) was presented and again achieved criterion accuracy in the first ten trials. In summary, although the younger child made a considerable number of errors and required more trials before acquiring the first single-symbol discrimination, he learned the second and third single-symbol discriminations more quickly and with only one error occurring for both discriminations.

Mixed-symbol sequence. During the second phase when the three original single-symbol discriminations were presented in an unpredictable mixed sequence, the younger child made 11 errors during the mixed-symbol sequence (See Fig. 4). Four errors (79% accuracy) occurred for the rabbit+ vs. plum- discrimination. Three errors (84% accuracy) occurred for the scissors+ vs. cane- discrimination, and four errors (78% accuracy) occurred for the grasses+ vs. mule- discrimination. The younger child required 56 trials before he achieved criterion accuracy for the mixed-symbol sequence. Intermixing the three single-symbol discriminations in an unpredictable sequence disrupted their original criterion accuracy for the younger child.

Conflict compound. When the conflict compound was presented, the younger child made two errors (90% accuracy) and required 20 trials to reach criterion accuracy (See Fig. 4). Both errors occurred because he selected a reversed S- symbol (rabbit) in the conflict compound in the first two trials. In the remaining 18 trials, the younger child selected reversed S+ symbols (plum and mule) in the conflict compound in 16 of the trials and the unchanged S+ symbol (scissors) in two of the trials. When criterion accuracy was achieved, the younger child selected the unchanged S+ symbol (scissors) in 2 of the 18 correct trials (11%), a reversed S+ symbol (plum) in 11 of the 18 correct trials (61%), and a reversed S+ symbol (mule) in 5 of the 18 correct trials (28%) (See Fig. 5). The younger child did not shift his attention to the unchanged S+ symbol (scissors) in the conflict compound. He responded primarily to reversed S+ symbols (plum and mule) in the conflict compound, with two exceptions, when criterion accuracy was met.

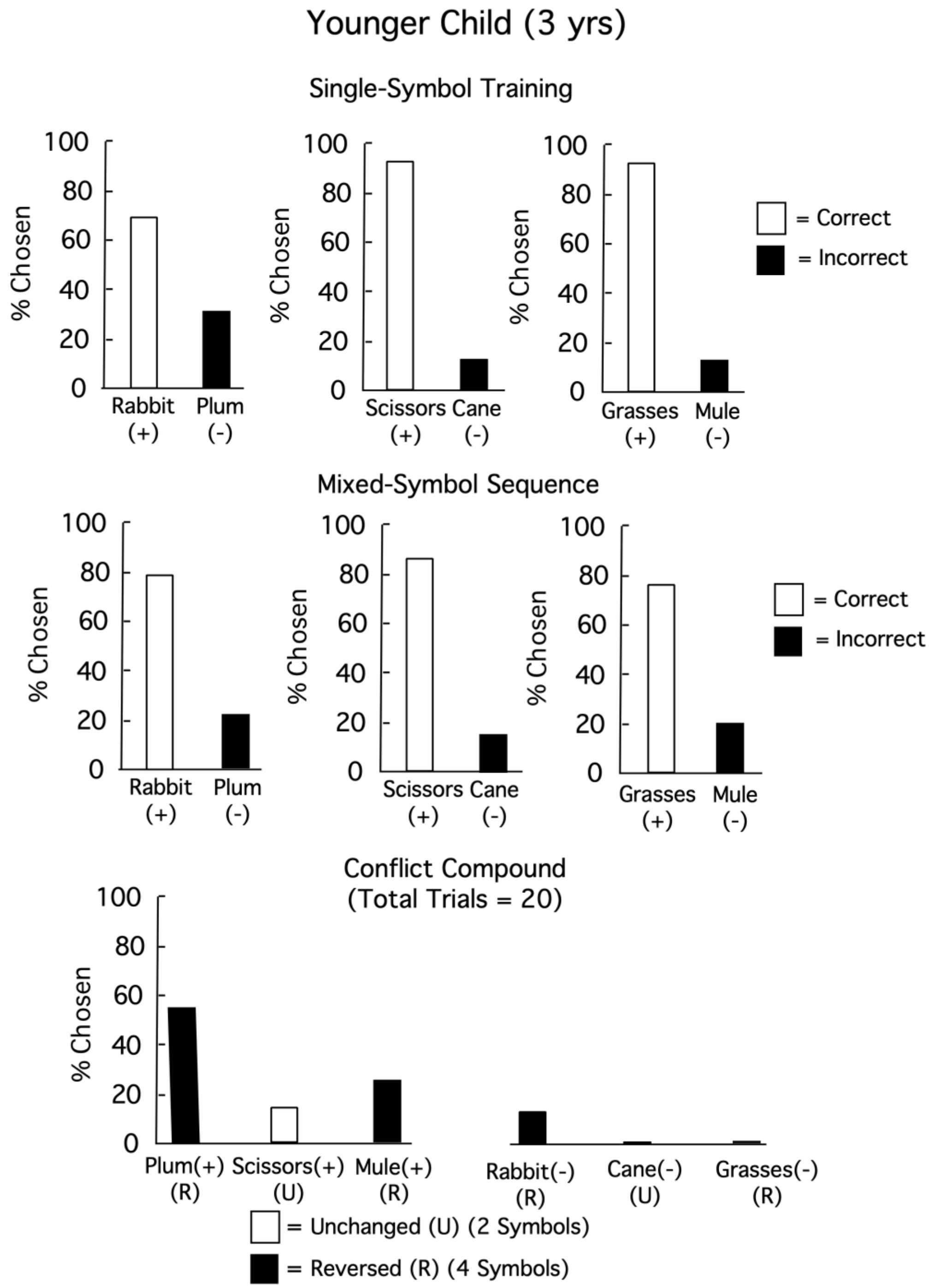

Figure 4. For the younger child, percent accuracy for the three symbol discriminations during single-symbol training and during the mixed-symbol sequence. In addition, percentage S+ and S- unchanged symbols (white bars) and S+ and S- reversed symbols (black bars) were chosen when the conflict compound was originally presented.

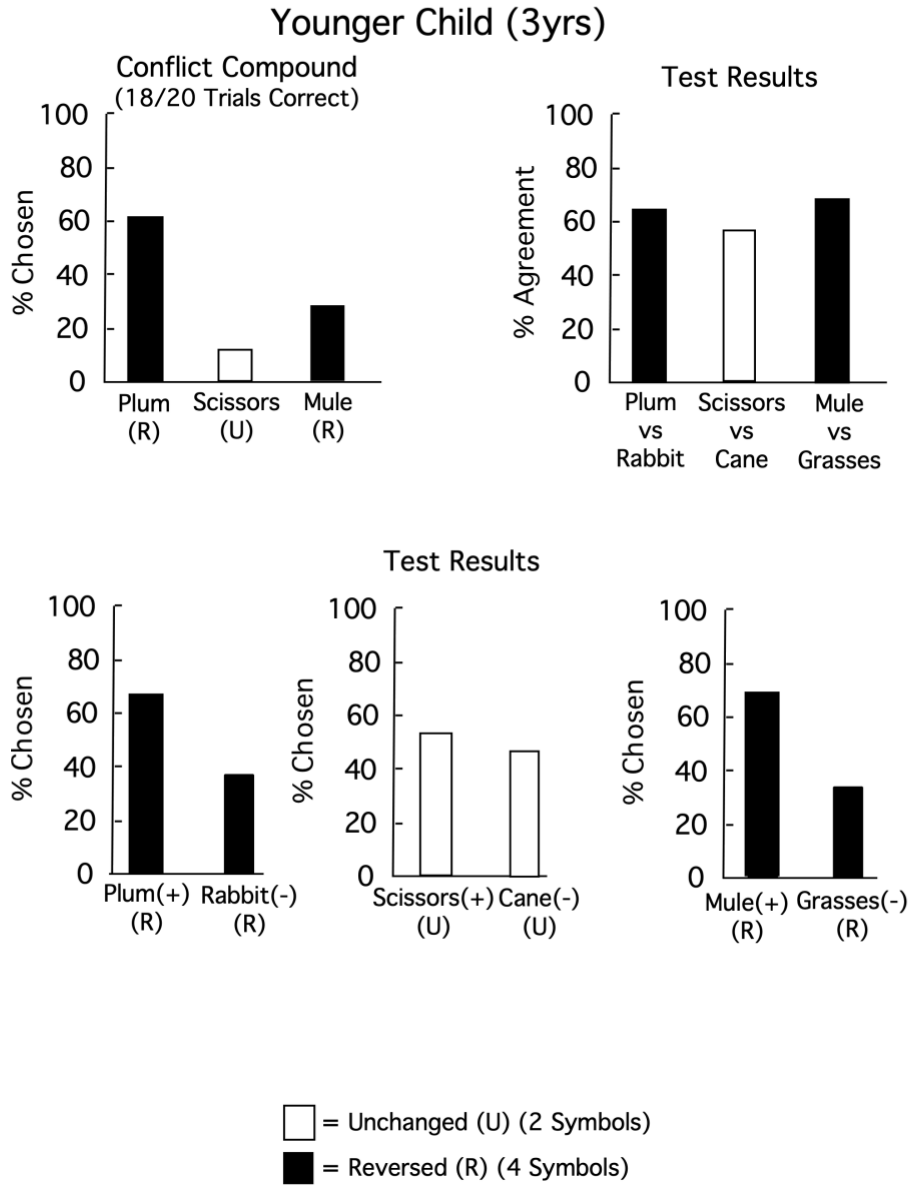

Figure 5. For the younger child, (left graph) percentage each of the three S+ symbols was chosen during reinforced trials when criterion accuracy was originally achieved for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies of the conflict compound. The top symbols shown for the younger child were positive and the bottom symbols were negative in the conflict-compound discrimination. Bottom graphs show the percentage of trials the individual symbols were chosen in the test trials. White bars and black bars indicate unchanged and reversed symbols, respectively.

Test results. The test performance of the younger child, following criterion accuracy, also indicated he did not selectively attend to the unchanged symbol (scissors) in the conflict compound. None of the three symbol-pairs exercised stimulus control in agreement (80% or higher) with the reinforcement contingencies of the conflict compound (See Fig. 5). The unchanged-symbol pair exercised only a 54% level of agreement with the reinforcement contingencies of the conflict compound. One of the reversed-symbol pairs was associated with a 64% level of agreement with the reinforcement contingencies of the conflict compound. The other reversed-symbol pair was associated with a 67% level of agreement (See Fig. 5).

The original stimulus control of the unchanged symbol pair was disrupted because of the interfering effect of the reversed symbols in the conflict compound. The younger child selected both the unchanged S+ symbol and the unchanged S- symbol during the test trials. The original stimulus control of the symbols, whose prior reinforcement contingencies were reversed in the conflict compound, was also disrupted following acquisition of the conflict compound. The younger child responded to both reversed S+ symbols and reversed S- symbols during the reversed symbol test trials (See Fig. 5).

In summary, both the response topographies and the test performance of the younger child indicated that he did not shift his attention to the unchanged symbol in the conflict compound.

Younger Child (3 yrs) (Extended Training)

Single-symbol training. In the first phase of extended training, the younger child was presented again with the same three separate single-symbol discriminations (See Fig. 6). The prompts and reinforcement were again provided by the software. The younger child made only one error (90% accuracy) when the first single-symbol discrimination (rabbit+ vs. plum-) was presented and achieved criterion accuracy in the first ten trials. When the second single-symbol discrimination (scissors+ vs. cane-) was presented, he made three errors (82% accuracy) and required 17 trials to achieve criterion accuracy. One error (90% accuracy) occurred when the third single-symbol discrimination (grasses+ vs. mule-) was presented and the younger child achieved criterion accuracy in the first ten trials. In summary, the younger child made only a total of five errors when the three single-symbol discriminations were presented in extended training compared to a total of ten errors that occurred when the three single-symbol discriminations were originally presented.

Mixed-symbol sequence. In the second phase of extended training, the three single-symbol discriminations were again presented in an unpredictable mixed sequence (See Fig. 6). Only one error (89% accuracy) occurred for the rabbit+ vs. plum- discrimination. The younger child achieved 100% accuracy for both the scissors+ vs. cane- discrimination and the grasses+ vs. mule- discrimination. During extended training, the younger child made only one error in the mixed-symbol sequence and required only 29 trials to achieve criterion accuracy. In contrast, eleven errors and 56 trials were required to achieve criterion accuracy when the mixed-symbol sequence was initially presented. Although initially intermixing the three single-symbol discriminations in an unpredictable sequence disrupted their original criterion accuracy, the criterion accuracy for each of the three single-symbol discriminations was successfully maintained when extended training was provided. Intermixing the three single-symbol discriminations in an unpredictable sequence did not disrupt their criterion accuracy in extended training (See Fig.6).

Conflict compound. When extended training was provided for the conflict compound, the younger child required 22 trials to reach criterion accuracy. He made a total of three errors (86% accuracy), and two of the errors occurred in the first three trials when the young child selected reversed S- symbols (rabbit and grasses). The third error occurred on the thirteenth trial when he selected the unchanged S- symbol (cane) (See Fig. 6). In the remaining 19 trials during extended training, the younger child selected the unchanged S+ symbol (scissors)l in the conflict compound. When criterion accuracy was achieved a second time for the conflict compound, he selected the unchanged S+ symbol (scissors) in each of the 18 correct trials (100%) (See Fig. 7). The younger child shifted his attention to the unchanged S+ symbol (scissors) in the conflict compound after only two responses occurred to the reversed S- symbols when extended training was provided. Prior to extended training, the younger child did not shift his attention to the unchanged S+ symbol (scissors) in the conflict compound.

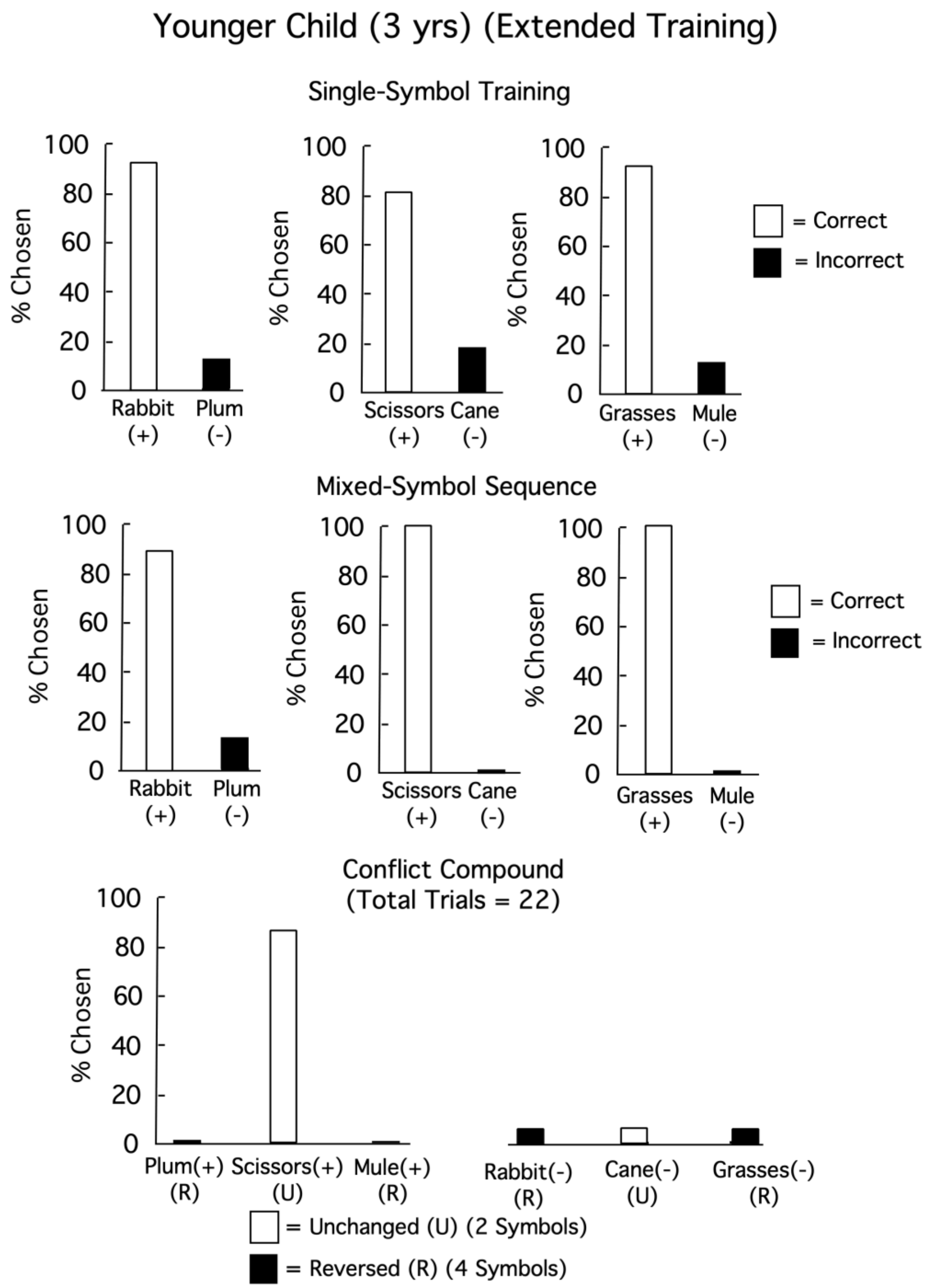

Figure 6. For the younger child, percent accuracy for the three symbol discriminations when single-symbol training and the mixed-symbol sequence were presented a second time. In addition, percentage S+ and S- unchanged symbols (white bars) and S+ and S- reversed symbols (black bars) were chosen when the conflict compound was presented a second time.

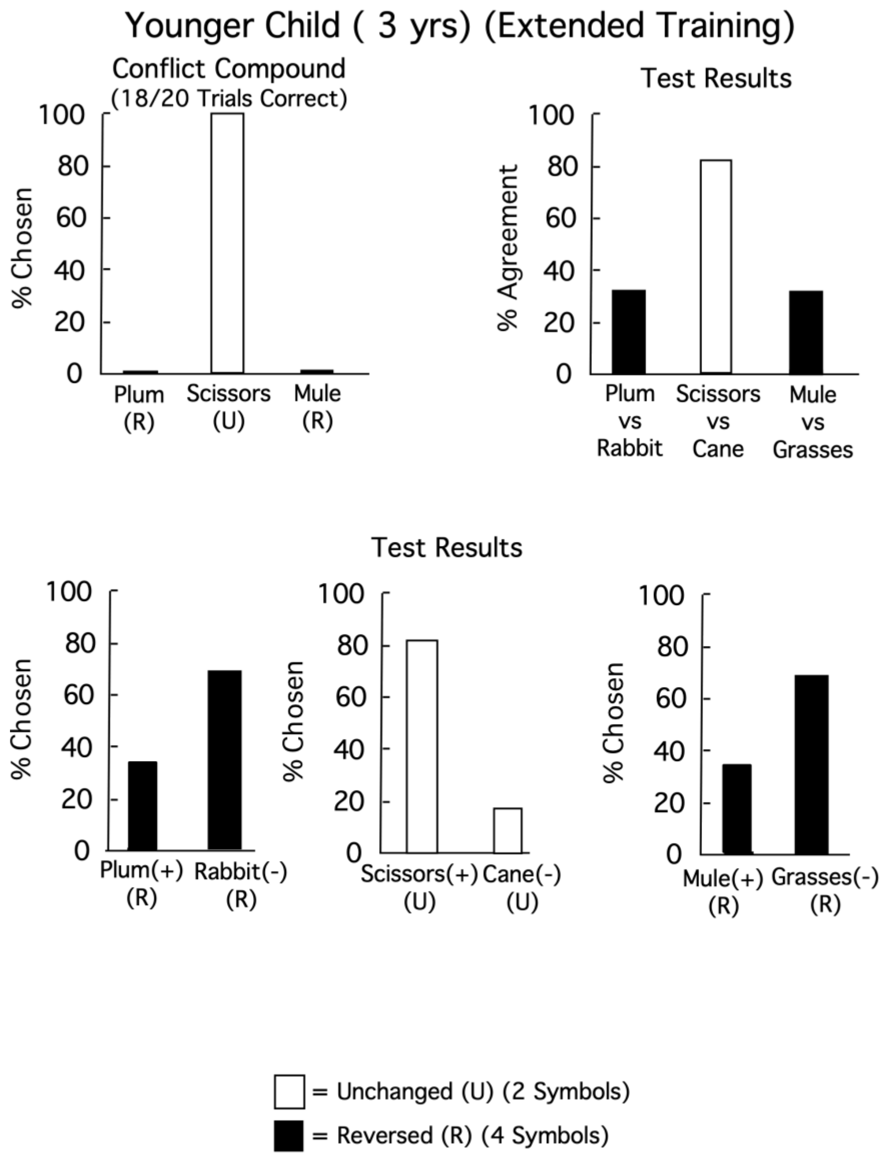

Figure 7. For the younger child, (left graph) percentage each of the three S+ symbols was chosen during reinforced trials when criterion accuracy was achieved a second time for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies of the conflict compound following extended training. The top symbols shown for the younger child were positive and the bottom symbols were negative in the conflict-compound discrimination. Bottom graphs show the percentage of trials the individual symbols were chosen in the test trials following extended training. White bars and black bars indicate unchanged and reversed symbols, respectively.

Test results. His test performance, based on less than 36 trials because of equipment malfunction, further confirmed because of extended training that the younger child shifted his attention to the unchanged S+ symbol (scissors) in the conflict compound when criterion accuracy was achieved. This was concluded since only the unchanged S+ symbol (scissors) exercised stimulus control in agreement (80% or higher) with the reinforcement contingencies of the conflict compound following extended training (See Fig. 7). The unchanged-symbol pair exercised an 83% level of agreement with the reinforcement contingencies of the conflict compound as the younger child selected the unchanged S+ symbol (scissors) in 83% of the unchanged-symbol test trials. In contrast, only a 33% level of agreement occurred for both reversed S+ symbols (plum and mule) after extended training was provided (See Fig. 7).

When the conflict compound was presented a second time during extended training, the two stimulus-response relations paired with extinction (because their prior reinforcement contingencies were reversed in the compound) decreased in frequency. The stimulus-response relations paired with extinction in the compound were also disrupted. This was shown because the younger child selected the reversed S+ symbols (plum and mule) in 33% of the reversed-symbol test trials. He selected the reversed S- symbols (rabbit and grasses) in 67% of the test trials, which had previously been S+ symbols in single-symbol training. Although the original stimulus control of the symbols (whose prior reinforcement contingencies were reversed in the conflict compound) was disrupted following acquisition of the conflict compound, the original stimulus control of the unchanged symbol remained intact (See Fig. 7). In contrast, the test performance of the younger child before extended training was provided revealed the stimulus control of all three symbol pairs was disrupted.

In summary, after extended training was provided, both the response topographies and the test performance of the younger child revealed that he shifted his attention to the unchanged S+ symbol in the conflict compound after only a few responses to the reversed S- symbols initially occurred.

Older Child (6 yrs)

Single-symbol training. The older child made only two errors during single-symbol training and achieved, as a result, a high level of accuracy for each of the three single-symbol discriminations when the stimulus-control procedures were initially presented (See Fig. 8). Although he achieved high accuracy scores for all three discriminations throughout single-symbol training, in contrast to the younger child, his response latencies showed changes in stimulus control not revealed by his accuracy scores.

For the first single-symbol discrimination where rabbit was the S+ symbol and plum was the S- symbol, the older child did not make any errors (100% accuracy) and achieved criterion accuracy in the first nine trials. His average response latency for the first single-symbol discrimination was 2.4 seconds (See Fig. 9. Initially, his response latencies in the first two trials of the first discrimination were 8.7 seconds and 2.9 seconds respectively. The response latencies of the older child decreased in subsequent trials and varied between .9 and 2 seconds.

For the second single-symbol discrimination where scissors was the S+ symbol and cane was the S- symbol, the older child made two errors (86% accuracy) and achieved criterion accuracy in the first 14 trials. The average response latency (1.3 seconds) of the second single-symbol discrimination was less than the average response latency (2.4 seconds) of the first discrimination (See Fig. 10). The initial response latency of 3.7 seconds in the first trial of the second discrimination was also lower than the 8.7 seconds latency recorded in the first trial of the first discrimination task. Response latencies decreased in subsequent trials of the second-symbol discrimination and varied between .6 and 1.5 seconds.

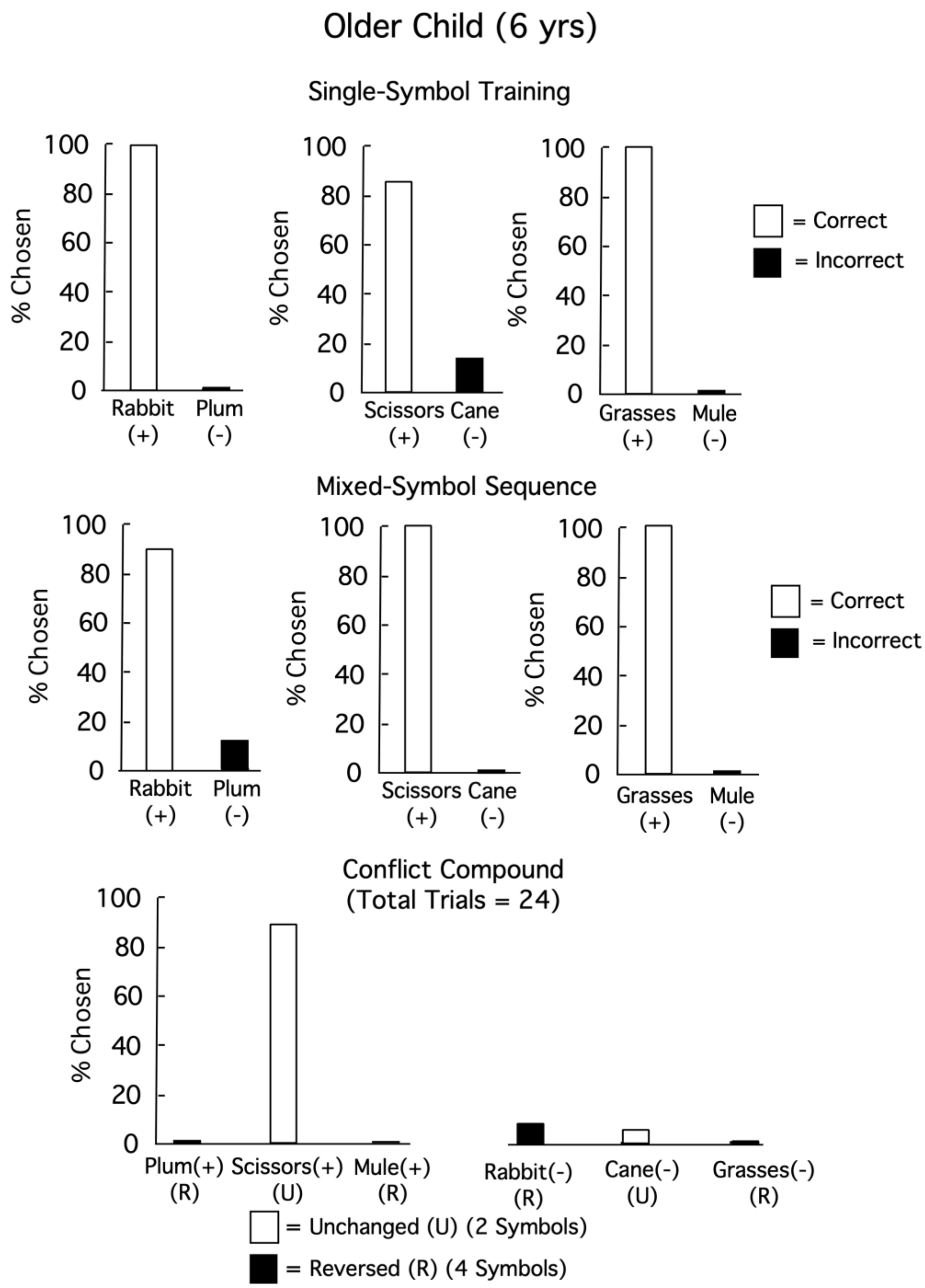

Figure 8. For the older child, percent accuracy for the three symbol discriminations during single-symbol training and during the mixed-symbol sequence. In addition, percentage S+ and S- unchanged symbols (white bars) and S+ and S- reversed symbols (black bars) were chosen when the conflict compound was presented.

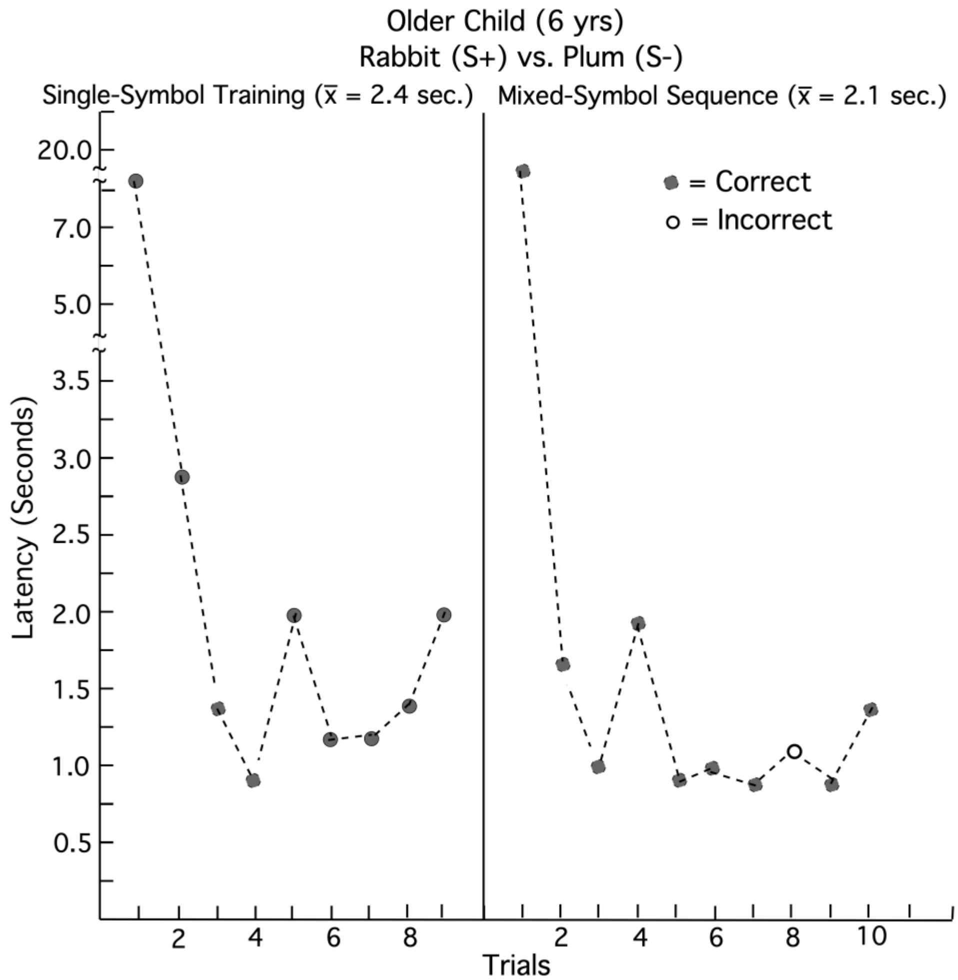

Figure 9. For the older child, response latency for rabbit (+) vs. plum (-) during single-symbol training and during the mixed-symbol sequence.

In the third single-symbol discrimination in which grasses was the S+ symbol and mule was the S-symbol, the older child did not make any errors (100% accuracy) and achieved criterion accuracy in the first nine trials. His average response latency for the third-symbol discrimination was 1.6 seconds, which was comparable to the average response latency of his second discrimination (1.3 seconds) (See Fig. 11). Although response latencies of 3.7 seconds and 2.8 seconds occurred in the third and eighth trials of the third single-symbol discrimination, in the remaining trials his response latencies varied between .6 and 1.7 seconds.

In summary, the older child achieved high accuracy scores for all three single-symbol discriminations. His response latencies, however, showed changes in stimulus control not reflected by the older child's accuracy scores.

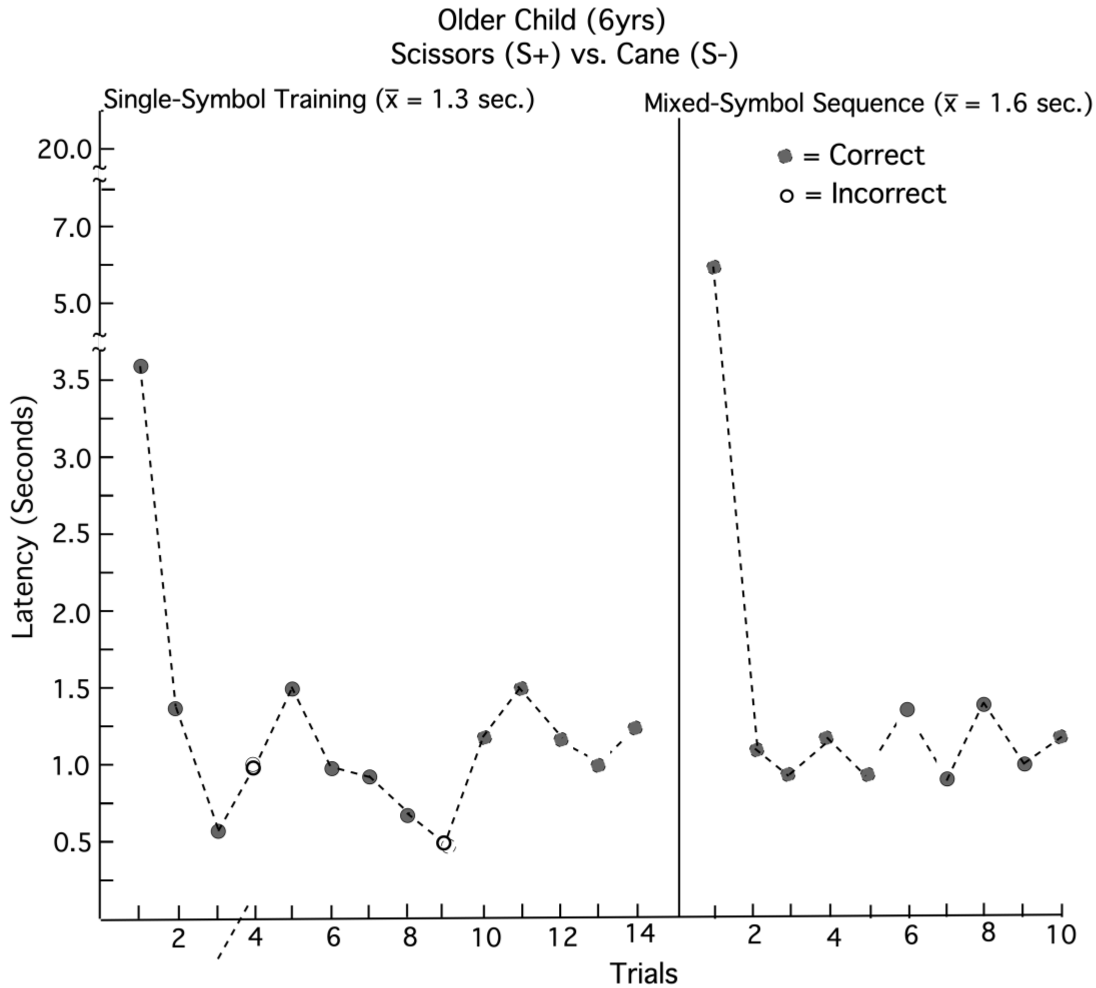

Figure 10. For the older child, response latency for scissors (+) vs. cane (-) during single-symbol training and during the mixed-symbol sequence.

Mixed-symbol sequence. During the second phase when the three original single-symbol discriminations were presented in an unpredictable mixed sequence, the older child achieved high accuracy for each of the three discriminations. (See Fig. 8). He made only one error (90% accuracy) for the first single-symbol discrimination and achieved 100% accuracy for both the second and third single-symbol discriminations in the mixed-symbol sequence. As a result, the older child achieved criterion accuracy in the first 29 trials. Although intermixing the three single-symbol discriminations in an unpredictable sequence did not disrupt their original criterion accuracy for the older child, his response latencies again demonstrated changes in stimulus control not revealed by his accuracy scores.

The average response latency for the first single-symbol discrimination (rabbit+ vs. plum-) during the mixed-symbol sequence was 2.1 seconds, which was a slight decrease from the original average response latency of 2.4 seconds for the first single-symbol discrimination (See Fig. 9). There was a large increase, however, in response latency (9.8 seconds) in the first trial of the first single-symbol discrimination during the mixed-symbol sequence. This disruption in stimulus control did not persist as response latencies varied between .8 and 1.9 seconds in subsequent trials. A pause of 20 seconds did occur, however, between the ninth and tenth trials of the mixed-symbol sequence for the first single-symbol discrimination.

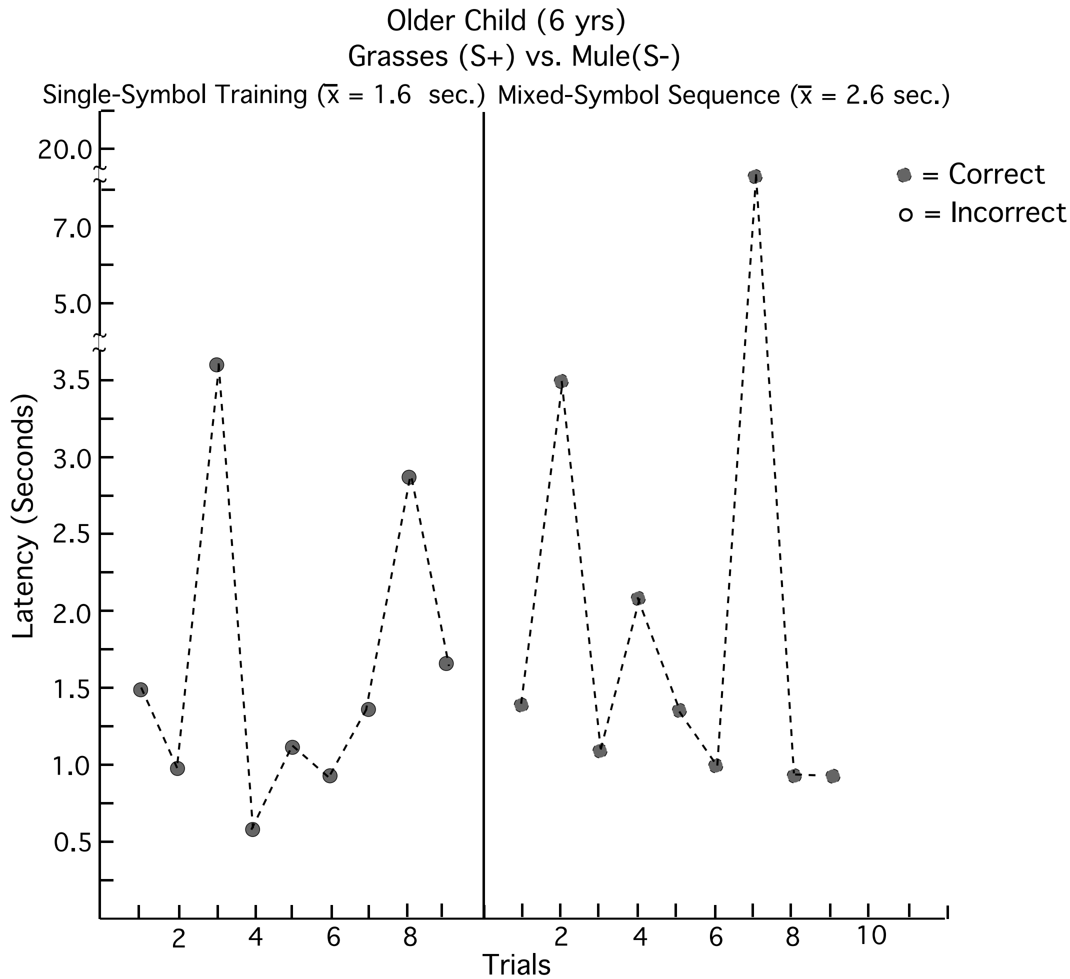

Figure 11. For the older child, response latency for grasses (+) vs. mule (-) during single-symbol training and during the mixed-symbol sequence.

The average response latency for the second single-symbol discrimination (scissors+ vs. cane-) during the mixed-symbol sequence was 1.6 seconds, which was slightly larger than the original average response latency (1.3 seconds) for the second single-symbol discrimination (See Fig. 10). This slight increase in the average response latency for the second discrimination was the result of a longer response latency of 5.9 seconds that occurred in the first trial of the second discrimination during the mixed-symbol sequence. In subsequent trials, response latencies decreased and varied between .9 and 1.4 seconds. The average response latency (1.6 seconds) of the second single-symbol discrimination during the mixed-symbol sequence was less than the average response latency (2.1 seconds) of the first single-symbol discrimination during the mixed-symbol sequence.

For the third single-symbol discrimination (grasses+ vs. mule-), the average response latency during the mixed-symbol sequence was 2.6 seconds, which was larger than the original average response latency of 1.6 seconds for the third single-symbol discrimination (See Fig. 11). This increase in average response latency was the result of the longer response latencies of 3.5 and 11 seconds that occurred in the second and seventh trials of the mixed-symbol sequence for the third discrimination. In the remaining trials, response latencies varied between .9 and 2.1 seconds. The average response latency (2.6 seconds) of the third discrimination during the mixed-symbol sequence was also larger than the average response latencies of both the second discrimination (1.6 seconds) and the first discrimination (2.1 seconds) during the mixed-symbol sequence.

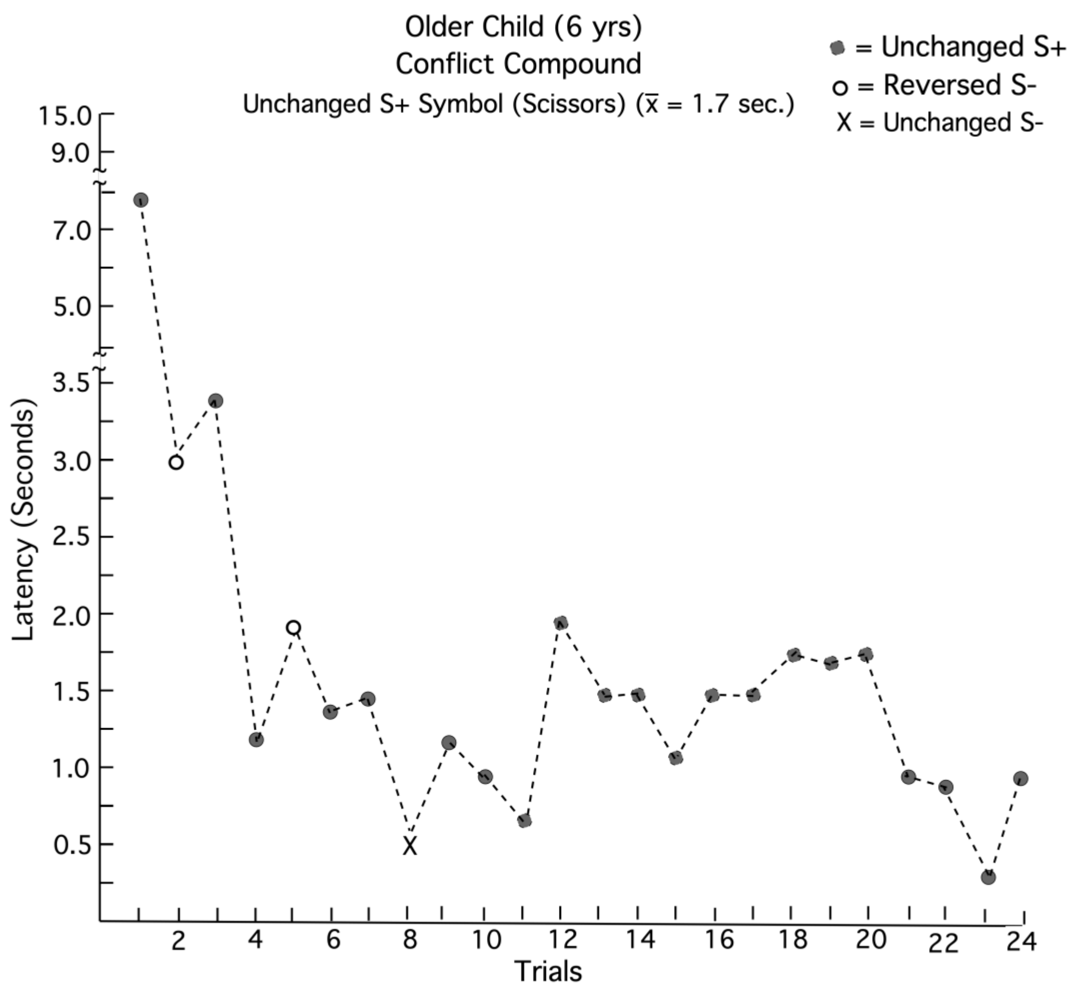

Figure 12. For the older child, response latency for unchanged S+ symbol (scissors) during presentation of the conflict compound

In summary, the response latencies of the older child revealed that in some trials the stimulus control of the three single-symbol discriminations was disrupted when the three discriminations were intermixed. This was shown by the increase in response latency that occurred in the initial trials of the first and second single-symbol discriminations during the mixed-symbol sequence. Increases in response latency also occurred in later trials of the third single-symbol discrimination during the mixed-symbol sequence. This disruption in stimulus control during the mixed-symbol sequence, revealed by the older child's response latencies, was not indicated by his accuracy scores.

Conflict compound. The older child made only three errors (88% accuracy) when the conflict compound was presented and achieved criterion accuracy in first 24 trials (See Fig. 8). Two errors occurred because he selected a reversed S- symbol (rabbit) in the second and fifth trials of the conflict-compound discrimination. The older child also made a third error when he selected the unchanged S- symbol (cane) in the eighth trial of the conflict compound. In the remaining 21 trials, the older child selected the unchanged S+ symbol (scissors) in the conflict compound. When criterion accuracy was achieved, the older child consistently selected the unchanged S+ symbol (scissors) in each of the 18 correct trials of the conflict-compound discrimination. He also shifted his attention to the unchanged S+ symbol with only two responses to a reversed symbol occurring (See Fig. 8).

The response topographies of the older child demonstrated that he consistently responded to the unchanged S+ symbol (scissors) in each of the 18 correct trials when criterion accuracy for the conflict-compound discrimination was achieved. He also consistently selected the S+ symbol (scissors) (100% accuracy) during the mixed-symbol sequence. The response latency of the older child, however, revealed a reduction in stimulus control for the unchanged S+ symbol (scissors) when the conflict compound was initially presented (See Fig. 12). When the conflict compound was presented, his response latency for the unchanged S+ symbol (scissors) increased to 7.7 seconds and gradually decreased in the initial trials of the conflict compound. Fluctuations in response latency for the unchanged S+ symbol (scissors) continued to occur, however, throughout the presentation of the conflict compound. In contrast, his response latencies for the S+ symbol (scissors) during the final trials of the mixed-symbol sequence, which immediately preceded the presentation of the conflict compound, remained below two seconds.

In summary, the response accuracy and response topographies of the older child revealed high and stable levels of stimulus control for the S+ symbol (scissors) in both the mixed-symbol sequence and the conflict compound. His response latencies, however, showed a reduction in stimulus control for the unchanged S+ symbol (scissors) when the conflict compound was initially presented. This initial reduction in stimulus control of the unchanged S+ symbol (scissors) in the conflict compound, demonstrated by the longer response latencies of the older child, occurred because of the interfering effect of the reversed symbols in the conflict compound. The interfering effect of the reversed symbols on the stimulus control of the unchanged S+ symbol (scissors) was not revealed, in contrast, by his response accuracy and response topographies.

Test results. The test performance of the older child further confirmed that he shifted his attention to the unchanged symbol (scissors) in the conflict compound when he achieved criterion accuracy. This was shown as only the unchanged-symbol pair (scissors+ vs cane-) exhibited stimulus control in agreement with the reinforcement contingencies of the conflict compound (See Fig. 13). The unchanged-symbol pair demonstrated a 100% level of agreement with the reinforcement contingencies of the conflict compound since the older child consistently selected the unchanged S+ symbol (scissors) throughout the unchanged-symbol test trials. Because the older child consistently selected the reversed S- symbols (rabbit and grasses) during the reversed-symbol test trials, a 0% level of agreement with the reinforcement contingencies of the conflict compound, in contrast, occurred for both reversed-symbol pairs (See Fig. 13).

The stimulus-response relations paired with extinction in the compound (because their prior reinforcement contingencies were reversed) decreased in frequency when the conflict compound was presented. This occurred without the original stimulus-response relations being disrupted. The older child never selected the reversed S+ symbols (plum and mule) during the reversed-symbol test trials. He selected, instead, only the reversed S- symbols (rabbit and grasses) during the reversed-symbol test trials, which had previously been S+ symbols in single-symbol training (See Fig. 13). The symbols selected during the test trials indicated the two original stimulus-response relations paired with extinction in the compound remained intact even after they failed to occur when the conflict compound was presented.

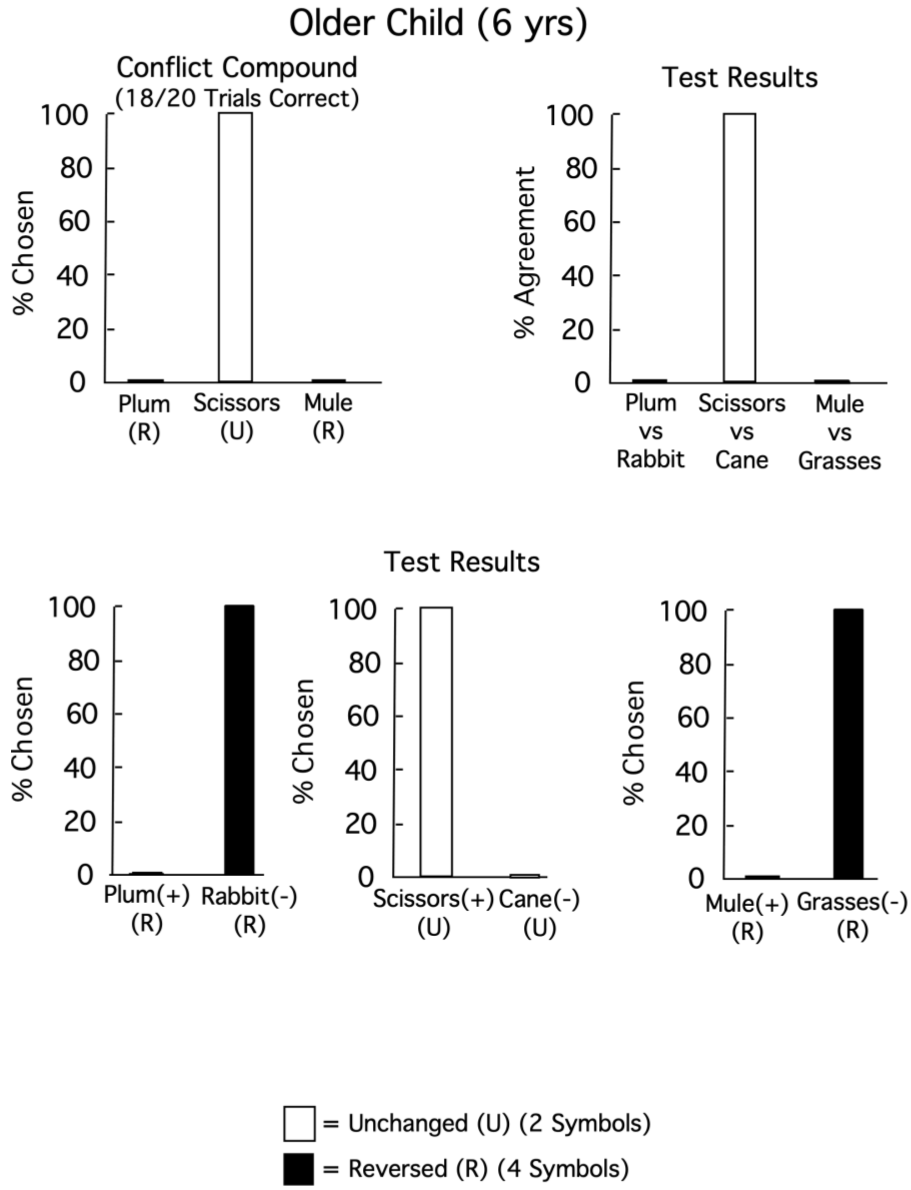

Figure 13. For the older child, (left graph) percentage each of the three S+ symbols was chosen during reinforced trials when criterion accuracy was achieved for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies of the conflict compound. The top symbols shown for the older child were positive and the bottom symbols were negative in the conflict-compound discrimination. Bottom graphs show the percentage of trials the individual symbols were chosen in the test trials. White bars and black bars indicate unchanged and reversed symbols, respectively.

The response latencies of the older child during the test trials also confirmed that the three original stimulus-response relations were not disrupted because of being combined to form the conflict compound. The unchanged S+ symbol (scissors) showed an initial reduction in stimulus control in the conflict compound because of increased response latency. During the unchanged-symbol test trials, however, the average response latency (1.4 seconds) for scissors was comparable to the average response latency (1.6 seconds) for scissors during the mixed-symbol sequence administered before the conflict-compound discrimination was presented (See Fig. 14). Although the increased response latency indicated the stimulus control of the unchanged S+ symbol (scissors) was initially reduced in the conflict compound, the response latencies for scissors during the unchanged-symbol test trials revealed the original stimulus control of scissors remained intact.

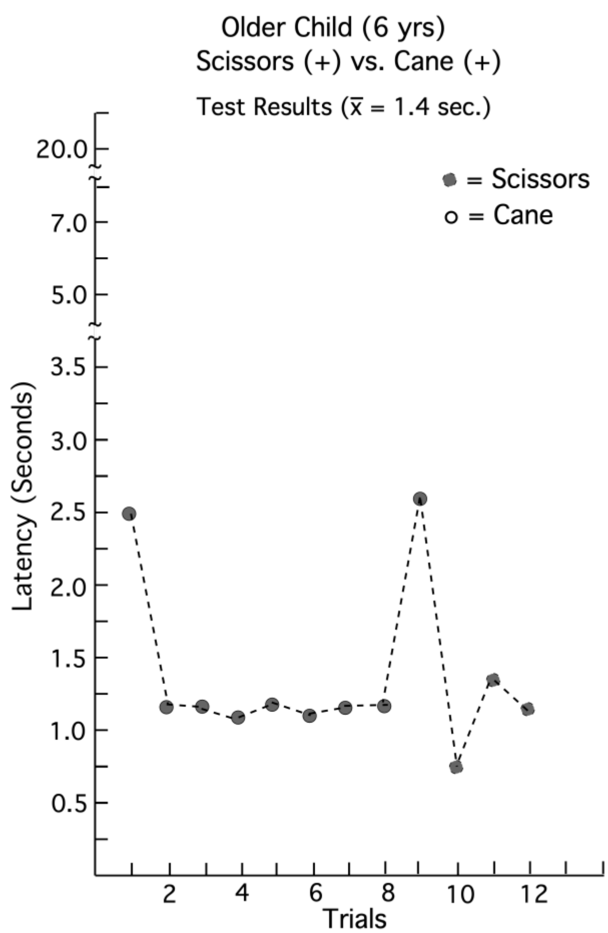

Figure 14. For the older child, response latency for scissors vs. cane during test trials.

The response latencies of the two stimulus-response relations, whose prior reinforcement contingencies were reversed in the conflict compound, also demonstrated their original stimulus control was not disrupted because of appearing in the conflict compound. Although rabbit was a reversed S- symbol in the conflict compound, it was consistently selected during the reversed-symbol test trials. The average response latency (1.5 seconds) for rabbit during the reversed-symbol test trials (See Fig. 15) was less than the average response latency (2.1 seconds) for rabbit when it was a S+ symbol in the mixed-symbol sequence (See Fig. 15). The consistent selection of rabbit and the shorter response latency for rabbit in the reversed-symbol test trials demonstrated the original stimulus control of rabbit was not disrupted when the prior reinforcement history of rabbit was reversed in the conflict compound.

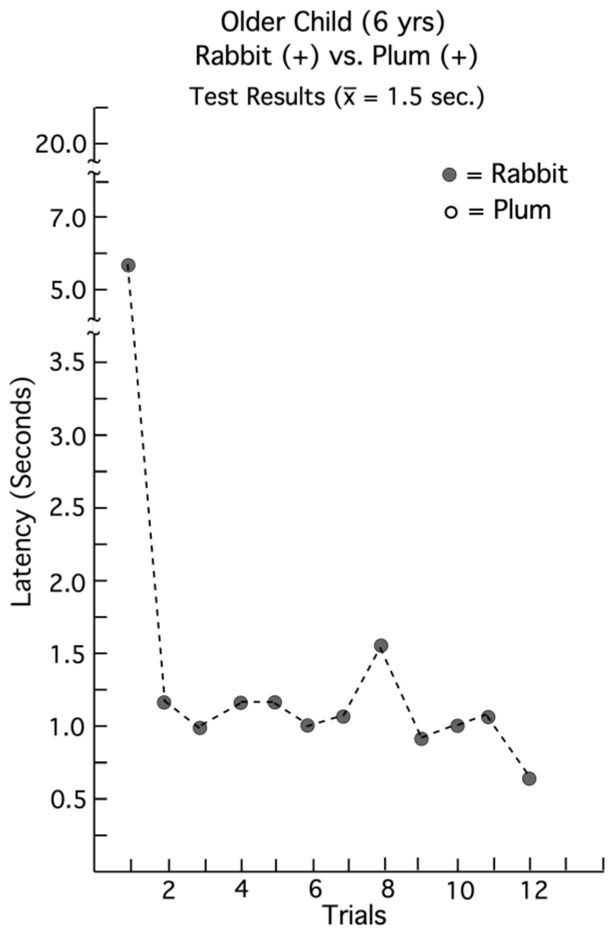

Figure 15. For the older child, response latency for rabbit vs. plum during test trials.

Grasses was a reversed S- symbol in the conflict compound and it was also consistently selected during the reversed-symbol test trials. The average response latency (1.2 seconds) for grasses during the reversed-symbol test trials (See Fig. 16) was less than the average response latency (2.6 seconds) for grasses when it was a S+ symbol in the mixed-symbol sequence (See Fig. 11). The consistent selection of grasses and the shorter response latency for grasses in the reversed-symbol test trials demonstrated the original stimulus control of grasses was also not disrupted when the prior reinforcement history of grasses was reversed in the conflict compound.

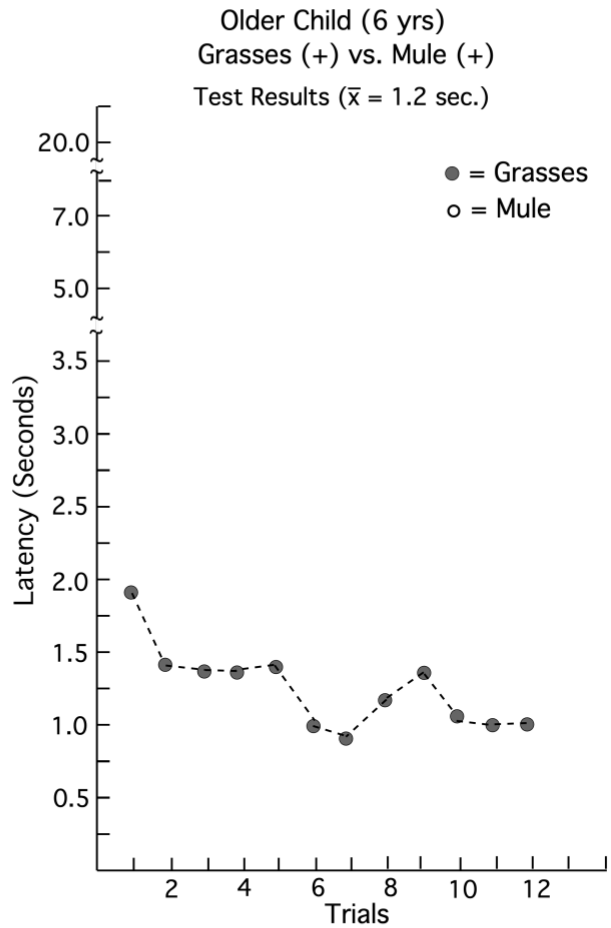

Figure 16. For the older child, response latency for grasses vs. mule during test trials

Discussion

Establishing prior reinforcement histories for separate stimulus components was effective in determining which features of compound visual cues young children attended to. Even when the stimulus-control procedures were administered online at remote sites where the author was not present, prior reinforcement histories proved effective in determining how the young children attended to a stimulus compound with conflicting prior reinforcement histories. The children selectively attended to the symbol with an unchanged prior reinforcement history in the stimulus compound. They ignored symbols with a reversed prior reinforcement history in the compound. This also occurred where touch screens were not utilized, and where only minimal positive reinforcement was provided in contrast to earlier investigations (Huguenin, 1987; Huguenin, 1997; Huguenin, 2000).

Individual differences were revealed, however, in how the young children attended to the conflict compound by employing online multiple testing procedures, which were automatically administered by the software. Neither the response topographies nor the test performance of the younger child (3 yrs) indicated that he selectively attended to the symbol with an unchanged reinforcement history in the conflict compound when he originally achieved criterion accuracy. The younger child responded to reversed symbols in the conflict compound, with two exceptions, when the conflict compound was initially presented. The test performance of the younger child, following initial criterion accuracy, also indicated he did not selectively attend to the unchanged symbol in the conflict compound. None of the three symbol pairs exercised stimulus control in agreement with the reinforcement contingencies of the conflict compound during the test trials.

After extended training was provided, however, prior reinforcement histories were effective in determining how the younger child attended to the conflict compound. Following extended training, the younger child shifted his attention to the unchanged symbol. He consistently selected the unchanged symbol in each of the correct trials when criterion accuracy was achieved a second time for the conflict compound. He also shifted his attention to the unchanged symbol after only two responses to the reversed S- symbols occurred when the conflict-compound discrimination was repeated. The test performance of the younger child further confirmed that he selectively attended to the unchanged symbol. This was concluded since only the unchanged symbol exercised stimulus control in agreement with the reinforcement contingencies of the conflict compound following extended training. After extended training was provided, both the response topographies and the test performance of the younger child revealed that he now shifted his attention to the unchanged symbol in the conflict compound. This supports earlier findings (Huguenin, 2000) which also found that extended training was required before prior reinforcement histories determined which features of a visual compound that adolescents with developmental disabilities attended to.

The response topographies and the test performance of the older child (6 yrs) revealed, in contrast, that he selectively attended to the unchanged symbol in the conflict compound while ignoring the reversed symbols when the conflict compound was originally presented online. This occurred when the older child first achieved criterion accuracy for the conflict-compound discrimination as opposed to the younger child who required extended training. When criterion accuracy was originally achieved for the conflict-compound discrimination, the older child consistently responded to the unchanged symbol in each of the 18 correct trials. He also shifted to the unchanged symbol after only two responses occurred to the reversed S- symbols. The test trials of the older child further confirmed that he selectively attended to the unchanged symbol. Only the unchanged-symbol pair exercised stimulus control in agreement with the reinforcement contingencies of the conflict compound. A 100% level of agreement occurred during the unchanged-symbol test trials while a 0% level of agreement occurred during the reversed-symbol test trials. In an earlier investigation (Huguenin, 1987)), five-year old and six-year-old children also selectively attended to the unchanged symbol in a conflict compound without requiring extended training when similar procedures were administered on a desktop computer in an office setting. These results indicate that difficulties in shifting attention in accordance with prior reinforcement histories in older children could indicate children at risk for attentional disorders.

The response latencies of the older child, however, revealed changes in stimulus control for the unchanged symbol when the conflict compound was initially presented, which were not shown by his response topographies and response accuracy. The response accuracy and response topographies of the older child revealed a high level of stimulus control for the unchanged symbol in the conflict compound. His response latencies, however, showed a reduction in stimulus control for the unchanged symbol when it initially appeared in the conflict compound. A reduction in stimulus control was demonstrated by the initially longer response latencies of the older child for the unchanged symbol in the conflict compound compared to his response latencies in the final trials of the mixed-symbol sequence. When additional trials of the conflict-compound discrimination were provided, the response latencies of the older child for the unchanged symbol decreased, but his response latencies continued to fluctuate in the remaining trials of the conflict compound. This interfering effect of the reversed symbols on reducing the level of stimulus control of the unchanged symbol in the conflict compound was not revealed, however, by his response accuracy and response topographies.

These results demonstrated the utility of incorporating response latency as an additional response measurement to provide a more fine-grained and detailed analysis of attention to visual compounds, which also occurred in a previous investigation (Huguenin, 2024). While the response topographies and response accuracy of the older child summarized his visual attention, his response latencies expressed changes in stimulus control which were not revealed by his response topographies and response accuracy. Recording response latencies could identify attentional disorders, such as overselective attention or difficulties shifting attention, that occur frequently in autistic children (Patten & Watson, 2011) and which might not be revealed by other types of assessment. Past research has found autistic children exhibit longer response latencies than children of typical development for tasks requiring them to shift attention (Landry & Bryson, 2004; McLaughlin et al, 2021). Recording response latencies online could permit children at risk for developing autism to be identified at a younger age. Recording response latencies in addition to response topographies and response accuracy could be especially beneficial for identifying children with milder forms of autism who are typically diagnosed later in childhood (Lupindo et al, 2022).

Administering the stimulus-control procedures and automatically analyzing the results online also eliminated the need for sophisticated computer equipment or an expertise in discrimination learning to carry out the described procedures. Since a report was generated following the session, immediate feedback was also provided concerning the children's performance. These results further demonstrate in addition to past investigations (Huguenin, 2023, 2024) the feasibility of providing similar visual attention assessments online to discover visual attention impairments that could identify children at risk for developing autism and developmental disabilities. Past research has shown that the earlier interventions are provided to children with autism, the greater the levels of development they can achieve (Koegel et al, 2014; Maksimovic et al, 2023). If individuals are not diagnosed in early childhood, opportunities for early interventions to address impairments resulting from autism are significantly reduced (Lupindo et al, 2022). Providing visual attention assessments online requiring only parental supervision would permit larger numbers of children with autism to be identified and enable early interventions to be implemented at a younger age.

In summary, stimulus-control procedures, which were fully automated and administered online were successful in assessing the visual attention of young children. Prior reinforcement histories associated with individual stimuli determined which stimulus elements in a stimulus compound the young children attended to and which stimulus elements they ignored even when the procedures were administered online at remote sites. Recording response topographies and response accuracy revealed individual differences, however, in how quickly the young children shifted their attention in accordance with prior reinforcement histories. The younger child, in contrast, to the older child, required extended training before he shifted his attention in accordance with prior reinforcement histories when a stimulus compound was presented.

References

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.

Brown, M., Matson, J.L., & Tevis, C. (2022). Assessing effects of early intervention. In. J. L. Matson and P. Sturmey (eds.), Handbook of autism and pervasive developmental disorder. Autism and child psychopathology series.

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

Cipani, E. (2012). Stimulus overselectivity: Empirical basis and diagnostic methods. The Behavior Analyst Today, 13, 3-11.

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

Eimas, P.D. (1969). A developmental study of hypothesis behavior and focusing. Journal of Experimental Child Psychology, 8, 160-172.

Hale, G.A., & Morgan, J.S. (1973). Developmental trends in children's component selection. Journal of Experimental Child Psychology, 15, 302-314.

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. (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. (2011). Overselective attention to words in young children: Utilizing multiple assessments. Behavior Analysis and Technology Monograph 110427, 1-31. (www.ba-and-t.com)

Huguenin, N.H. (2014). Assessing overselective attention to words in young children: Effects of single letter pretraining. Behavior Analysis and Technology Monograph 140526, 1-21. (www.ba-and-t.com)

Huguenin, N.H. (2023). Employing online multiple tests including response latency to remotely assess visual attention in participants of differing ages. Behavior Analysis and Technology Monograph 230306, 1-46) (www.ba-and-t.com)

Huguenin, N.H. (2024). Employing online response latency to provide a more detailed analysis of individual differences in visual attention. Behavior Analysis and Technology Monograph 240329, 1-31. (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.

Keehn, B., Muller, R-A., & Townsend, J. (2013). Atypical attentional networks and the emergence of autism. Neuroscience & Biobehavioral Reviews, 37, 164-183.

Kelly, M., & Reed, P. (2020). Age effects on the development of stimulus over-selectivity are mediated by cognitive flexibility and selective attention. International Journal of Behavioral Development, 45, 89-96.

Koegel, L.K., Koegel, R.L., Ashbaugh, K., & Bradshaw, J. (2014). The importance of early identification and intervention for children with or at risk for autism spectrum disorders. International Journal of Speech-Language Pathology, 16, 50-56.

Landry, R., & Bryson, S.E. (2004). Impaired disengagement of attention in young children with autism. Journal of Child Psychology and Psychiatry, 45 (6), 1115-1122.

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.

Lupindo, B.M., Maw, A., & Shabalala, N. (2022). Late diagnosis of autism: Exploring experiences of males diagnosed with autism in adulthood. Current Psychology, 1-18.

Maksimovic, S., Marisavljevic, M., Stanojevic, N., Cirovic, M., Punisic, S., Adamovic, T., Dordevic, J., Krgovic, I., & Subotic, M. (2023). Importance of early intervention in reducing autistic symptoms and speech-language deficits in children with autism spectrum disorder. Children, 10, 122.

McLaughlin, C.S., Grosman, H.E., Guillory, S.B., Isenstein, E.L., Wilkinson, E., del Pilar Trelles, M., Halpern, D.B., Siper, P.M., Kolevzon, A., Buxbaum, J.D., Wang, A. T., & Foss-Feig, J.H. (2021). Reduced engagement of visual attention in children with autism spectrum disorder. Autism, 25(7), 2064-2073.

Mo, S., Liang, L., Bardikoff, N., & Sabbagh, M.A. (2019). Shifting visual attention to social and non-social stimuli in autism spectrum disorders. Research in Autism Spectrum Disorders, 65, 56-64.

Patten, E., & Watson, L.R. (2011). Interventions targeting attention in young children with autism. American Journal of Speech-Language Pathology, 20, 60-69.

Ploog, B.O. (2010). Stimulus overselectivity four decades later: A review of the literature and its implications for current research in autism spectrum disorder. Journal of Autism and Developmental Disorders, 40, 1332-1349.

Ploog, B.O., & Kim, N. (2007). Assessment of stimulus overselectivity with tactile compound stimuli in children with autism. Journal of Autism and Developmental Disorders, 37, 1514-1524.

Smith, K. H. (2005). Variables influencing stimulus overselectivity in normally developing children. Masters thesis submitted to the graduate faculty of Auburn University, Auburn, Alabama.

Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. International Journal of Developmental Neuroscience, 23 143-152.

Footnotes

The author wishes to acknowledge the technical assistance of Robert Huguenin. A full text version of the article is available by download from www.ba-and-t.com. Email: nhuguenin@ba-and-t.com