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Employing Online Response Latency to Provide a More Detailed Analysis of Individual Differences in Visual Attention

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Abstract

Assessing visual attention is important because it can identify attentional deficits that can interfere with development and academic performance. Stimulus-control procedures, which were fully automated and administered online at remote sites, were successful in assessing the visual attention of four participants. Establishing prior reinforcement histories for separate stimulus components was effective in determining which features of compound visual cues the participants attended to. Their response topographies and test performance indicated they selectively attended to only the symbol with an unchanged prior reinforcement history in the stimulus compound. Symbols with a reversed prior reinforcement history in the compound were ignored. While the response topographies and response accuracies of the participants summarized their visual attention, their response latencies expressed changes in visual attention not revealed by either their response topographies or response accuracies. When the conflict compound was presented, the participants consistently selected the unchanged symbol in the compound when criterion accuracy was achieved. The unchanged symbol also exhibited a high level of stimulus control in agreement with the reinforcement contingencies of the conflict compound during the test trials. A loss of stimulus control for the unchanged symbol was shown for three of the participants, however, when it appeared in the conflict compound. This was because of their longer response latencies that occurred for the unchanged symbol in the conflict compound compared to when it was presented alone. Recording response latencies also revealed individual differences for the participants in the extent to which the interfering effect of the reversed symbols reduced the level of stimulus control of the unchanged symbol in the conflict compound. By recording response latency, individual differences were discovered in how quickly they shifted their attention in accordance with prior reinforcement histories when the stimulus compound was presented. These individual differences in shifting attention, in contrast, were not revealed by their response accuracies or response topographies. Recording response latencies could identify attentional disorders, such as overselective attention or difficulties shifting attention, which have a higher incidence in autistic children, and which might not be revealed by other types of assessment. Past research has found autistic children exhibit longer response latencies compared to children of typical development for tasks requiring them to shift attention. Recording response latencies, therefore, in addition to response topographies and response accuracy might permit children to be identified at a younger age who are at risk for developing autism. This could be especially beneficial for identifying children with milder forms of autism who are typically diagnosed later in childhood compared to children with more distinctive characteristics of autism. Early interventions could be administered, as a result, at a younger age.

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

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(Full text follows)

Discovering manipulations that affect how children attend to complex stimuli is important because of the presence of attentional deficits that many children possess which interfere with their learning and development. One attentional impairment that can interfere with a child's development is overselective attention. Overselective attention occurs when a child demonstrates restricted attention, as the child attends to only a limited number of stimulus elements in a compound display. Overselective attention is common in individuals with developmental disabilities, and it is frequently reported in individuals diagnosed with autism (Bailey, 1981; Dickson, Deutsch, Wang, & Dube, 2006; Dickson, Wang, Lombard, & Dube, 2006; Dube & McIlvane, 1999; Fabio, Giannatiempo, Antonietti, & Budden, 2009; Huguenin, 1985, 1997, 2004; Kelly, Leader, & Reed, 2015; Koegel & Wilhelm, 1973; Lovaas & Schreibman, 1971; Lovaas, Schreibman, Koegel, & Rehm, 1971; Ploog & Kim, 2007; Reed, Broomfield, McHugh, McCausland, & Leader, 2009; Rincover & Ducharme, 1987; Schreibman & Lovaas, 1973; Schreibman, Koegel, & Craig, 1977; Schreibman, Kohlenberg, & Britten, 1986; Stromer, McIlvane, Dube, & Mackay, 1993; Ullman, 1974; Whiteley, Zaparniuk, & Asmundson, 1987; Wilhelm & Lovaas, 1976). 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; Dunlap, Koegel, & Burke, 1981; Ploog, 2010). Difficulties in shifting attention from one stimulus to another have also been reported to occur more often in children with autism compared to children of typical development (Patten & Watson, 2011). Because attentional impairments are reported to be an early indicator of autism (Zwaigenbaum, Brysons, Rogers, Roberts, Brian, & Szatmari, 2005), detecting attentional impairments can permit early intervention programs to be implemented at a younger age, which is critical in enhancing a child's later development (Brown, Matson, & Tevis, 2022).

One manipulation that can determine the components of stimulus compounds that are attended to in individuals with developmental disabilities and young children 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. Computer technology presented stimulus-compound tasks composed of six symbols with conflicting prior reinforcement histories to both groups. Multiple stimulus-control tests were presented. One test assessed stimulus control by presenting stimulus components separately following acquisition of the compound discriminations. The other test measured the response topographies of the compound stimuli by using a touch screen attached to a computer monitor screen, which automatically recorded which stimuli the students touched in the compounds. In most instances, the response topographies and test performance of three young children indicated that they selectively attended to only symbols with an unchanged prior reinforcement history in the conflict compounds when criterion accuracy was achieved. Symbols with a reversed prior reinforcement history in the compounds were ignored. Three adolescents with intellectual disabilities also eventually learned to selectively attend to unchanged symbols in the conflict 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).

In a recent study (Huguenin, 2023), prior reinforcement histories associated with individual stimuli were also effective in determining how participants differing in age attended to a stimulus compound even when the procedures were administered online at remote sites. This also occurred, in contrast to the earlier study (Huguenin, 1997), with laptop computers, where touch screens were not utilized, and where social and monetary reinforcement were not provided. The response topographies and test performance of two of the participants (an adolescent and an adult) indicated that they selectively attended to only the symbol with an unchanged prior reinforcement history in the stimulus compound when criterion accuracy was achieved. A third participant (an adult) had opposing response topographies and test results. Although she responded to both the unchanged symbol and reversed symbols in the conflict compound when criterion accuracy was achieved, her test performance indicated that she selectively attended to the unchanged symbol. Finally, although prior reinforcement histories failed to initially control how a young child attended to a visual compound, when the procedures were repeated, he too selectively attended to the unchanged stimulus element.

The purpose of the current investigation was to employ response latencies as an assessment of stimulus control in addition to recording response accuracy and response topographies to provide a more complete analysis of how four participants attended to a compound stimulus display. In a previous investigation (Huguenin, 2023), measuring response latency demonstrated changes in stimulus control which were not evident when other response measurements were employed. This was because while response topographies and response accuracies summarized visual attention, response latencies expressed changes in visual attention which were not revealed by either response topographies or response accuracies. In the current investigation, response latencies were recorded to provide a more detailed analysis of individual differences in how four participants attended to a compound with conflicting prior reinforcement histories. It was determined if recording response latencies might reveal individual differences in stimulus control for the participants which were not evident by their response accuracy or response topographies.

If incorporating response latency provides a more fine-grained analysis of attention to visual compounds, this could identify attentional deficits in children, such as overselective attention or difficulties shifting attention, that might not be revealed by other types of assessment. This could serve to identify children who are 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 in order to provide necessary interventions. Past research has shown that the earlier interventions are provided to children with autism, the greater the levels of development they can achieve (Koegel, Koegel, Ashbaugh, & Bradshaw, 2014). If individuals are not diagnosed with autism in early childhood, opportunities for early interventions to address impairments resulting from autism and to increase developmental levels are significantly reduced. Providing visual attention assessments including response latency online could permit larger numbers of children with autism to be identified and enable early interventions to be implemented at a younger age.

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Method

Subjects

Four adults participated in this study.

Apparatus

The stimulus-control procedures were provided online and were accessible on the author's website (www.ba-and-t.com). The procedures were administered automatically at remote sites.

General Procedure

Each session consisted of approximately 100 trials. A trial began when symbols, centered on two white illuminated backgrounds, appeared on the participant's screen. The trial ended when the participant selected a symbol in either illuminated area. A 3 sec. intertrial interval followed when the screen was dark, and then the next trial began. Correct choices during training sessions resulted in a flashing 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 participant's screen. Reinforcement was not provided if an incorrect response occurred. During test sessions, reinforcement was provided regardless of which symbol the participant selected.

After each step, the results were automatically analyzed, and a printable report was also generated following the session. This was displayed on the participant's screen. As a result, the participants received immediate feedback concerning their performance. 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 participant attended to the relevant features of the visual materials. The report also included an assessment of attention durability that 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 participant 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 participant's 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). In addition to response accuracy, response latencies were also recorded for each of the three single-symbol visual discriminations. Response latency was defined as the amount of time that elapsed between the presentation of the symbol pair on the participant's screen and the participant's symbol selection.

Single Symbol Training

(+)	(-)
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. x

In the first discrimination task, rabbit and plum symbols appeared on the participant's screen, and reinforcement was provided whenever the participant selected the rabbit symbol (S+). 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 participant selected the cane symbol (S).

The prompt was again provided on the first trial to designate 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. The prompt was also provided on the first trial to indicate the correct choice (grasses), and the symbol pair was presented until criterion accuracy was achieved.

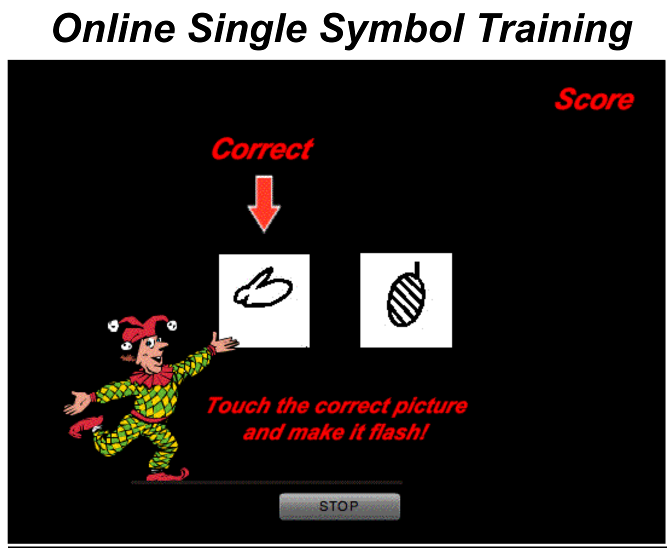

Figure 2. Diagram of the prompt provided on the first trial of each of the three visual discriminations, which consisted of a cartoon character and an arrow pointing to the correct choice (S+ symbol).

<u>Mixed-Symbol Sequence</u>

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, and 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. Response accuracy and response latency were recorded throughout the mixed-symbol sequence.

<u>Conflict Compound</u>

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 (nonreinforcement), 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. The conflict-compound discrimination was presented until criterion accuracy was achieved (90% accuracy in a 20-trial sequence). The symbol the participant selected each time the conflict compound appeared on the screen was also recorded. In addition, response latency was recorded throughout the presentation of the conflict compound.

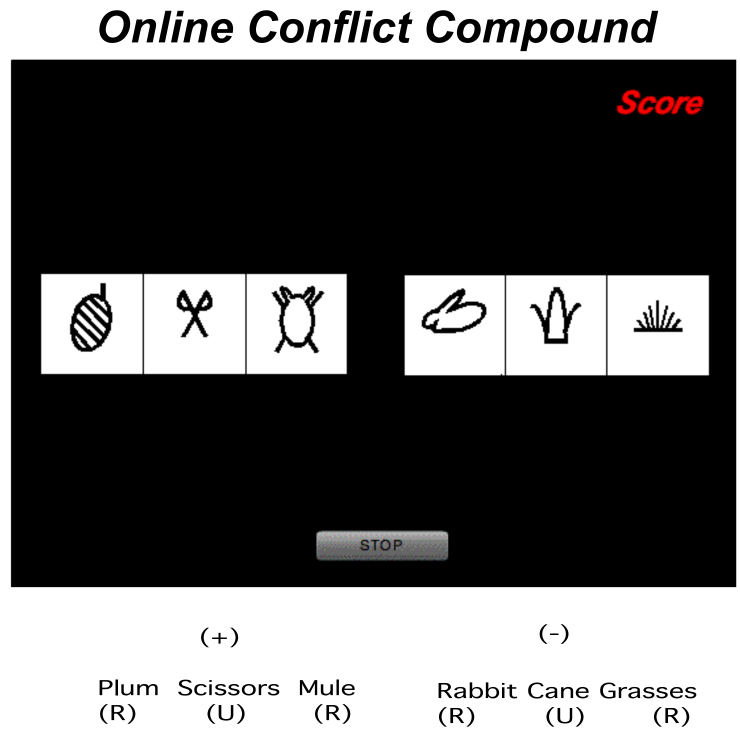

Figure 3. Diagram of the conflict-compound discrimination. Plus (+) indicates stimulus compound paired with reinforcement and minus (-) denotes stimulus compound paired with extinction. The S+ and S- compounds were presented simultaneously and were each composed of three symbols. The positions of the 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 was achieved for the conflict compound, test trials were presented. This consisted of 36 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 participant selected. The purpose of the test was to determine which symbols the participant was attending to when criterion accuracy was obtained for the conflict-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.

Because the symbol the participant selected each time the conflict compound was presented was recorded, this also provided a direct comparison of test trial results with symbols selected in the conflict compound when compound criterion accuracy was met. Response latencies were also recorded during the 36 test trials.

Results

Participant 1 (Adult)

Single-symbol training. Participant 1 did not make any errors throughout single-symbol training. He achieved 100% accuracy for each of the three single-symbol discriminations (See Fig. 4). Although his accuracy scores (100% accuracy) indicated identical performance for the three discriminations, his response latencies showed changes in stimulus control not revealed by his response accuracy. In the first single-symbol discrimination (rabbit+ vs. plum-), the response latencies in the initial trials were 17.8 and 3.2 seconds respectively. In the following trials, his response latencies decreased and varied between 1.2 and 1.6 seconds. Although Participant 1 had a relatively long response latency in the initial trial, his response latencies quickly decreased and remained at short latencies.

The average response latency of Participant 1 for the second single-symbol discrimination (scissors+ vs. cane-) was 1.3 seconds, which was less than the average response latency (3.4 seconds) of the first single-symbol discrimination. The initial response latency of 1.9 seconds in the first trial of the second discrimination was also much lower than the than the initial response latency of 17.8 seconds recorded in the first trial of the first discrimination. Response latencies in subsequent trials remained at short latencies and varied between 0.9 and 1.4 seconds.

In the third single-symbol discrimination (grasses+ vs. mule-), the average response latency (1.2 seconds) of Participant 1 was comparable to his average response latency (1.3 seconds) of the second single-symbol discrimination. There were response latencies of 1.8 and 1.7 seconds in the first two trials of the third discrimination. In the remaining trials, response latencies decreased and varied in the third discrimination between 0.9 and 1.3 seconds, which were similar to the response latencies of the second discrimination.

In summary, the accuracy scores of Participant 1 remained at 100% accuracy for all three single-symbol discriminations. His decreases in average response latency, however, revealed an improvement in stimulus control, which was not shown by his accuracy scores. A larger average response latency was recorded for the first single-symbol discrimination compared to the smaller average response latencies of the second and third single-symbol discriminations.
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Mixed-symbol sequence. Participant 1 did not make any errors in the second phase when the three single-symbol discriminations were presented in an unpredictable mixed sequence (See Fig. 4). He achieved 100% accuracy for all three single-symbol discriminations when they were presented in a mixed sequence and achieved criterion accuracy in the first 28 trials. His response latencies, however, again revealed changes in stimulus control during the mixed-symbol sequence that were not shown by his accuracy scores.

The average response latency of Participant 1 was 1.2 seconds for the first single-symbol discrimination (rabbit+ vs. plum-) during the mixed-symbol sequence, which was a decrease from his original average response latency (3.4 seconds) for the first single-symbol discrimination. There was a slight increase in response latency (2.0 seconds) in the first trial of the first single-symbol discrimination during the mixed-symbol sequence. During the later trials of the mixed-symbol sequence, his response latencies for the first single-symbol discrimination decreased. These changes in average response latency for the first discrimination occurred when 100% accuracy was demonstrated in both single-symbol training and the mixed-symbol sequence.

The average response latency of Participant 1 for the second single-symbol discrimination (scissors+ vs. cane-) during the mixed-symbol sequence was 1.7 seconds, which was slightly larger than his original average response latency of 1.3 seconds for the second single-symbol discrimination. The slight increase in the average response latency for the second single-symbol discrimination during the mixed-symbol sequence was the result of a response latency of 6.5 seconds that occurred in the first trial. In the subsequent trials, the response latencies for the second-symbol discrimination during the mixed-symbol sequence decreased and varied between 0.9 and 1.7 seconds.

The average response latency of Participant 1 for the third single-symbol discrimination (grasses+ vs. mule-) during the mixed-symbol sequence was 1.3 seconds, which was comparable to his original average response latency of 1.2 seconds for the third discrimination. A response latency of 1.8 seconds occurred for the third single-symbol discrimination in the first trial of the mixed-symbol sequence. In the following trials, the response latencies of Participant 1 decreased and remained at shorter latencies in the mixed-symbol sequence.

In summary, the average response latencies of Participant 1 confirmed, in addition to his response accuracy, that the stimulus control of the three single-symbol discriminations was not disrupted when the three single-symbol discriminations were intermixed during the mixed-symbol sequence. This was shown by the fact that the average response latency during the mixed-symbol sequence was less than the original average response latency for one of the single-symbol discriminations. For the other two single-symbol discriminations, average response latencies during the mixed-symbol sequence were comparable to the original average response latencies observed for the two discriminations. These average response latencies indicated stimulus control was not disrupted for two of the single-symbol discriminations during the mixed-symbol sequence. For the remaining single-symbol discrimination, stimulus control during the mixed-symbol sequence was improved.

Conflict compound. Participant 1 achieved criterion accuracy when the conflict compound was presented in the first 20 trials (See Fig. 4). Participant 1 made only one error (95% accuracy), and the error occurred in the second trial because he selected grasses, which was a reversed S- symbol. In the remaining trials, Participant 1 consistently selected the unchanged symbol (scissors). When criterion accuracy was achieved, Participant 1 selected the unchanged S+ symbol (scissors) in each of the 18 correct trials (See Fig. 5). He also shifted to the unchanged S+ symbol with only one response to a reversed symbol occurring.

The response topographies of Participant 1 demonstrated that he consistently responded to the unchanged S+ symbol (scissors) in each of the 18 correct trials when he achieved criterion accuracy for the conflict-compound discrimination. The S+ symbol (scissors) was also consistently selected (100% accuracy) during the mixed-symbol sequence. His response latencies, however, revealed changes in stimulus control, which were not shown by his response topographies and response accuracy (See Fig. 6). When the conflict compound was presented, his response latency for the unchanged S+ symbol (scissors) initially increased to 16.6 seconds and gradually decreased across the first five trials. In contrast, 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 Participant 1 for the S+ symbol (scissors) revealed high and stable levels of stimulus control in both the mixed-symbol sequence and the conflict compound. His response latency, however, showed a reduction in stimulus control for the unchanged S+ symbol (scissors) when the conflict compound was initially presented, which was not revealed by either his response accuracy or his response topographies. This initial reduction in stimulus control of the unchanged S+ symbol (scissors), demonstrated by the longer response latencies of Participant 1, 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, however, by the response accuracy and response topographies of Participant 1.

Test results. The test performance of Participant 1 also confirmed that he shifted his attention to the unchanged symbol (scissors) in the conflict compound when he achieved criterion accuracy. Only the unchanged-symbol pair (scissors+ vs. cane-) exhibited stimulus control in agreement with the reinforcement contingencies of the conflict compound (See Fig. 5). Because Participant 1 consistently selected the unchanged S+ symbol (scissors) throughout the unchanged-symbol test trials, the unchanged-symbol pair demonstrated a 100% level of agreement with the reinforcement contingencies of the conflict compound.

During the reversed-symbol test trials, Participant 1 consistently selected the reversed S- symbols (rabbit and grasses), and a 0% level of agreement with the reinforcement contingencies of the conflict compound occurred, as a result, for both reversed-symbol pairs (See Fig. 5). Both original stimulus-response relations paired with extinction in the compound, because their prior reinforcement contingencies were reversed, remained intact even after they failed to occur when the conflict compound was presented. This was shown as Participant 1 selected only the reversed S- symbols during the reversed-symbol test trials, which had previously been S+ symbols in single-symbol training (See Fig. 5).

The response latencies of Participant 1 during the test trials also confirmed that the three original stimulus-response relations were not disrupted as a result of being combined to form the conflict compound. The average response latency for scissors in the conflict compound was 2.4 seconds. During the unchanged-symbol test trials, however, the average response latency for scissors decreased to 0.9 second. This was slightly lower than the average response latency (1.7 seconds) for scissors during the mixed-symbol sequence administered before the conflict-compound discrimination was presented. The increased response latency of Participant 1 for the unchanged S+ symbol (scissors) in the conflict compound indicated that the stimulus control of scissors was initially reduced. His decreased response latencies for scissors during the unchanged-symbol test trials, however, revealed the original stimulus control for scissors remained intact despite the initial reduction in stimulus control of scissors in the conflict compound.

The response latencies during the test trials of the two stimulus-response relations, whose prior reinforcement histories were reversed in the conflict compound, also demonstrated their original stimulus control was not disrupted. Rabbit was a reversed S- symbol in the conflict compound, but it was consistently selected during the reversed-symbol test trials. The average response latency (1.1 seconds) for rabbit during the reversed-symbol test trials was also comparable to the average response latency (1.2 seconds) for rabbit when it was a S+ symbol in the mixed-symbol sequence. The short response latencies, with one exception, of Participant 1 for rabbit in the reversed-symbol test trials demonstrated the original stimulus control of rabbit was not disrupted when its prior reinforcement contingency was reversed in the conflict compound.

Grasses was also a reversed S- symbol in the conflict compound. Participant 1 also consistently selected grasses during the reversed-symbol test trials. The average response latency (1.4 seconds) for grasses during the reversed-symbol test trials was virtually identical to the average response latency (1.3 seconds) for grasses when it was a S+ symbol in the mixed-symbol sequence. The short latencies for grasses in the reversed-symbol test trials also confirmed the original stimulus control of grasses was not disrupted when its prior reinforcement history was reversed in the conflict compound.

Participant 2 (Adult)

Single-symbol training. Participant 2 did not make any errors during single-symbol training. He also achieved 100% accuracy for each of the three single-symbol discriminations (See Fig. 7). His response latencies, however, demonstrated changes in stimulus control not revealed by his accuracy scores, which had also been the case for Participant 1. The average response latency of Participant 2 was 4.5 seconds for the first single-symbol discrimination where rabbit was the S+ symbol and plum was the S- symbol. His response latencies in the first two trials of the first discrimination were 21.3 and 7.9 seconds respectively. In the subsequent trials, his response latencies quickly decreased and varied between 1.2 and 2.1 seconds.

The average response latency of Participant 2 for the second single-symbol discrimination (scissors+ vs. cane-) was 2.3 seconds, which was less than the average response latency (4.5 seconds) of the first single-symbol discrimination. His initial response latency (5.8 seconds) recorded in the first trial of the second discrimination was also much lower than the initial response latency (21.3 seconds) of the first discrimination. The response latencies decreased in the following trials and, with one exception, were less than two seconds. In the sixth trial, a response latency of 4.5 seconds occurred.

The average response latency of Participant 2 for the third single-symbol discrimination (grasses+ vs. mule-) was 1.7 seconds, which was slightly lower than the average response latency (2.3 seconds) of the second single-symbol discrimination. A response latency of 5.1 seconds occurred in the first trial of the third single-symbol discrimination. His response latencies again quickly decreased in the subsequent trials and varied between 1.2 and 1.5 seconds.

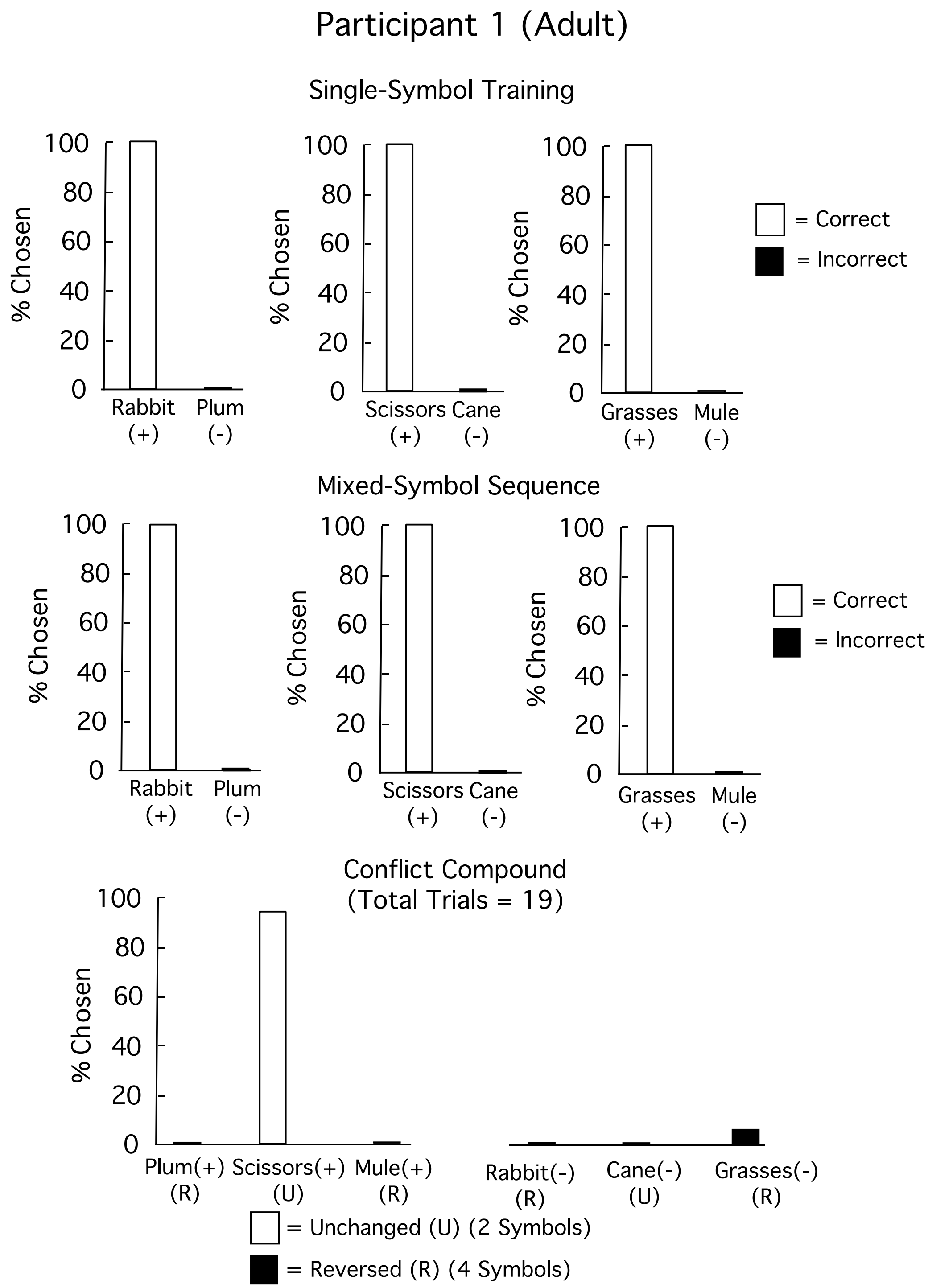

Figure 4. For Participant 1, percent accuracy for the three symbol discriminations during single-symbol training and during the mixed-symbol sequence. In addition, percentage S+ and S- unchanged symbols (white bars) and S+ and S- reversed symbols (black bars) were chosen when the conflict compound was presented.

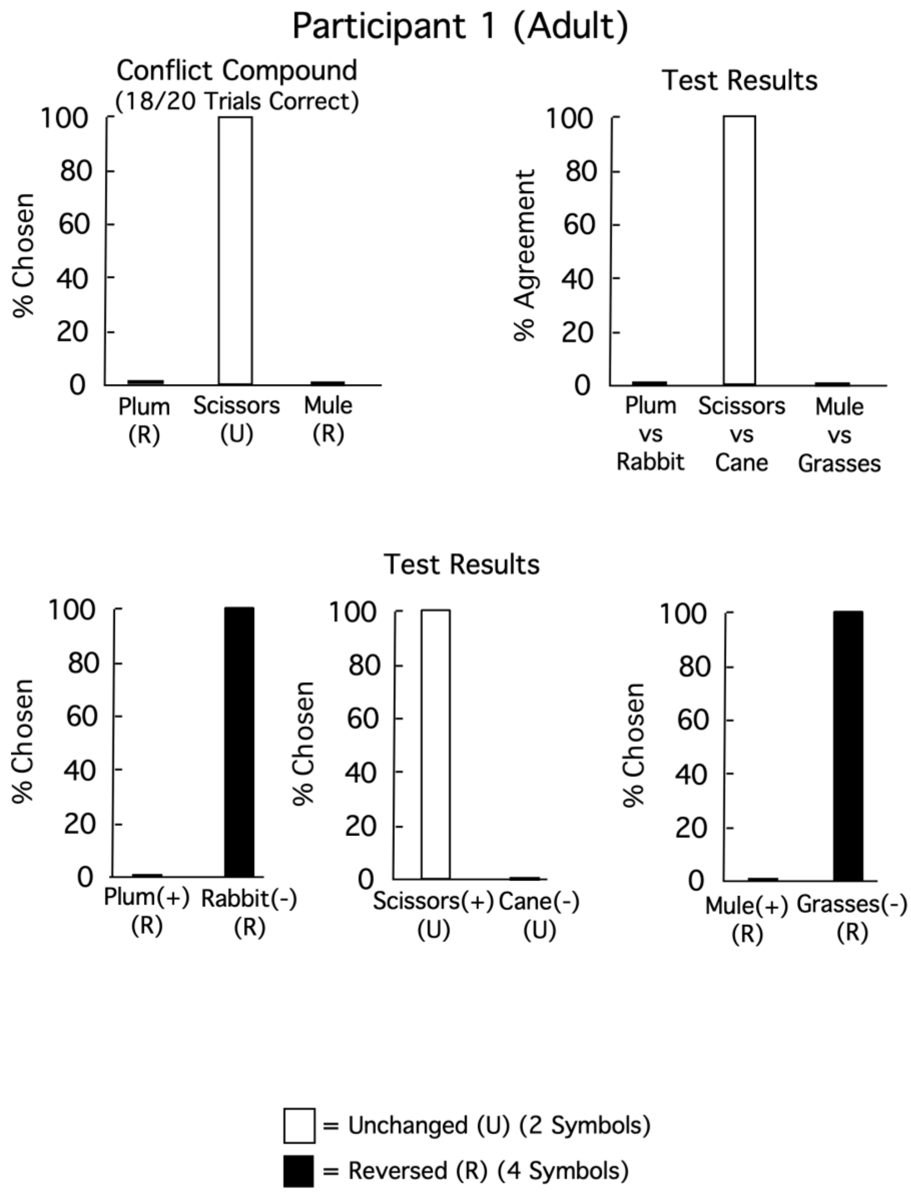

Figure 5. For Participant 1, (left graph) percentage each of the three S+ symbols were chosen during reinforced trials when criterion accuracy was achieved for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies of the conflict compound. The top symbols shown for Participant 1 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.

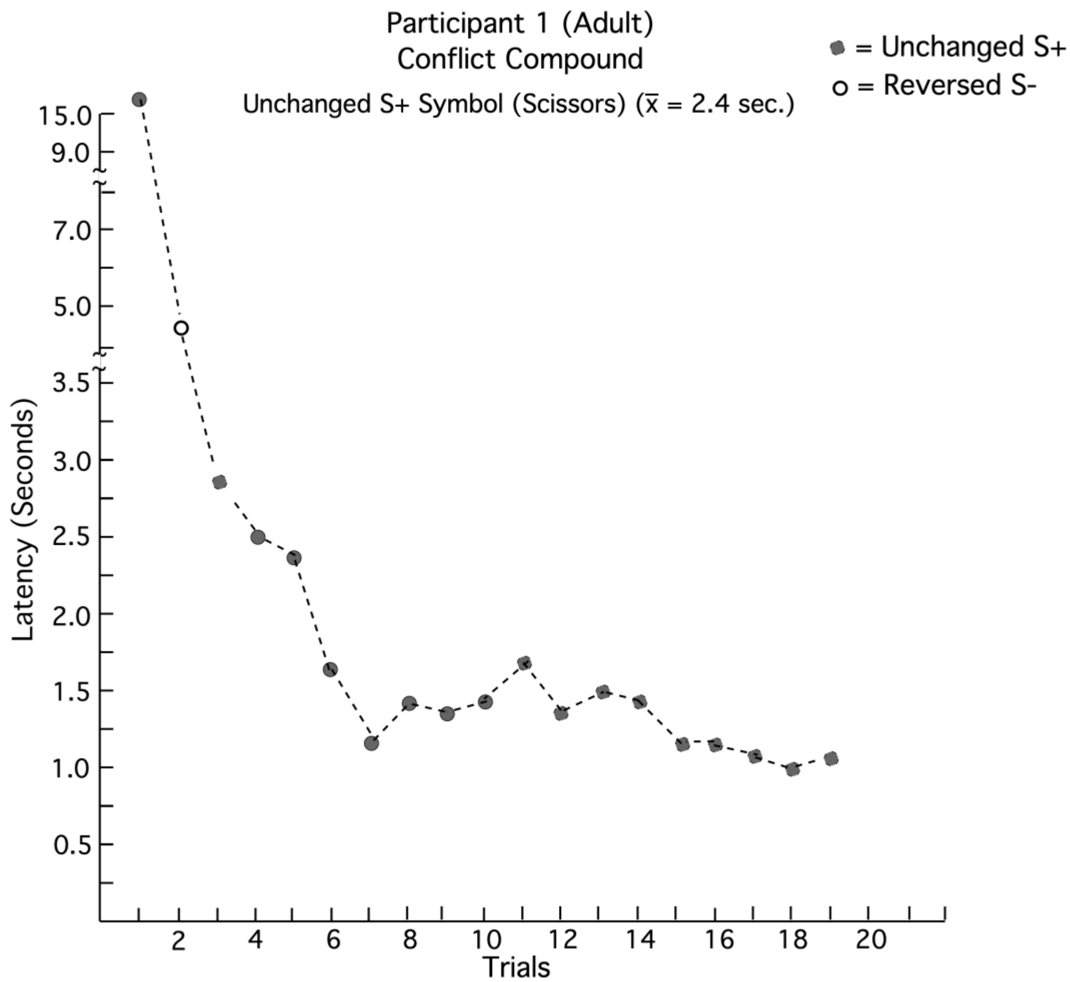

Figure 6. For Participant 1, response latency for the unchanged S+ symbol (scissors) during presentation of the conflict compound.

In summary, even though the accuracy scores of Participant 2 remained at 100% for all three single-symbol discriminations, his decreases in average response latency across the three single-symbol discriminations showed an improvement in stimulus control. This improvement in stimulus control was not, however, reflected by his accuracy scores.

Mixed-symbol sequence. Participant 2 also did not make any errors when the three original single-symbol discriminations were presented in an unpredictable mixed sequence (See Fig. 7). He again achieved 100% accuracy for each of the three single-symbol discriminations when they were intermixed, and he achieved, as a result, criterion accuracy in the first 28 trials. Intermixing the three single-symbol discriminations in an unpredictable sequence did not disrupt their original criterion accuracy for Participant 2. The response latencies of Participant 2, however, demonstrated an improvement in stimulus control during the mixed-symbol sequence not revealed by his accuracy scores, which had also occurred for Participant 1.

The average response latency of Participant 2 during the mixed-symbol sequence for the first single-symbol discrimination (rabbit+ vs. plum-) was only 1.5 seconds. This was a decrease from his original average response latency (4.5 seconds) for the first single-symbol discrimination. The decrease in average response latency during the mixed-symbol sequence for the first single-symbol discrimination also occurred when 100% accuracy was demonstrated in both single-symbol training and the mixed-symbol sequence. In the first two trials of the mixed-symbol sequence, there was a small increase in his response latencies for the first single-symbol discrimination. The response latencies decreased in the later trials and remained slightly above one second.

Participant 2 also demonstrated a decrease in average response latency (1.9 seconds) for the second single-stimulus discrimination (scissors+ vs. cane) during the mixed-symbol sequence compared to the original average response latency for the second discrimination (2.3 seconds). With the exceptions of response latencies of three and four seconds recorded in the first and fifth trials, response latencies remained below two seconds during the mixed-symbol sequence for the second-symbol discrimination.

The average response latency for the third single-symbol discrimination (grasses+ vs. mule-) during the mixed-symbol sequence was 1.5 seconds, which was slightly less than the original average response latency (1.7 seconds) for the third discrimination. A smaller decrease in average response latency was observed during the mixed-symbol sequence for the third single-symbol discrimination because of a slight increase in response latency that occurred in most of the trials of the mixed-symbol sequence.

In summary, the response latencies of Participant 2 also confirmed, in addition to his response accuracy, that the stimulus control of the three single-symbol discriminations was not disrupted during the mixed-symbol sequence when the three discriminations were intermixed. The average response latencies of Participant 2 for the three single-symbol discriminations during the mixed-symbol sequence were less than their original average response latencies. The decrease in response latencies indicated the stimulus control not only was not disrupted for the three single-symbol discriminations during the mixed-symbol sequence but also slightly improved.

Conflict compound. Participant 2 made only two errors (90% accuracy) when the conflict compound was presented (See Fig. 7). He achieved criterion accuracy in the first 20 trials. Both errors occurred because Participant 2 selected a reversed S- symbol in the second and third trials of the conflict-compound discrimination. One error consisted of selecting rabbit, and the second error occurred because of selecting grasses, which were both reversed S- symbols. Participant 2 consistently selected the unchanged S+ symbol (scissors) in the conflict compound in the remaining 18 trials when criterion accuracy was achieved (See Fig. 8). After only two responses occurred to reversed S- symbols, Participant 2 shifted to the unchanged S+ symbol in the conflict compound.

Although Participant 2 consistently responded to the unchanged S+ symbol (scissors) in the conflict compound as well as consistently selecting the S+ symbol (scissors) during the mixed-symbol sequence, his responses latencies revealed changes in stimulus control. The average response latency of Participant 2 for the S+ symbol (scissors) during the mixed-symbol sequence was 1.9 seconds, but when the conflict compound was presented, his average response latency for the unchanged S+ symbol (scissors) increased to 4.7 seconds (See Fig. 9). In the initial four trials of the conflict-compound discrimination, the response latencies of Participant 2 for the unchanged S+ symbol (scissors) were 9.3 seconds, 5.4 seconds, 4.1 seconds, and 9.0 seconds, respectively. In the later trials of the conflict-compound discrimination, long latencies of 13.3 seconds, 6.8 seconds, and 9.3 seconds also occurred for the unchanged S+ symbol (scissors). These longer latencies of Participant 2 contrasted with his response latencies for the S+ symbol (scissors) during the mixed-symbol sequence which were, with two exceptions, below two seconds.

In summary, the response accuracy and response topographies of Participant 2 for the S+ symbol (scissors) demonstrated high and stable levels of stimulus control in both the mixed-symbol sequence and the conflict compound. His response latencies, because of longer response latencies, however, showed a reduction in stimulus control for the unchanged S+ symbol (scissors) in the conflict compound, which also occurred for Participant 1. The response latency of Participant 1 showed a reduction in stimulus control for the unchanged S+ symbol (scissors) when the conflict compound was initially presented. Participant 2, however, displayed a reduction in stimulus control for the unchanged S+ symbol (scissors), which persisted throughout the trials of the conflict compound due to the interfering effect of the reversed symbols.

Test results. The test results of Participant 2 also indicated that he shifted his attention to the unchanged symbol (scissors) in the conflict compound when he achieved criterion accuracy. Only the unchanged-symbol pair (scissors+ vs. cane-) exhibited stimulus control in agreement with the reinforcement contingencies of the conflict compound (See Fig. 8). The unchanged-symbol pair demonstrated a 100% level of agreement, as Participant 2 consistently selected the unchanged S+ symbol (scissors) during the unchanged-symbol test trials.

Since Participant 2 always 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 occurred for both reversed-symbol pairs (See Fig. 8). The stimulus-response relations paired with extinction in the conflict compound, due to a reversal of their prior reinforcement contingencies, decreased in frequency without disrupting their original stimulus control. Participant 2 selected only the reversed S- symbols during the reversed-symbol test trials, which had previously been S+ symbols in single-symbol training (See Fig. 8). The stimulus-response relations paired with extinction in the compound remained intact even after they failed to occur when the conflict compound was presented.

The response latencies of Participant 2 also demonstrated during the test trials that the three original stimulus-response relations were not disrupted because of being combined to form the conflict compound, which had also been the case for Participant 1. Although the average response latency for scissors in the conflict compound increased to 4.7 seconds, indicating a reduction in stimulus control, the average response latency for scissors during the unchanged-symbol test trials decreased to 1.4 seconds. This was similar to the average response latency (1.9 seconds) for scissors during the mixed-symbol sequence administered before the conflict compound was presented. The decreased response latencies of Participant 2 for scissors during the unchanged-symbol test trials revealed the original stimulus control for scissors remained intact despite a reduction in stimulus control for scissors during the conflict compound.

The response latencies of the two stimulus-response relations, whose prior reinforcement contingencies were reversed in the conflict compound, also indicated their original stimulus control was not disrupted because of appearing in the conflict compound. Rabbit and grasses, which were reversed S- symbols in the conflict compound, were both consistently selected by Participant 2 during the reversed-symbol test trials. The average response latency (1.9 seconds) for rabbit during the reversed-symbol test trials was comparable to its average response latency (1.5 seconds) when rabbit was a S+ symbol in the mixed-symbol sequence. The average response latency (1.4 seconds) for grasses during the reversed-symbol test trials was virtually identical to its average response latency (1.5 seconds) when grasses was a S+ symbol in the mixed-symbol sequence. The consistent selection of rabbit and grasses and their short latencies in the reversed-symbol test trials demonstrated their original stimulus control was not disrupted when their prior reinforcement contingencies were reversed in the conflict compound.

Participant 3 (Adult)

Single-symbol training. Participant 3 did not make any errors during single-symbol training (See Fig. 10. She achieved 100% accuracy for each of the three single-symbol discriminations, which had also occurred for Participants1 and 2. In contrast to Participants 1 and 2, however, her response latencies showed less change in stimulus control for the three single-symbol discriminations. The average response latency of Participant 3 for the first single-symbol discrimination (rabbit+ vs. plum-) was 1.1 seconds. This was less than the average response latencies of both participant 1(3.4 seconds) and participant 2 (4.5 seconds) for the first single-symbol discrimination. Her response latency in the first trial of the first discrimination was 3.7 seconds. In the following trials, her response latencies decreased and, with one exception, were less than one second.

The average response latency of Participant 3 for the second-symbol discrimination (scissors+ vs. cane-) was 0.9 second, which was slightly less than her average response latency (1.1 seconds) for the first single-symbol discrimination. In the first trial of the second discrimination, a response latency of 1.8 seconds occurred. In the following trials, her response latencies again remained below one second.

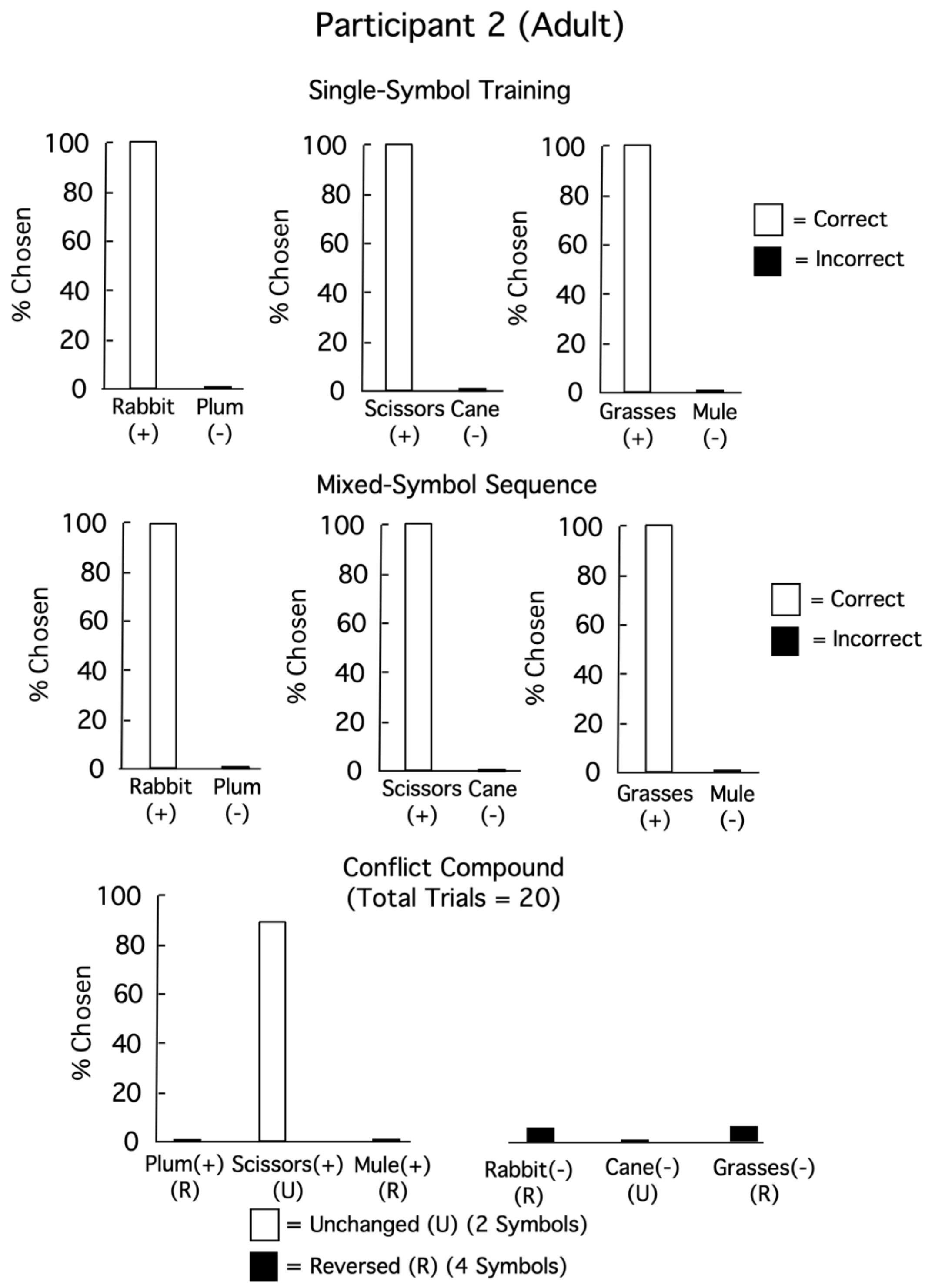

Figure 7. For Participant 2, percent accuracy for the three symbol discriminations during single-symbol training and during the mixed-symbol sequence. In addition, percentage S+ and S- unchanged symbols (white bars) and S+ and S- reversed symbols (black bars) were chosen when the conflict compound was presented.

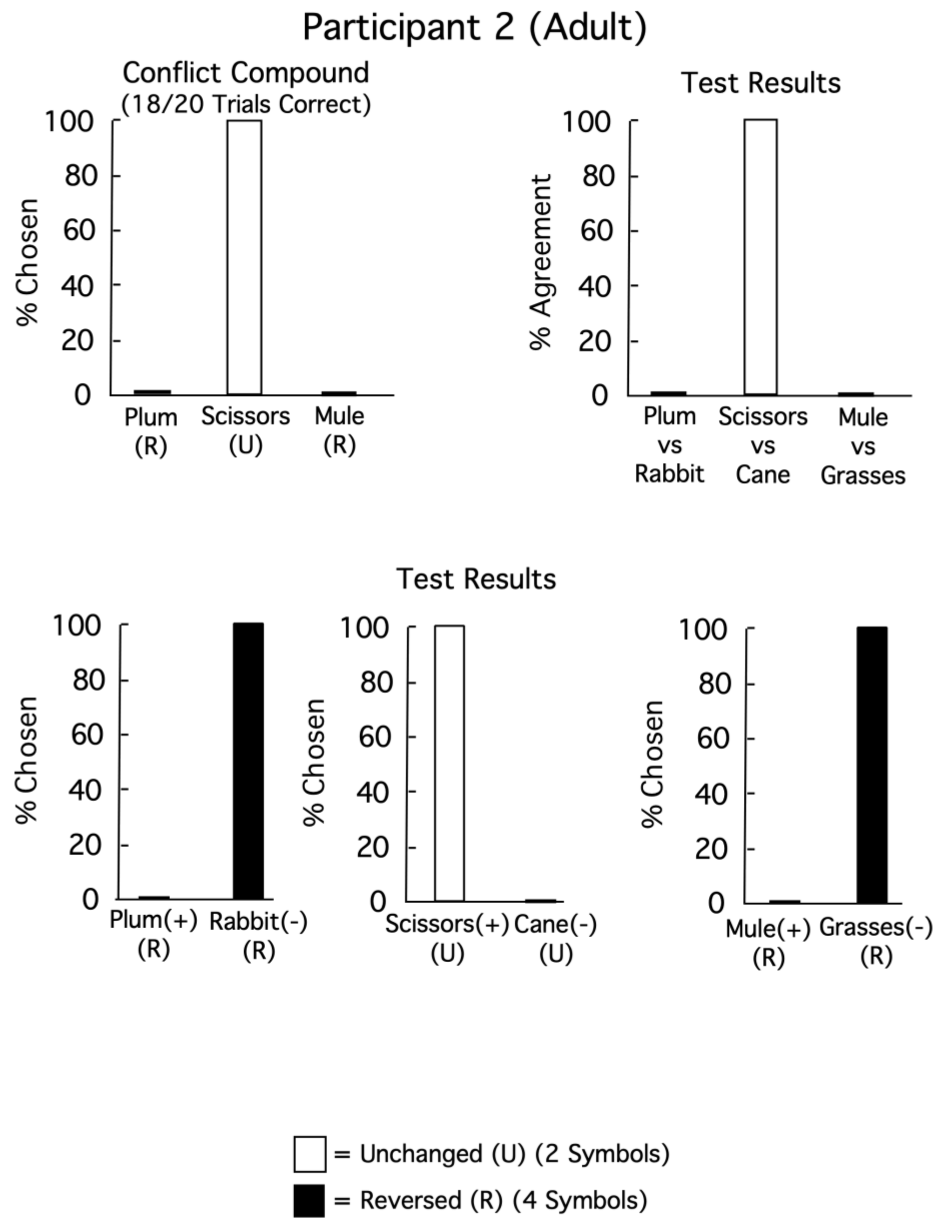

Figure 8. For Participant 2, (left graph) percentage each of the three S+ symbols were chosen during reinforced trials when criterion accuracy was achieved for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies of the conflict compound. The top symbols shown for Participant 2 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.

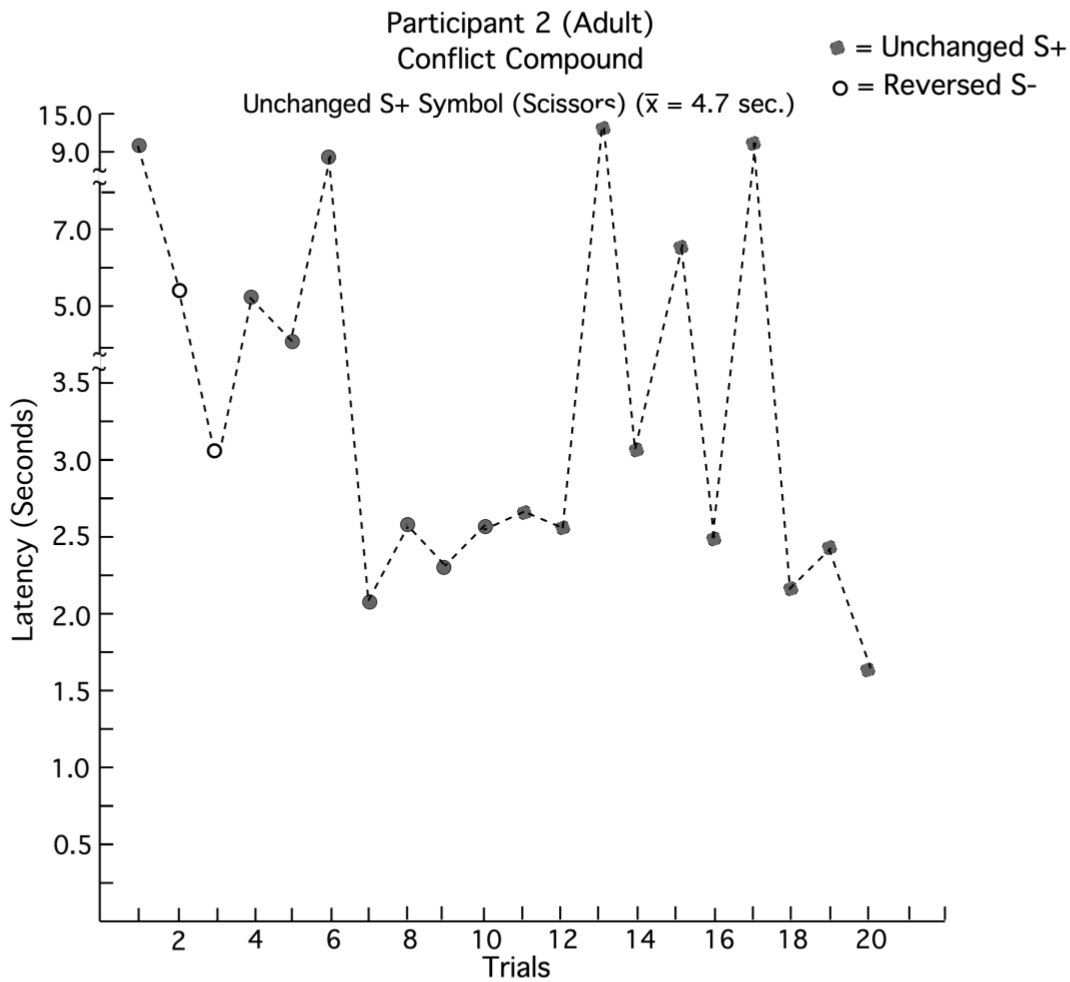

Figure 9. For Participant 2, response latency for the unchanged S+ symbol (scissors) during presentation of the conflict compound.

For the third single-symbol discrimination (grasses+ vs. mule-), the average response latency of Participant 3 was only 0.7 second, which was slightly less than her average response latency for the second single-symbol discrimination (0.9 second). A response latency of 1.1 seconds occurred in the first trial of the third single-symbol discrimination. Her response latencies remained below one second in the following trials.

In summary, Participant 3 achieved 100% accuracy for all three single-symbol discriminations, as Participants 1 and 2 had also achieved. Her average response latencies across the three single-symbol discriminations, however, demonstrated a smaller decrease in response latency compared to Participants 1 and 2.

Mixed-symbol sequence. When the three original single-symbol discriminations were presented in an unpredictable mixed sequence, Participant 3 did not make any errors (See Fig. 10). She achieved 100% accuracy for each of the three single-symbol discriminations when they were intermixed and achieved, as a result, criterion accuracy in the first 28 trials. Presenting the three single-symbol discriminations in a mixed sequence did not disrupt their original criterion accuracy. The average response latencies of Participant 3 for the three single-symbol discriminations during the mixed-symbol sequence also confirmed that presenting the three discriminations in a mixed sequence did not disrupt their original stimulus control.

The average response latency of Participant 3 for the first single-symbol discrimination (rabbit+ vs. plum-) during the mixed-symbol sequence was 0.8 second, which was slightly less than her original average response latency (1.1 seconds) for the first discrimination. The response latencies for the first discrimination also remained less than one second throughout the mixed-symbol sequence. Both the response accuracy and the response latencies of Participant 3 demonstrated that the original stimulus control of the first single-symbol discrimination was not disrupted during the mixed-symbol sequence.

For the second single-symbol discrimination (scissors+ vs. cane-), the average response latenciy of Participant 3 during the mixed-symbol sequence was 0.8 second, which was comparable to her original average response latency (0.9 second) for the second discrimination. With one exception, her response latencies for the second discrimination remained less than one second during the mixed-symbol sequence. The response latencies as well as the response accuracy of Participant 3 also revealed that the original stimulus control of the second single-symbol discrimination was not disrupted during the mixed-symbol sequence.

The average response latency of Participant 3 for the third single-symbol discrimination (grasses+ vs. mule-) during the mixed-symbol sequence was also 0.8 second, which was virtually identical to her original average response latency (0.7 second) for the third discrimination. The response latencies for the third discrimination, with one exception, were again less than one second during the mixed-symbol sequence. The response accuracy and the response latencies of Participant 3 also demonstrated that the original stimulus control of the third single-symbol discrimination remained intact and was not disrupted during the mixed-symbol sequence.

In summary, the response latencies of Participant 3 also confirmed her response accuracy that the stimulus control of the three single-symbol discriminations was not disrupted when the three discriminations were intermixed. This was also the case for Participants 1 and 2.

Conflict compound. Participant 3 achieved criterion accuracy in the first 20 trials when the conflict compound was presented without any errors occurring (See Fig. 10). She selected the unchanged S+ symbol (scissors) in the first trial of the conflict compound and continued to select the unchanged S+ symbol (scissors) in each of the 18 correct trials when criterion accuracy was achieved (See Fig. 11). Participant 3 attended to the unchanged S+ symbol in the conflict compound without any responses to the reversed S-symbols occurring.

The response topographies of Participant 3 revealed that she consistently responded to the unchanged S+ symbol (scissors) when the conflict compound was presented. She also consistently selected the S+ symbol (scissors) (100% accuracy) during the mixed-symbol sequence. Her response latencies, in contrast, revealed changes in stimulus control not demonstrated by her response topographies or response accuracy, which had also occurred for Participants 1 and 2. The average response latency of Participant 3 was 0.8 second for the S+ symbol (scissors) during the mixed-symbol sequence. Her average response latency for the unchanged S+ symbol (scissors) increased to 3.4 seconds when the conflict compound was presented (See Fig. 12). In the initial three trials of the conflict-compound discrimination, the response latencies of Participant 3 for the unchanged S+ symbol (scissors) were 7.1 seconds, 13.0 seconds, and 7.2 seconds, respectively. Elevated response latencies continued to occur when the conflict was presented until the eighth trial of the conflict compound. In contrast, the responss latencies for the S+ symbol (scissors) during the mixed-symbol sequence varied between 0.5 and 1.2 seconds.

In summary, the response accuracy and response topographies of Participant 3 exhibited high and stable levels of stimulus control for the S+ symbol (scissors) in both the mixed-symbol sequence and when the conflict compound was presented. In contrast, her response latencies, because of longer response latencies, demonstrated a reduction in stimulus control for the unchanged S+ symbol (scissors) during the initial trials of the conflict compound, which had also occurred for Participant 1. The initial reduction in stimulus control for the unchanged S+ symbol (scissors) in the conflict compound, due to the interfering effect of the reversed symbols, was not, however, revealed by her response accuracy or response topographies.

Test results. The test performance of Participant 3 also confirmed that she selectively attended to the unchanged symbol (scissors) in the conflict compound when criterion accuracy was obtained. Only the unchanged-symbol pair (scissors+ vs. cane-) exhibited stimulus control in agreement with the reinforcement contingencies of the conflict compound (See Fig. 11). Participant 3 consistently selected the unchanged S+ symbol (scissors) during the unchanged-symbol test trials, and as a result, a 100% level of agreement with the reinforcement contingencies of the conflict compound was demonstrated.

Because during the reversed-symbol test trials Participant 3 consistently selected the reversed S- symbols (rabbit and grasses), a 0% level of agreement with the reinforcement contingencies of the conflict compound was obtained for both reversed-symbol pairs (See Fig. 11). The test results of Participant 3 indicated the two original stimulus-response relations paired with extinction in the compound, because their prior reinforcement contingencies were reversed, were not disrupted. Participant 3 selected only the reversed S- symbols (rabbit and grasses) during the reversed-symbol test trials, which were previously the S+ symbols in single-symbol training (See Fig. 11). 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, which also occurred for both Participants 1 and 2.

The response latencies of Participant 3 during the test trials also confirmed that the three original stimulus-response relations were not disrupted because of having been previously combined to form the conflict compound. Although the average response latency for scissors in the conflict compound increased to 3.4 seconds, the average response latency for scissors decreased to 0.9 second during the unchanged-symbol test trials. This was comparable to the average response latency (0.8 second) for scissors during the mixed-symbol sequence that was administered before the conflict-discrimination was presented. The increased response latencies of Participant 3 revealed the stimulus control of the unchanged S+ symbol (scissors) was initially reduced when the conflict compound was presented. The decreased response latencies for scissors during the unchanged-symbol test trials, however, indicated the original stimulus control for scissors remained intact despite the reduction in stimulus control for scissors when the conflict compound was initially presented.

The response latencies of Participant 3 during the reversed-symbol test trials also revealed the two stimulus-response relations, whose prior reinforcement contingencies were reversed in the conflict compound, were not disrupted as a result of appearing in the conflict compound. Rabbit and grasses, which were previously S+ symbols in original training, were both consistently selected in the reversed-symbol test trials. This occurred despite the fact they were both reversed S- symbols in the conflict compound. The average response latency (1.0 second) for rabbit during the reversed-symbol test trials was comparable to the average response latency (0.8 second) for rabbit when it was a S+ symbol in the mixed-symbol sequence. The average response latency (0.9 second) for grasses during the reversed-symbol test trials was also comparable to the average response latency (0.8 second) for grasses when it was a S+ symbol in the mixed-symbol sequence. The short response latencies for rabbit and grasses in the reversed-symbol test trials further demonstrated the original stimulus control of both rabbit and grasses was not disrupted when their prior reinforcement contingencies were reversed in the conflict compound.

Participant 4 (Adult)

Single-symbol training. Participant 4 did not make any errors during single-symbol training (See Fig. 13). She achieved 100% accuracy for each of the three single-symbol discriminations. Her response latencies also showed less change in stimulus control, which had also occurred for Participant 3, compared to Participants 1 and 2. The average response latency of Participant 4 for the first single-symbol discrimination was 1.0 second. In the initial trial of the first discrimination, her response latency was 3.6 seconds. The response latencies of Participant 4 quickly decreased in the following trials and varied between 0.7 and 1.2 seconds.

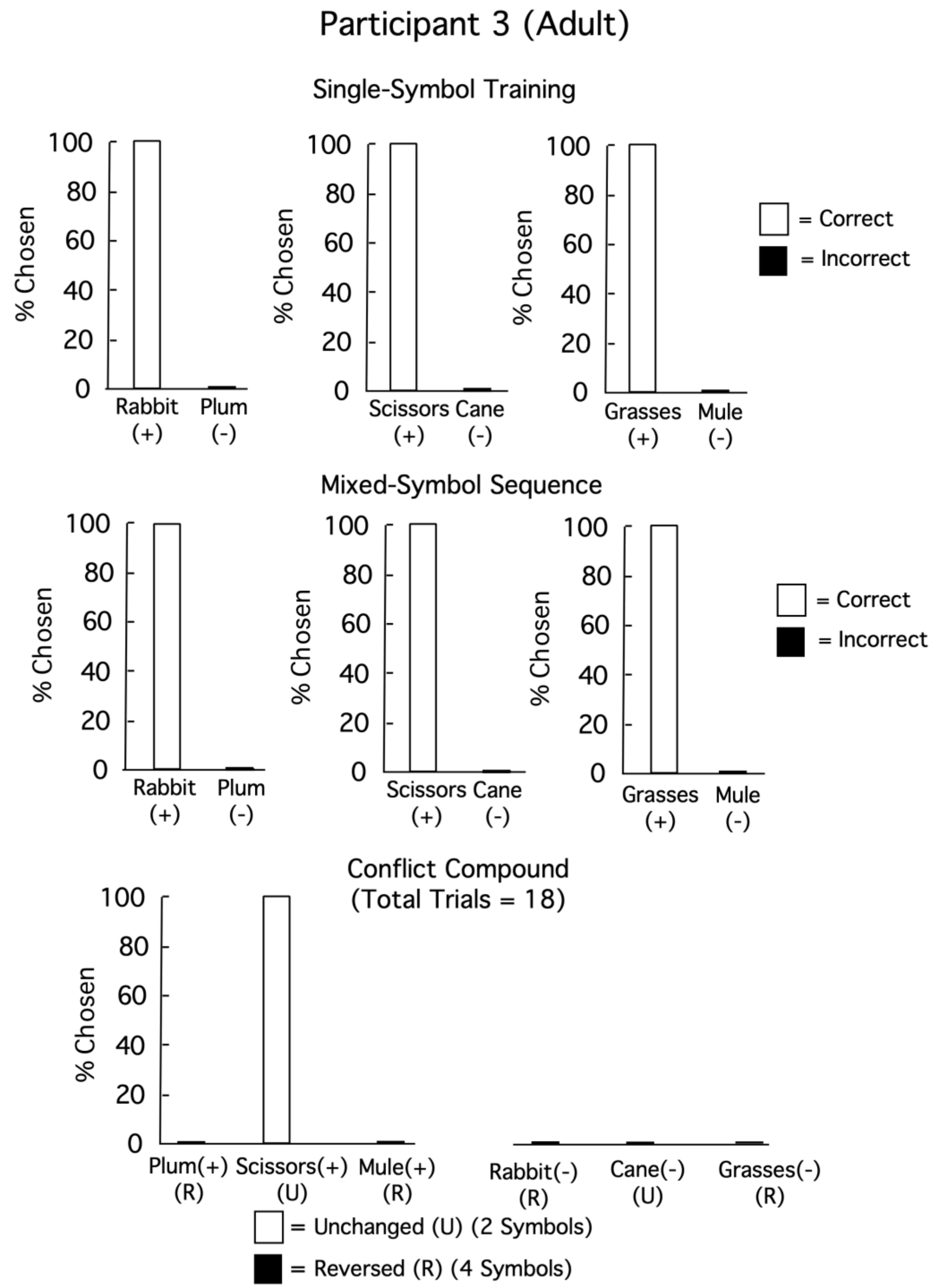

Figure 10. For Participant 3, percent accuracy for the three symbol discriminations during single-symbol training and during the mixed-symbol sequence. In addition, percentage S+ and S- unchanged symbols (white bars) and S+ and S- reversed symbols (black bars) were chosen when the conflict compound was presented.

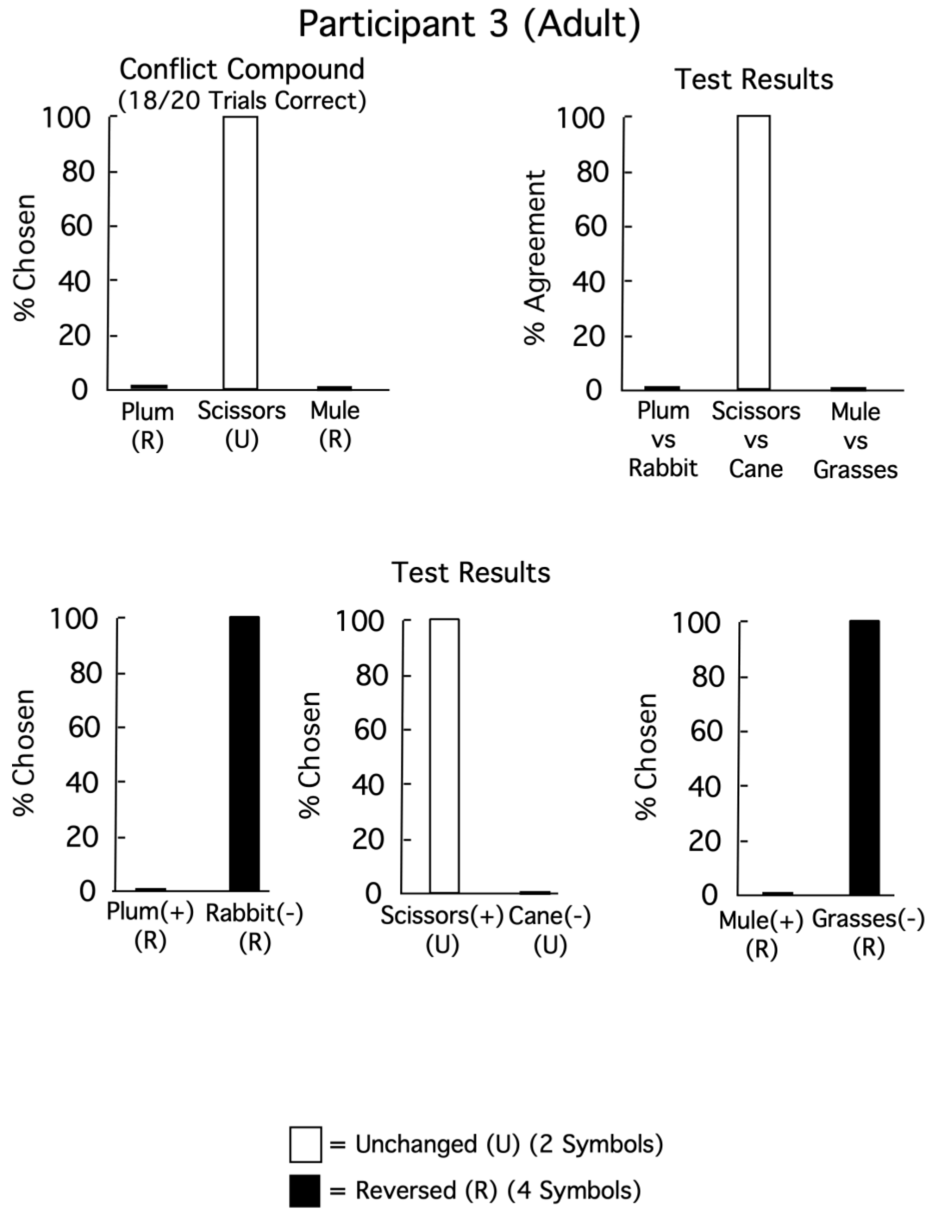

Figure 11. For Participant 3, (left graph) percentage each of the three S+ symbols were chosen during reinforced trials when criterion accuracy was achieved for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies of the conflict compound. The top symbols shown for Participant 3 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.

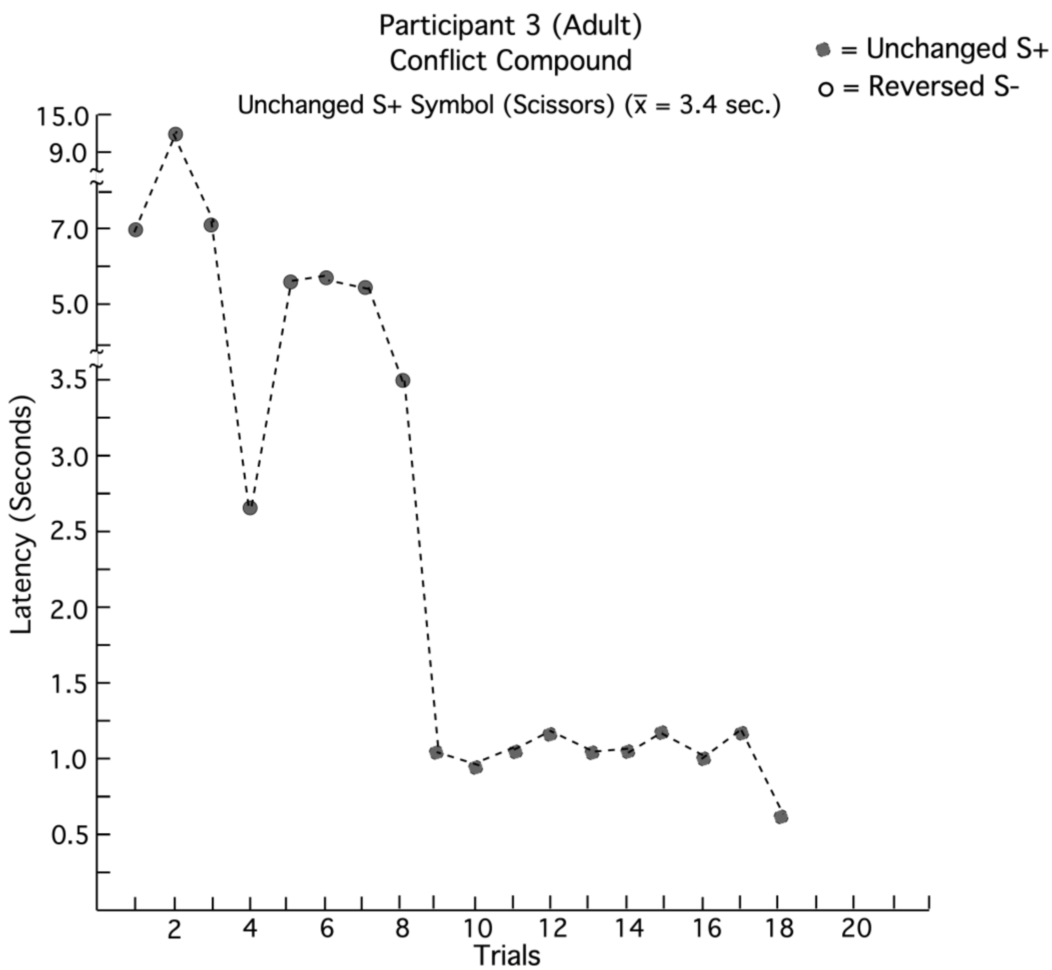

Figure 12. For Participant 3, response latency for the unchanged S+ symbol (scissors) during presentation of the conflict compound.

The average response latency of Participant 4 for the second single-discrimination was 1.2 seconds, which was slightly higher than her average response latency (1.0 second) for the first discrimination. A response latency of 3.3 seconds occurred in the first trial of the second discrimination. In subsequent trials, the response latencies decreased and varied between .6 and 1.3 seconds.

For the third single-symbol discrimination, the average response latency of Participant 4 was only 0.8 second, which was lower than the average response latency (1.2 seconds) for the second single-symbol discrimination. In the initial trial of the third discrimination, a response latency of 1.6 seconds occurred, and in the following trials, the response latencies remained less than one second.

In summary, Participant 4 achieved 100% accuracy for all three single-symbol discriminations which had occurred for the other participants. As was also the case for Participant 3, the average response latencies of Participant 4 for the three single-symbol discriminations showed a smaller change in response latency compared to Participants 1 and 2.

Mixed-symbol sequence. Participant 4 also did not make any errors when the three single-symbol discriminations were presented in an unpredictable mixed sequence (See Fig. 13). She achieved 100% accuracy for each of the three single-symbol discriminations when they were intermixed and achieved criterion accuracy in the first 28 trials. Presenting the three single-symbol discriminations in a mixed sequence did not disrupt their original criterion accuracy. The average response latencies for the three single-symbol discriminations during the intermixed sequence also demonstrated their original stimulus control remained intact.

The average response latency (0.9 second) of Participant 4 for the first single-symbol discrimination (rabbit+ vs. plum-) during the mixed-symbol sequence was virtually identical to her original average response latency (1.0 second) for the first discrimination. All the response latencies for the first single-symbol discrimination during the mixed-symbol sequence, with one exception, were less than one second. Both the response accuracy and the response latencies of Participant 4 showed the original stimulus control of the first single-symbol discrimination was not disrupted during the mixed-symbol sequence.

The average response latency of Participant 4 for the second single-symbol discrimination (scissors+ vs. cane-) was 1.1 seconds during the mixed-symbol sequence, which was also comparable to her original average response latency (1.2 seconds) for the second discrimination. A response latency of 2.7 seconds occurred in the first trial of the second single-symbol discrimination during the mixed-symbol sequence. In subsequent trials, the response latencies during the mixed-symbol sequence for the second single-symbol discrimination varied between 0.6 and 1.1 seconds. The response accuracy and response latencies of Participant 4 also demonstrated the original stimulus control of the second single-symbol discrimination was not disrupted during the mixed-symbol sequence.

The average response latency (0.9 second) of Participant 4 for the third single-symbol discrimination (grasses+ vs. mule-) during the mixed-symbol sequence was virtually identical to her original average response latency of 0.8 second for the third discrimination. The response latencies for the third single-symbol discrimination during the mixed-symbol sequence varied between 0.7 and 1.0 second. Both the response accuracy and response latencies of Participant 4 showed the original stimulus control of the third single-symbol discrimination was also not disrupted during the mixed-symbol sequence.

In summary, the response latencies in addition to the response accuracy of Participant 4 for the three single-symbol discriminations indicated their stimulus control was not disrupted during the mixed-symbol sequence as had also occurred for the other three participants. This was shown because the average response latencies of Participant 4 for the three single-symbol discriminations during the mixed-symbol sequence were comparable to their original average response latencies.

Conflict compound. Participant 4 made two errors (90% accuracy) when the conflict compound was presented and achieved criterion accuracy in the first 20 trials (See Fig. 13). Both errors occurred because she selected a reversed S- symbol (grasses) in the first and second trials of the conflict-compound discrimination. Participant 4 selected the unchanged S+ symbol (scissors) in the conflict compound in the remaining 18 trials. When criterion accuracy was achieved, Participant 4 selected the unchanged S+ symbol (scissors) in each of the 18 correct trials (See Fig. 14). She shifted to the unchanged S+ symbol after only two responses initially occurred to a reversed symbol.

The response topographies of Participant 4 showed that she 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. She also consistently selected the S+ symbol (scissors) during the mixed-symbol sequence. The response accuracy and the response topographies of Participant 4 for the S+ symbol (scissors) demonstrated high and stable levels of stimulus control in both the mixed-symbol sequence and the conflict compound.

The response latencies of Participant 4 also revealed that the stimulus control of the unchanged S+ symbol (scissors) was not reduced when the conflict-compound discrimination was presented in contrast to the other three participants. Although response latencies increased slightly when Participant 4 selected reversed S- symbols in the initial trials of the conflict compound, her response latencies for the unchanged S+ symbol (scissors) did not increase when the conflict compound was presented (See Fig. 15). They varied between 0.7 and 1.4 seconds. Her average response latency (0.9 second) for the unchanged S+ symbol (scissors) in the conflict compound was comparable to her average response latency (1.1 seconds) for the S+ symbol (scissors) during the mixed-symbol sequence. In summary, the response latencies of Participant 4 demonstrated that the stimulus control of the unchanged S+ symbol (scissors) was not reduced when it was presented in the conflict-compound discrimination in opposition to the results of the other participants.

Test results. The test performance of Participant4 also indicated that she shifted her attention to the unchanged S+ symbol (scissors) in the conflict-compound discrimination when she achieved criterion accuracy. Only the unchanged-symbol pair (scissors+ vs. cane-) exhibited stimulus control in agreement with the reinforcement contingencies of the conflict compound (See Fig. 14). Participant 4 selected the unchanged S+ symbol (scissors), with one exception, during the unchanged-symbol test trials and achieved a 92% level of agreement with the reinforcement contingencies of the conflict-compound discrimination.

During the reversed-symbol test trials, Participant 4 selected, with one exception, the reversed S- symbols (rabbit and grasses). Participant 4 achieved a 0% level of agreement with the reinforcement contingencies of the conflict compound for the reversed-symbol pair (plum+ vs. rabbit-). She achieved an 8% level of agreement with the reinforcement contingencies of the conflict compound for the reversed-symbol pair (mule+ vs. grasses-) (See Fig. 14). These test results revealed that the two original stimulus-response relations paired with extinction in the conflict compound, when their prior reinforcement contingencies were reversed, decreased in frequency without the stimulus-response relations being disrupted. This was shown as Participant 4 selected the reversed S- symbols, with one exception, during the reversed-symbol test trials, which had previously been the S+ symbols in single-symbol training (See Fig. 14). 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. This had also occurred for the other three participants.

The response latencies of Participant 4 during the test trials further demonstrated that the three original stimulus-response relations were not disrupted because of previously been combined to form the conflict compound. The average response latency (0.9 second) for scissors in the conflict compound was identical to the average response latency (0.9 second) for scissors during the unchanged-symbol test trials. This was also comparable to the average response latency (1.1 seconds) for scissors during the mixed-symbol sequence before the conflict compound was administered. Since the average response latencies of scissors were virtually identical before and after the conflict compound was presented further revealed the original stimulus control of scissors was not disturbed because of appearing in the conflict compound.

The response latencies of Participant 4 during the reversed-symbol test trials also confirmed the original stimulus-response relations whose prior reinforcement histories were reversed in the conflict compound were not disrupted. Rabbit and grasses, which were S+ symbols in original training, were both selected, with one exception, during the reversed-symbol test trials. This occurred even though they were S- symbols in the conflict-compound discrimination. The average response latency (0.8 second) for rabbit during the reversed-symbol test trials was also virtually identical to the average response latency (0.9 second) for rabbit when it was a S+ symbol in the mixed-symbol sequence. The average response latency (0.8 second) of Participant 4 for grasses during the reversed-symbol test trials and the average response latency (0.9 second) for grasses when it was a S+ symbol in the mixed-symbol sequence were also comparable. Since the response latencies for both rabbit and grasses during the reversed-symbol test trials were virtually identical to their response latencies when they were S+ symbols in the mixed-symbol sequence further confirmed their original stimulus control remained intact. This occurred despite a reversal of their reinforcement contingencies in the conflict compound.

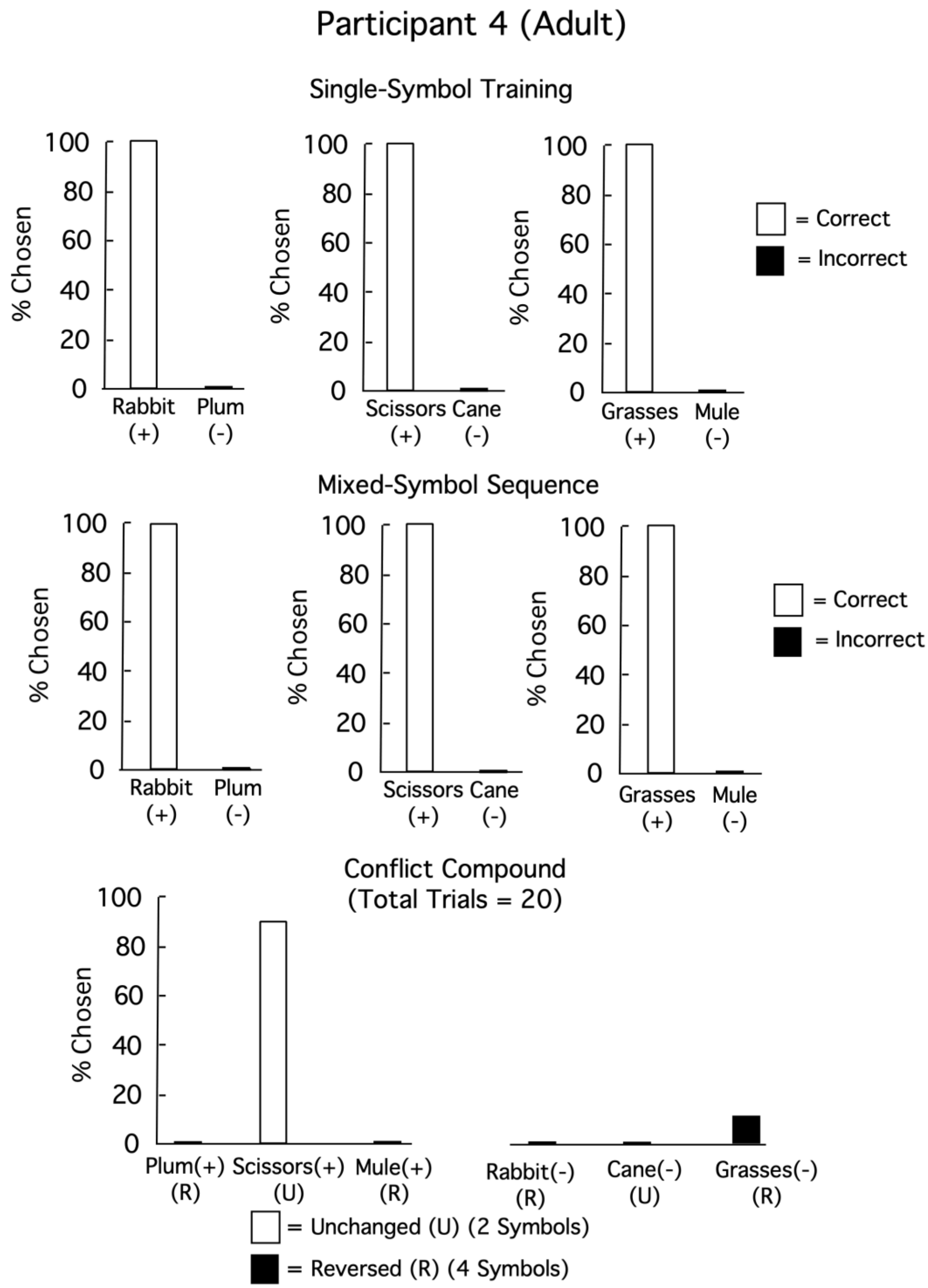

Figure 13. For Participant 4, percent accuracy for the three symbol discriminations during single-symbol training and during the mixed-symbol sequence. In addition, percentage S+ and S- unchanged symbols (white bars) and S+ and S- reversed symbols (black bars) were chosen when the conflict compound was presented.

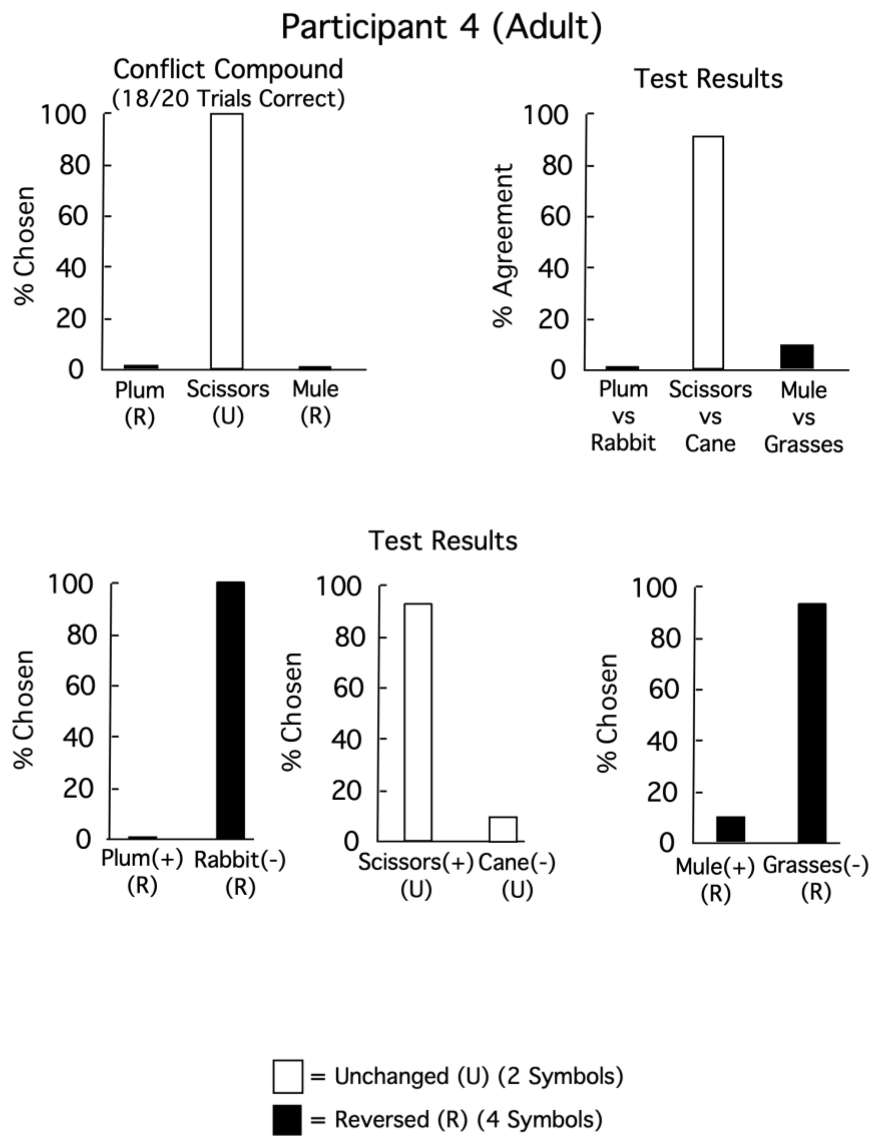

Figure 14. For Participant 4, (left graph) percentage each of the three S+ symbols were chosen during reinforced trials when criterion accuracy was achieved for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies of the conflict compound. The top symbols shown for Participant 4 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.

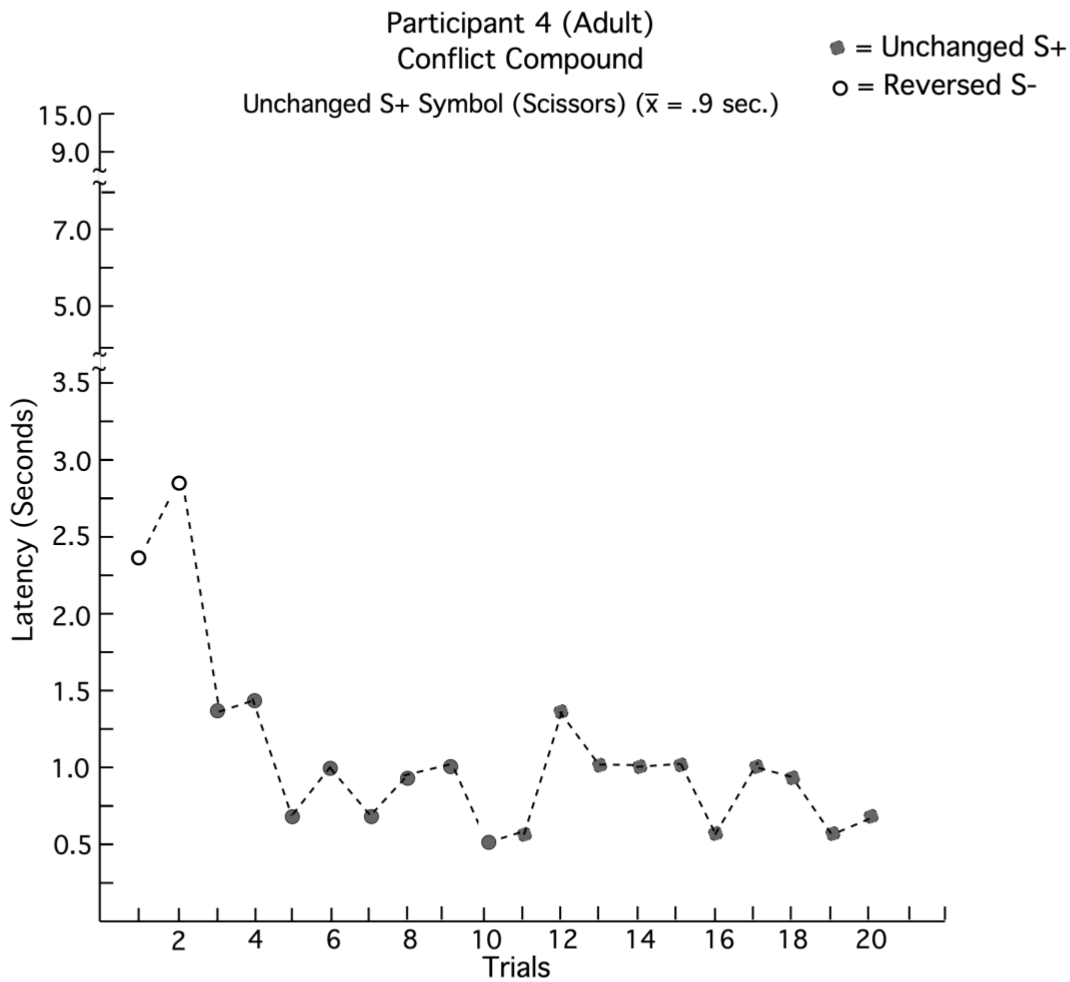

Figure 15. For Participant 4, response latency for the unchanged S+ symbol (scissors) during presentation of the conflict compound.

Discussion

Prior reinforcement histories of individual stimulus elements determined which features of visual stimulus compounds four adult participants attended to when the stimulus-control procedures were remotely administered online. The response topographies and test performance of the four participants indicated they attended in an identical manner to a stimulus compound with conflicting prior reinforcement histories. Each participant selectively attended to only the symbol with an unchanged prior reinforcement history in the stimulus compound when criterion accuracy was achieved. They always ignored the two symbols with a reversed prior reinforcement history in the compound. This was shown because the four participants selected only the unchanged symbol in the conflict compound when criterion accuracy was obtained. Three of the participants also shifted their attention to the unchanged symbol in the conflict compound with only one or two responses to the reversed S- symbols initially occurring. The remaining participant attended to the unchanged symbol in the conflict compound without any responses occurring to the reversed S- symbols.

The test trials of the four participants also confirmed that they selectively attended to the unchanged symbol. Only the unchanged-symbol pair exercised stimulus control in agreement with the reinforcement contingencies of the conflict compound for each of the four participants. Because the four participants consistently selected, with one exception, the unchanged S+ symbol during the unchanged-symbol test trials, the unchanged-symbol pair demonstrated a 100% or near 100% level of agreement with the reinforcement contingencies of the conflict compound. A 0% or near 0% level of agreement with the reinforcement contingencies of the conflict compound occurred for the reversed-symbol pairs. The four participants consistently selected, with one exception, the reversed S- symbols during the reversed-symbol test trials, which had previously been S+ symbols in single-symbol training. The original stimulus-response relations paired with extinction in the conflict compound, because their prior reinforcement contingencies were reversed, remained intact for all four participants even after they failed to occur when the conflict compound was presented.

The response latencies of the participants, however, revealed changes in stimulus control when the conflict compound was presented that were not shown by either their response topographies or response accuracy. The response latencies of three of the participants showed a decrease in stimulus control for the unchanged S+ symbol (scissors) when the conflict compound was presented. The response accuracy and response topographies of one participant revealed high levels of stimulus control for the unchanged S+ symbol (scissors) in the conflict compound. His response latencies, in contrast, showed a reduction in stimulus control for scissors when it appeared in the compound. A reduction in stimulus control was demonstrated by the longer response latencies of the participant for the unchanged S+ symbol (scissors), which persisted throughout the presentation of the conflict compound. Shorter response latencies occurred, in contrast, for scissors in the mixed-symbol sequence and during the test trials when scissors was presented alone. The interfering effect of the reversed symbols that reduced the level of stimulus control of the unchanged S+ symbol (scissors) in the conflict compound was not revealed, however, by his response accuracy or response topographies.

The response latencies of two of the other participants also revealed a reduction in stimulus control for the unchanged S+ symbol (scissors) when it was presented in the conflict compound, which was not demonstrated by their response accuracies or response topographies. A reduction in stimulus control was indicated by the longer response latencies of the two participants for the unchanged S+ symbol (scissors) when the conflict compound was initially presented compared to their response latencies for scissors in the mixed-symbol sequence. When additional trials of the conflict-compound discrimination were provided, however, the response latencies of both participants for the unchanged S+ symbol (scissors) decreased and remained at shorter latencies for the remaining trials of the conflict compound. The two participants differed, however, in the number of trials in which longer response latencies occurred for the S+ symbol (scissors) when the conflict compound was initially presented before decreasing to shorter latencies.

In contrast to the other participants, the response latencies of the fourth participant did not show a reduction in stimulus control for the unchanged S+ symbol (scissors) when it appeared in the conflict compound. The response latencies for the unchanged S+ symbol (scissors) did not increase when the conflict compound was presented to the fourth participant in opposition to the other three participants. Her response latencies for the unchanged S+ symbol (scissors) were comparable, instead, to her response latencies for scissors when scissors was presented alone in the mixed-symbol sequence and during the test trials. The response latencies of the fourth participant did increase slightly when she selected reversed S- symbols in the initial two trials of the conflict compound. Her response latencies for the unchanged S+ symbol (scissors) did not increase, however, when the conflict compound was presented.

The results of this investigation demonstrated the effectiveness of employing response latency in providing a more fine-grained and detailed analysis of attention to visual compounds. While the response topographies and response accuracies of the four participants summarized their visual attention, their response latencies expressed changes in their visual attention, which were not revealed by either their response topographies or response accuracies. When the conflict compound was presented, the participants consistently selected the unchanged symbol in the conflict compound when criterion accuracy was achieved. The unchanged symbol also exhibited a high level of stimulus control in agreement with the reinforcement contingencies of the conflict compound during the test trials. A loss of stimulus control for the unchanged symbol was shown for three of the participants, however, when it appeared in the conflict compound. This was because of their longer response latencies for the unchanged symbol in the conflict compound compared to when the symbol was presented alone. Recording response latencies also revealed individual differences for the participants in the extent to which the reversed symbols reduced the level of stimulus control of the unchanged symbol in the conflict compound. By recording response latencies, individual differences were discovered in how quickly they shifted their attention in accordance with prior reinforcement histories. These individual differences were not revealed, however, by either their response accuracies or response topographies.

Recording response latencies could identify attentional disorders, such as overselective attention or difficulties shifting attention, which have a higher incidence in autistic children and might not be revealed by other types of assessment. Past research has found autistic children exhibit longer response latencies compared to children of typical development for tasks requiring them to shift attention (Landry & Bryson, 2004). Recording response latencies, therefore, in addition to response topographies and response accuracy might permit children to be identified at a younger age who are at risk for developing autism. This could be especially beneficial for identifying children with milder forms of autism who are typically diagnosed later in childhood compared to children with more distinctive physical characteristics of autism (Lupindo, Maw, & Shabalala, 2022). As a result, early interventions could be provided at a younger age.

Administering the stimulus-control procedures and automatically analyzing the results online in this investigation also eliminated the need for sophisticated computer equipment or an expertise in discrimination learning to carry out the described procedures. By automatically generating a report following the session, the participants also received immediate feedback concerning their performance. This demonstrates the feasibility of providing visual attention assessments online, requiring only parental supervision, to determine visual attention impairments that could identify children at risk for developing autism or other developmental disabilities.

In summary, stimulus-control procedures, which were fully automated and administered online were successful in assessing the visual attention of four adult participants. Establishing prior reinforcement histories for separate stimulus components was effective in determining which features of compound visual cues the participants attended to. By recording response latency, however, individual differences were discovered in how quickly they shifted their attention in accordance with prior reinforcement histories. These individual differences in shifting attention, in contrast, were not revealed by either their response accuracies or response topographies.

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Footnotes

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