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Employing Online Multiple Tests Including Response Latency to Remotely Assess Visual Attention in Participants of Differing Ages

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Abstract

Discovering manipulations that affect how children attend to complex stimuli is important because of attentional deficits that many children possess, which interfere with their development. Establishing prior reinforcement histories for separate stimulus components was examined in this study to determine if they controlled which features of compound visual cues four participants, who differed in age, attended to. The response topographies and test performance of the participants 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 were usually ignored. The procedures were administered automatically online at remote sites where the author was not present and were effective in determining how the participants attended to a stimulus compound. 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. In a second study, the results of a fifth participant demonstrated the utility of incorporating response latency as an additional response measurement to provide a more fine-grained and sensitive analysis of attention to visual compounds. While his response topographies and response accuracies summarized his visual attention across sessions, his response latencies expressed changes in visual attention within sessions which were not revealed by either his response topographies or response accuracies. When the conflict compound was presented, the participant quickly shifted his attention to the unchanged symbol. He consistently selected the unchanged symbol in the conflict compound when criterion accuracy was achieved. Only the unchanged symbol exhibited stimulus control in agreement with the contingencies of the conflict compound during the test trials. A loss of stimulus control for the unchanged symbol was shown, however, when it appeared in the conflict compound because of longer response latencies occurring for the unchanged symbol in the conflict compound compared to when it was presented alone. Recording response latencies could identify attentional disorders, such as overselective attention or difficulties shifting attention, which have a higher incidence in autistic children and that might not be revealed by response topographies or response accuracy. Because of the increase in children diagnosed with autism, it is increasingly difficult to provide adequate services at an early age. Online programs that are fully automated, such as the procedures in this study, could be provided in the home under parental supervision to provide attentional assessments. They could be administered at a young age to both identify visual impairments and improve visual attention, which is critical in enhancing later development.

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

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(Full text follows)

Developing procedures which 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 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),). It can also occur in young children of typical development (Bickel, Stella, & Etzel, 1984; Eimas, 1969; Hale & Morgan, 1973; Huguenin, 2006, 2011, 2014; 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; Dunlap, Koegel, & Burke, 1981; Ploog, 2010).

Because of restricted attention and other attentional impairments, which can occur in children and individuals with developmental disabilities, it is important to discover manipulations that can determine which elements of stimulus compounds they attend to. 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 an investigation (Huguenin, 1997), I examined the similarities and differences in how prior reinforcement histories affected attention to compound visual cues for both young children of typical development and adolescents with intellectual disabilities, both groups having comparable mental age. Computer technology was employed to present a series of 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 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 conflict compounds were usually 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). Longer single-stimulus pretraining and additional exposure to the conflict compounds were required before the adolescents shifted their attention in the stimulus conpounds in accordance with prior reinforcement histories. Two of the three adolescents with intellectual disabilities failed to originally shift their attention to unchanged symbols because of overselective attention. Both adolescents responded to the same symbol pair in all three conflict-compounds regardless of whether the prior reinforcement histories of the symbol pair were unchanged or reversed in the compound. After additional training was provided, however, their overselective attention was eliminated. The two adolescents now selectively attended to the unchanged symbols regardless of the positions they occupied in the three conflict-compounds following extended training.

The purpose of the current investigation was to assess if prior reinforcement histories associated with individual stimuli determined how participants differing in age attended to a stimulus compound when the procedures were administered online at remote sites where the author was not present. In contrast to my earlier study (Huguenin, 1997), this occurred with laptop computers, where touch screens were not utilized, and where social and monetary reinforcement were not provided. Administering the stimulus-control procedures and automatically analyzing the results online 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. Presenting a visual-attention test online requiring only parental supervision would permit early identification of children at risk for developing autism and would allow behavioral interventions to be implemented at a younger age, which would enhance later social, behavioral, and intellectual development (Brown, Matson, & Tevis, 2022).

Multiple testing procedures were also employed, administered by the software, which permitted a fine-grained analysis of individual differences in how the participants 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 conflict compound.
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Response topographies were also recorded by the software, which automatically recorded which stimuli the participants selected each time the conflict compound appeared on the computer screen and when criterion accuracy for the conflict compound was achieved. 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. In a previous investigation, recording response topographies revealed the occurrence of overselective attention when conflict compounds were presented to adolescents with severe developmental disabilities, which was not evident in test trials administered following criterion accuracy for the conflict compounds (Huguenin, 2000).

In a second study, response latencies were also recorded as a third assessment of stimulus control. Measuring response latency can demonstrate changes in stimulus control within individual sessions that are not evident when only response accuracy and response topographies are summarized across sessions. As a result, recording response latencies could provide a more sensitive analysis of individual differences in how compounds with conflicting prior reinforcement are attended to, which would not be revealed by recording response accuracy or response topographies alone. Recording response latency could also reveal attentional disorders not evident if only response accuracy or response topographies are recorded. This could be especially beneficial in screening for children at risk for developing autism.

Experiment I

Method

Subjects

Two adults, an adolescent, and a young child participated in this study. Two of the participants were acquaintances of the author, and two of the participants were not known by the author.

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 at remote sites where the author was not present, and all the participants used personal computers.

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 computer screen. The trial ended when the participant 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 participant's computer screen. Reinforcement was not provided if an incorrect response occurred. During test sessions, reinforcement was provided regardless of which symbol the participant selected. By automatically generating a report following the session, the participants also received immediate feedback concerning their performance.

After each step, the results were automatically analyzed by an algorithm, and a printable report was also generated. This was displayed on the participant's computer screen. 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. 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 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 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).

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.

In the first discrimination task, rabbit and plum symbols appeared on the computer screen, and reinforcement was provided whenever the participant 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 participant selected the cane symbol (S-). The same 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. The 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.

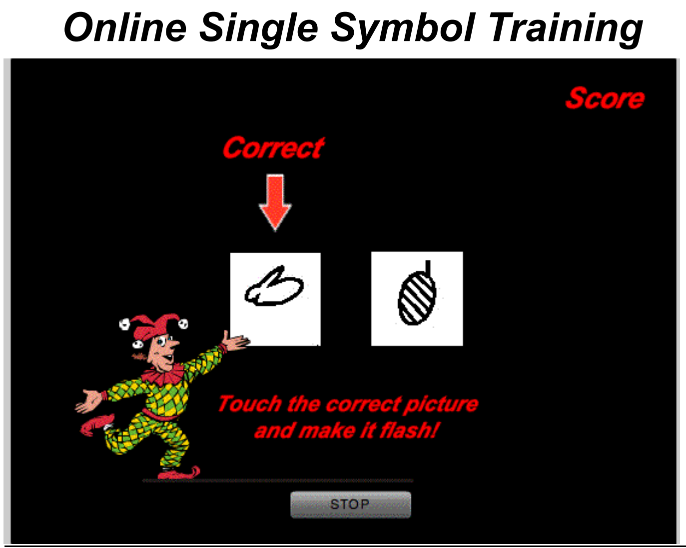


Figure 2. Diagram of the prompt which was provided on the first trial of each of the three visual discriminations, which consisted of a cartoon character and an arrow pointing to the correct choice (S+ symbol).

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.

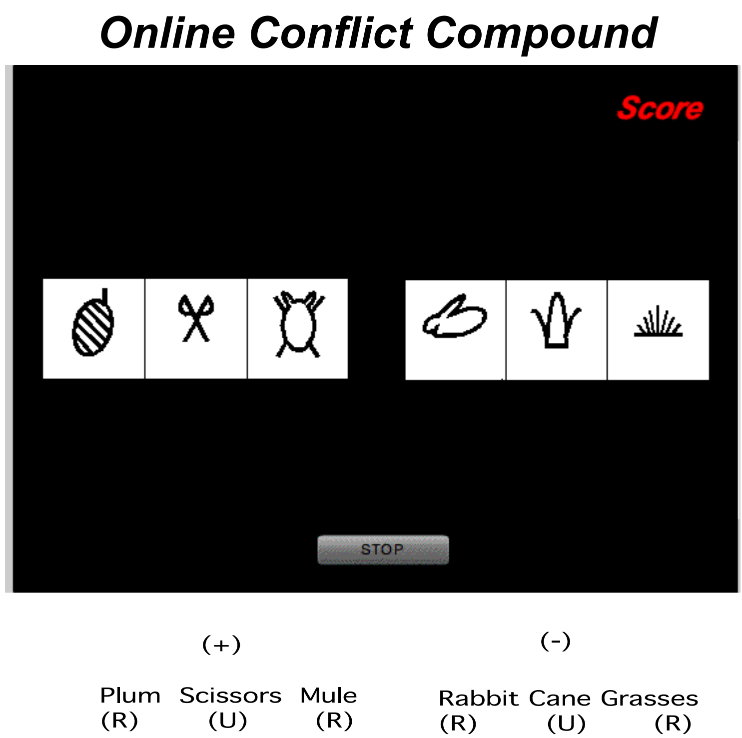


Figure 3. Diagram of the conflict-compound discrimination. Plus (+) indicates stimulus compound paired with reinforcement and minus (-) denotes stimulus compound paired with extinction. The S+ and S- compounds were presented simultaneously and were each composed of three symbols. The positions of the 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 participant selected. The purpose of the test was to assess which symbols the participant 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 participants selected each time the conflict compound appeared on the screen was also recorded with software, which provided a direct comparison of test session results with symbols selected in the conflict compound when compound criterion accuracy was met.

Extended Training

Additional exposure to the initial stimulus-control procedures was given to the young child, 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 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 again 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 child selected each time the conflict compound appeared on the screen.

Results

Participant 1 (Adolescent)

Single-symbol training. In the first phase of the assessment, Participant 1 learned three separate single-symbol discriminations online, and the prompts and reinforcement were provided by the software (See Fig. 4). Rabbit was the S+ symbol and plum was the S- symbol in the first single-symbol discrimination. Participant 1 made no errors (100% accuracy) for the first single-symbol discrimination and achieved criterion accuracy in the first nine trials. In contrast, Participant 1 made 16 consecutive errors before switching to the S+ symbol when the second single-symbol discrimination was presented. Scissors was the S+ symbol and cane was the S- symbol, and Participant 1 required 25 trials (36% accuracy) before achieving criterion accuracy for the second single-symbol discrimination. In the third single-symbol discrimination, grasses was the S+ symbol and mule was the S- symbol. Participant 1 made no errors (100% accuracy) for the third single-symbol discrimination and achieved criterion accuracy in the first nine trials. In summary, Participant 1 learned the first and third single-symbol discriminations quickly with no errors occurring but did make numerous errors and required more trials before acquiring the second single-symbol discrimination.

Mixed-symbol sequence. In the second phase of the assessment, the three original single-symbol discriminations were presented in an unpredictable mixed sequence until the criterion of 28 out of 30 trials correct was achieved. Participant 1 maintained each discrimination with no errors occurring for any of the three single-symbol discriminations during the mixed-symbol sequence and reached criterion accuracy in the first 30 trials (See Fig. 4). Intermixing the three single-symbol discriminations in an unpredictable sequence did not disrupt their original criterion accuracy for Participant 1.

Conflict compound. For the conflict compound, Participant 1 made three errors (85% accuracy) and achieved criterion accuracy in the first 21 trials (See Fig. 4). All three errors occurred because Participant 1 selected reversed S- symbols in the conflict compound in the first four trials. Two errors occurred because Participant 1 selected rabbit, a reversed S- symbol, and one error occurred because he selected grasses, which was also a reversed S- symbol. In the remaining trials, Participant 1 consistently selected the unchanged S+ symbol (scissors) in the conflict compound until criterion accuracy was achieved. When criterion accuracy was achieved, he selected the unchanged symbol (scissors) in the conflict compound in each of the 18 correct trials (See Fig. 5). In summary, Participant 1 shifted his attention to the unchanged symbol in the conflict compound after only three responses to the reversed S- symbols initially occurred.

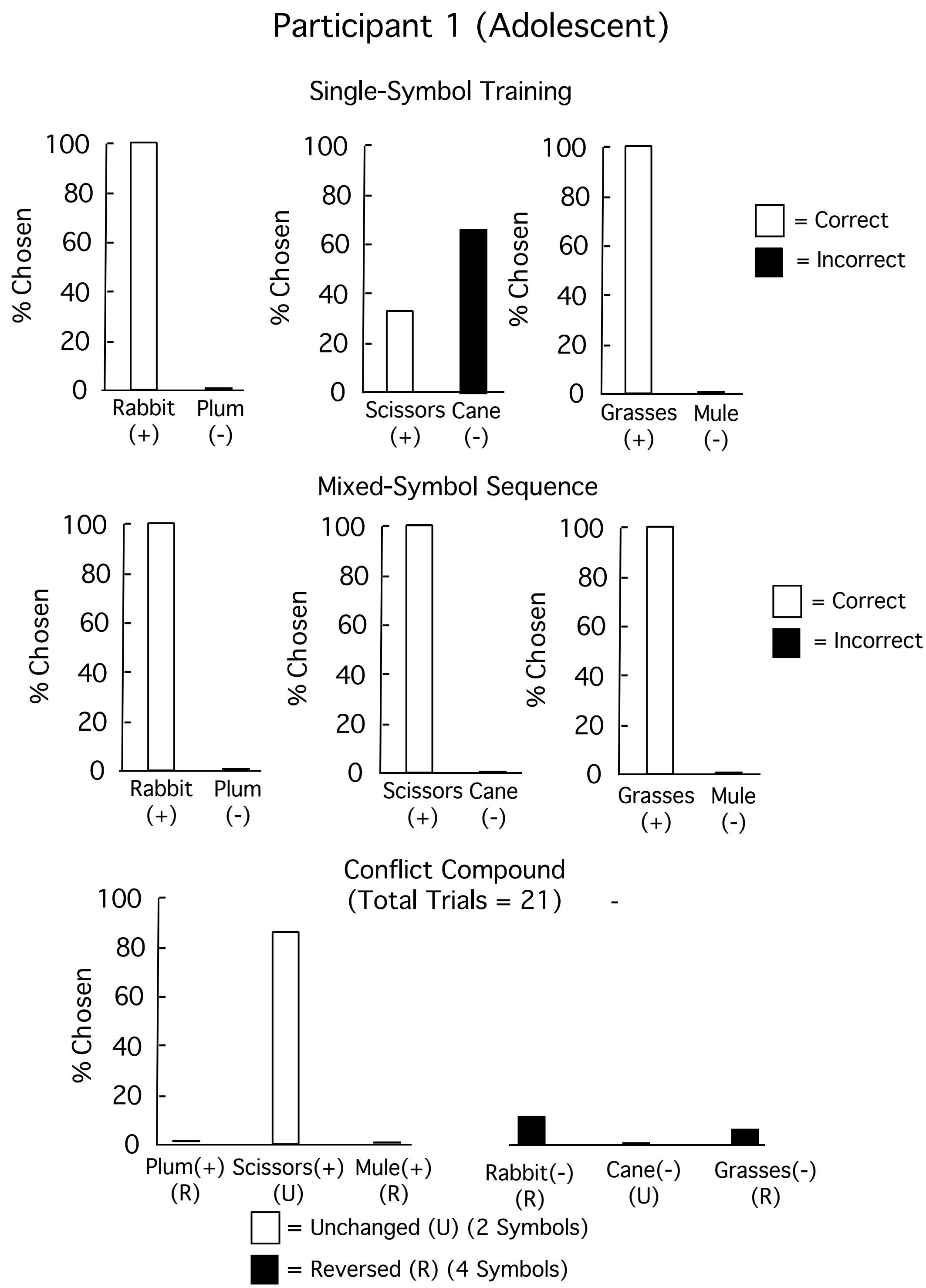


Figure 4. For Participant 1, percent accuracy for the three symbol discriminations during single-symbol training and during the mixed-symbol sequence. In addition, percentage S+ and S- unchanged symbols (white bars) and S+ and S- reversed symbols (black bars) were chosen when the conflict compound was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

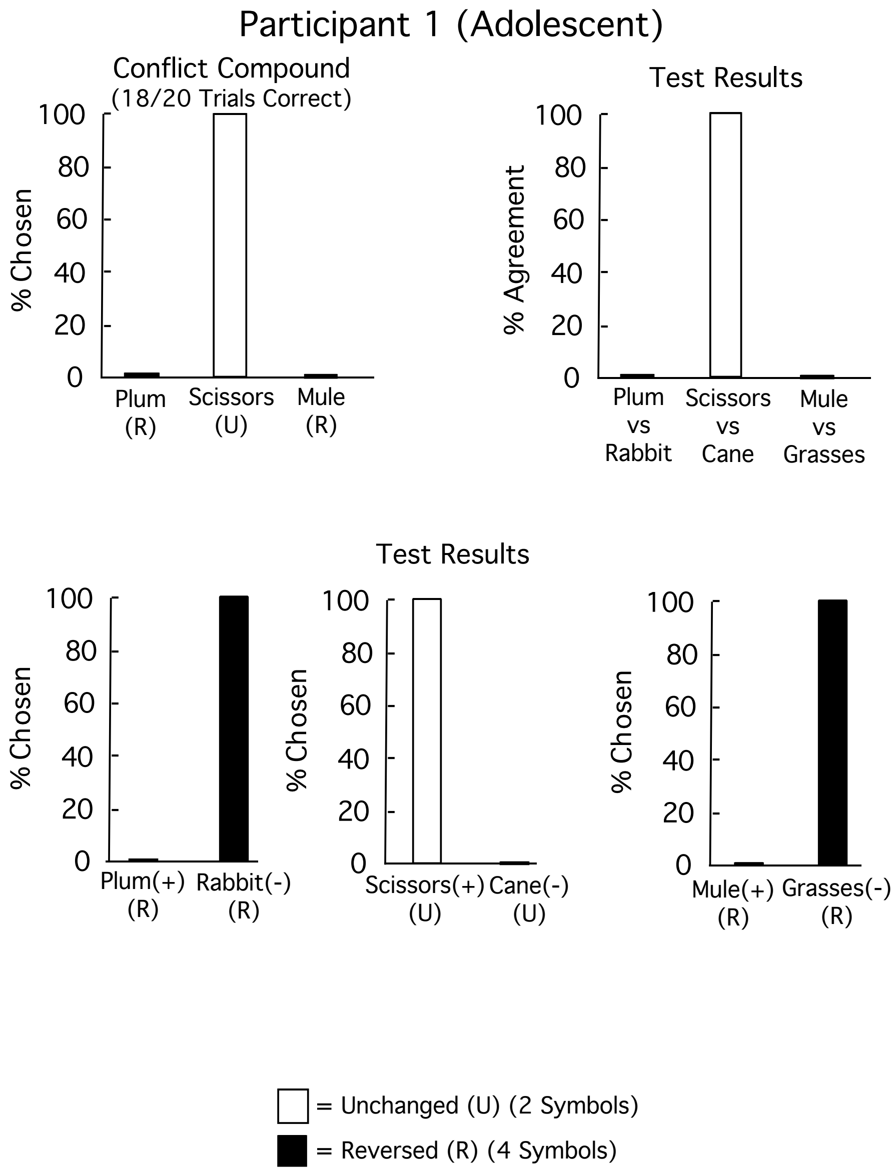


Figure 5. For Participant 1, (left graph) percentage each of the three S+ symbols were chosen during reinforced trials when criterion accuracy was achieved for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies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

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 criterion accuracy was met. Only the unchanged-symbol pair exhibited stimulus control in agreement with the reinforcement contingencies of the conflict compound (See Fig. 5). The unchanged-symbol pair exercised a 100% level of agreement with the reinforcement contingencies of the conflict compound, because Participant 1 consistently selected the unchanged S+ symbol (scissors) throughout the unchanged-symbol test trials. In contrast, a 0% level of agreement with the reinforcement contingencies of the conflict compound occurred for both reversed-symbol pairs, because Participant 1 consistently selected the reversed S- symbols (rabbit and grasses) throughout the reversed-symbol test trials (See Fig. 5).

During the test trials, which were administered following criterion accuracy for the conflict compound, Participant 1 selected the unchanged S+ symbol (scissors) during the unchanged-symbol test trials. He did not select the reversed S+ symbols (plum or mule) during the reversed-symbol test trials. He selected, instead, the reversed S- symbols (rabbit and grasses), which had previously been S+ symbols in single-symbol training (See Fig. 5). This demonstrated, therefore, that when the conflict compound was presented, the two stimulus-response relations paired with extinction (because their prior reinforcement contingencies were reversed in the compound) decreased in frequency without the original stimulus-response relations being disrupted. The two original stimulus-response relations remained intact even after they failed to occur when the conflict compound was presented.

In summary, both the response topographies and the test performance of Participant 1 indicated that he shifted his attention to the unchanged symbol in the conflict compound after only three responses to the reversed S- symbols initially occurred.

Participant 2 (Adult)

Single-symbol training. In the first phase, Participant 2 also acquired the same three separate single-symbol discriminations online. Prompts and reinforcement were again provided by the software (See Fig. 6). For the first single-symbol discrimination when rabbit was the S+ symbol and plum was the S- symbol, Participant 2 made no errors (100% accuracy) and achieved criterion accuracy in the first nine trials. He also achieved 100% accuracy for the second single-symbol discrimination in which scissors was the S+ symbol and cane was the S- symbol and again achieved criterion accuracy in the first nine trials. Participant 2 made no errors (100% accuracy) for the third single-symbol discrimination where grasses was the S+ symbol and mule was the S- symbol and continued to achieve criterion accuracy in the first nine trials. In summary, Participant 2 learned each discrimination quickly and with no errors occurring for any of the three single-symbol discriminations.

Mixed-symbol sequence. During the second phase, when the three original single-symbol discriminations appeared in an unpredictable mixed sequence, Participant 2 maintained each discrimination successfully with only two errors occurring during the mixed-symbol sequence when criterion accuracy was achieved (See Fig. 6). One error (90% accuracy) occurred for the rabbit+ vs. plum- discrimination and the other error (90% accuracy) occurred for the scissors+ vs. cane- discrimination. Participant 2 made no errors (100% accuracy) for the grasses+ vs. mule- discrimination during the mixed-symbol sequence. As a result, Participant 2 achieved criterion accuracy for the mixed-symbol sequence in the first 30 trials. Intermixing the three single-symbol discriminations in an unpredictable sequence did not disrupt their original criterion accuracy for Participant 2.

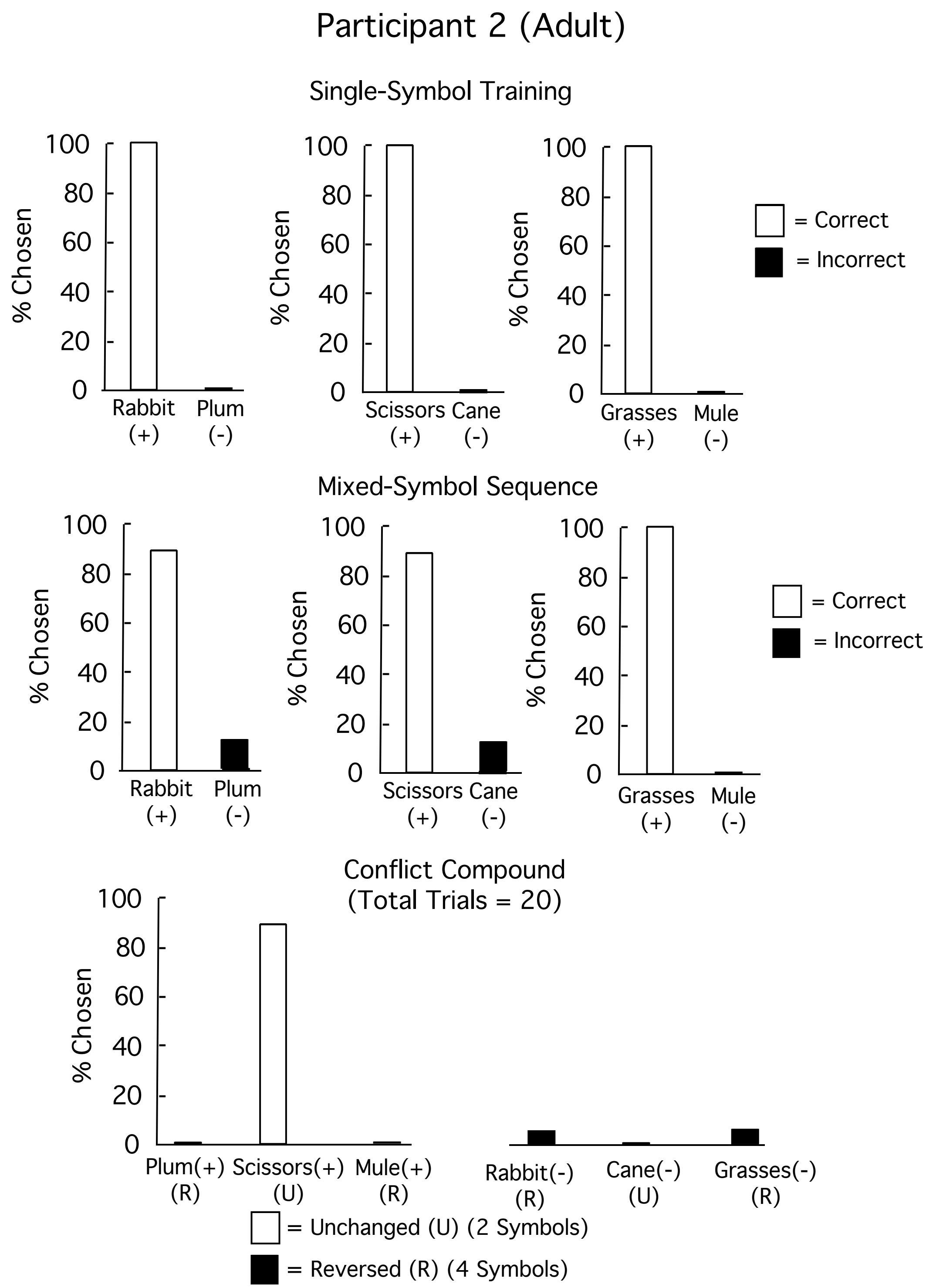


Figure 6. For Participant 2, percent accuracy for the three symbol discriminations during single-symbol training and during the mixed-symbol sequence. In addition, percentage S+ and S- unchanged symbols (white bars) and S+ and S- reversed symbols (black bars) were chosen when the conflict compound was presented.

Conflict compound. For the conflict compound, Participant 2 made only two errors (90% accuracy) and achieved criterion accuracy in the first 20 trials (See Fig. 6). Both errors were due to Participant 2 selecting a reversed S- symbol in the conflict compound in the first two trials. One error occurred because Participant 2 selected rabbit and the other error occurred because he selected grasses, which were both reversed S- symbols in the conflict compound. In the remaining 18 trials, however, Participant 2 selected the unchanged S+ symbol (scissors) in the conflict compound. When criterion accuracy was achieved, Participant 2 selected the unchanged symbol (scissors) in each of the 18 correct trials (See Fig. 7). After only two responses occurred to reversed S- symbols, Participant 2 shifted his attention to the unchanged symbol in the conflict compound.

Test results. The test performance of Participant 2 also confirmed that he shifted his attention to the unchanged symbol (scissors) in the conflict compound when criterion accuracy was achieved. This was because only the unchanged-symbol pair exercised stimulus control in agreement with the reinforcement contingencies of the conflict compound (See Fig. 7). The unchanged-symbol pair exercised a 100% level of agreement with the reinforcement contingencies of the conflict compound, as Participant 2 consistently selected the unchanged S+ symbol (scissors) throughout the unchanged-symbol test trials. A 0% level of agreement with the reinforcement contingencies of the conflict compound, in contrast, occurred for both reversed-symbol pairs since Participant 2 consistently selected the reversed S- symbols (rabbit and grasses) during the reversed-symbol test trials (See Fig. 7).

When the conflict compound was presented, the two stimulus-response relations paired with extinction (because their prior reinforcement contingencies were reversed in the compound) decreased in frequency without the original stimulus-response relations being disrupted. This occurred because Participant 2 never selected the reversed S+ symbols (plum or 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. 7). His test performance revealed the two original stimulus-response relations remained intact even after they failed to occur when the conflict compound was presented.

In summary, both the response topographies and the test performance of Participant 2 revealed that he shifted his attention to the unchanged symbol in the conflict compound after only two responses to the reversed S- symbols initially occurred.

Participant 3 (Adult)

Single-symbol training. In the first phase, Participant 3 learned the same three separate single-symbol discriminations online with the prompts and reinforcement provided by the software (See Fig. 8). When the first single-symbol discrimination (rabbit+ vs. plum-) was presented, Participant 3 made no errors (100% accuracy) and achieved criterion accuracy in the first nine trials. Participant 3 also made no errors (100% accuracy) when scissors was the S+ symbol and cane was the S- symbol in the second discrimination and achieved criterion accuracy in the first nine trials. When the third single-symbol discrimination was presented (grasses+ vs mule-), she continued to achieve criterion accuracy with no errors (100% accuracy) occurring in the first nine trials. In summary, Participant 3 learned the three single-symbol discriminations without errors occurring and quickly achieved criterion accuracy for each of the discriminations.

Mixed-symbol sequence. During the mixed-symbol sequence when the three original single-symbol discriminations were intermixed, no errors occurred for any of the discriminations (See Fig. 8). As a result, Participant 3 reached criterion accuracy (28 out of 30 trials correct) in the first 30 trials. The initial criterion accuracy for each of the three original single-symbol discriminations was successfully maintained even when the three single-symbol discriminations were presented in an intermixed unpredictable sequence. Their original criterion accuracy was not disrupted.

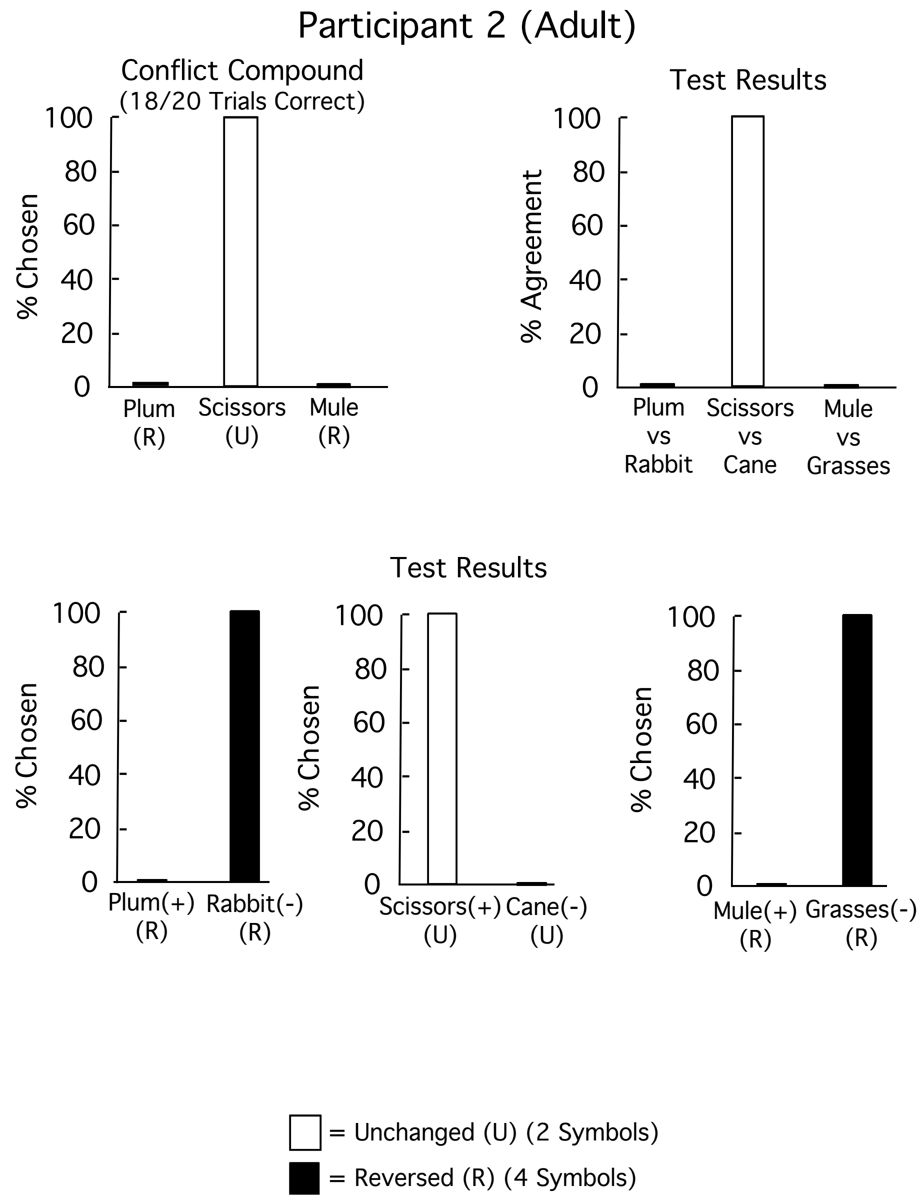
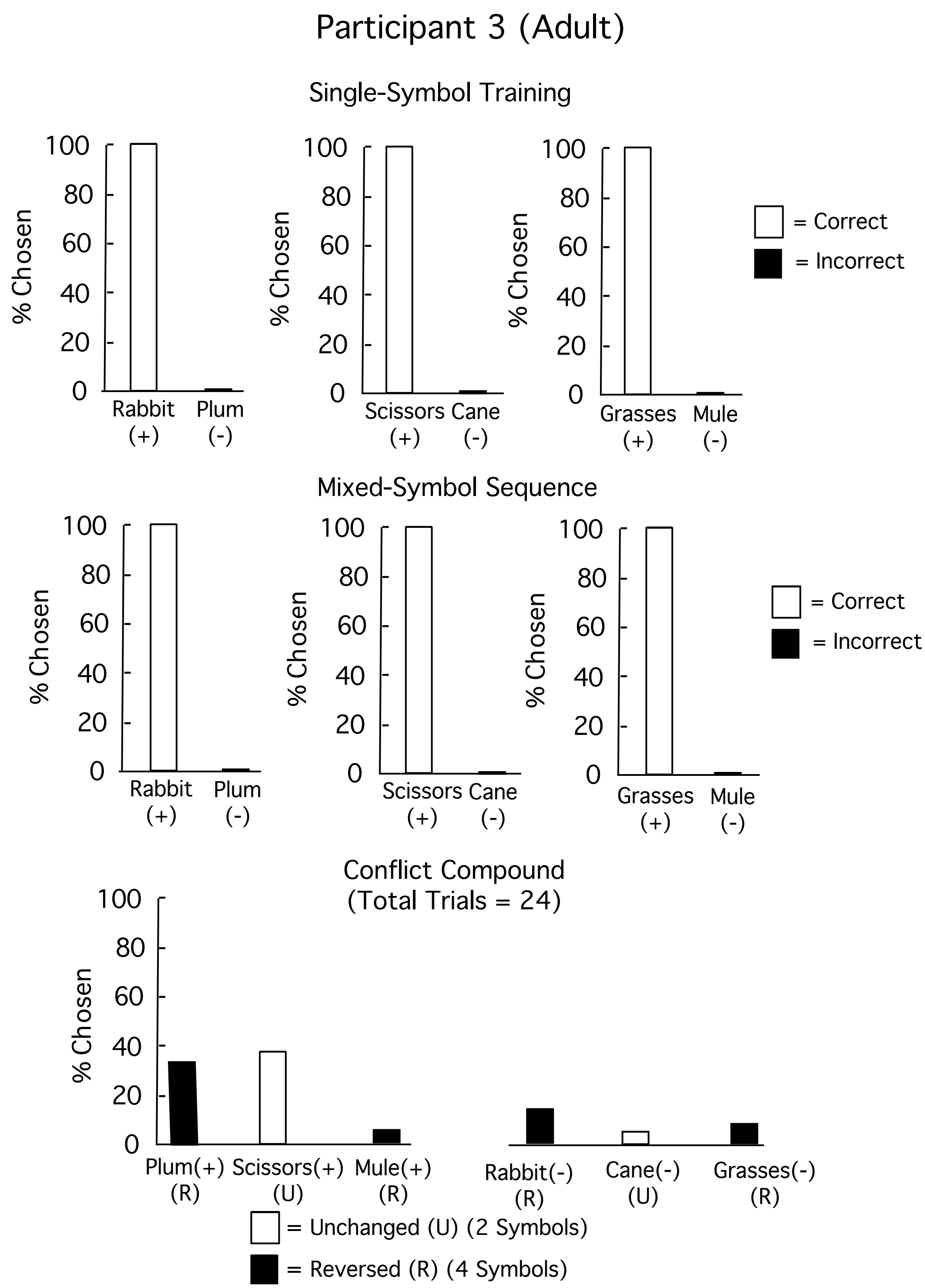


Figure 7. For Participant 2, (left graph) percentage each of the three S+ symbols were chosen during reinforced trials when criterion accuracy was achieved for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies 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.



<u>Figure 8</u>. 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.

Conflict compound. When the conflict compound was presented, Participant 3 made six errors (75% accuracy) and required 24 trials to achieve criterion accuracy (See Fig. 8). The six errors occurred in the first six trials. Five of these errors occurred because Participant 3 selected reversed S- symbols (rabbit and grasses) in the conflict compound, and one error occurred because she selected the unchanged S- symbol (cane) in the conflict compound. In the remaining 18 trials, Participant 3 selected reversed S+ symbols (plum and mule) in the conflict compound in nine of the trials and the unchanged S+ symbol (scissors) in the conflict compound in nine of the trials. When criterion accuracy was achieved for the conflict compound, Participant 3 selected the unchanged symbol (scissors) in nine of the 18 correct trials (50%) and one of the reversed symbols (plum) in eight of the 18 correct trials (44%). She selected the remaining reversed symbol (mule) in one of the 18 correct trials (6%) (See Fig. 9). The response topographies of Participant 3 indicated that she did not shift her attention to the unchanged symbol (scissors) in the conflict compound when criterion accuracy was achieved. She responded, instead, to both the unchanged symbol (scissors) and reversed symbols (plum and mule) in the conflict compound when criterion accuracy was obtained.

Test results. The test performance of Participant 3, following criterion accuracy, indicated, however, that she selectively attended to the unchanged symbol (scissors) in the conflict compound. This was because only the unchanged-symbol pair exercised stimulus control in agreement with the reinforcement contingencies of the conflict compound (See Fig. 9). The unchanged-symbol pair exercised a 100% level of agreement with the reinforcement contingencies of the conflict compound since Participant 3 consistently selected the unchanged S+ symbol (scissors) throughout the unchanged-symbol test trials. A 0% level of agreement with the reinforcement contingencies of the conflict compound occurred for both reversed-symbol pairs because Participant 3 consistently selected the reversed S- symbols (rabbit and grasses) throughout the reversed-symbol test trials (See Fig. 9). Both reversed S- symbols had been previously S+ symbols in single-symbol training. This meant that even though Participant 3 responded to reversed symbols in the S+ compound when criterion accuracy was achieved, in addition to the unchanged symbol in the S+ compound, the original stimulus control of the reversed symbols remained intact, as shown by the test results.

New stimulus control was not established by presenting the conflict compound. The original stimulus control of the symbols, whose prior reinforcement contingencies were reversed in the conflict compound, was disrupted since Participant 3 responded to both reversed S+ symbols and the unchanged S+ symbol in the conflict compound when criterion accuracy was achieved. It did not, however, result in the formation of new stimulus control topographies. The original stimulus-response relations of the reversed symbols remained intact and were not eliminated because of presenting the conflict compound as Participant 3 never selected the reversed S+ symbols (plum and mule) during the reversed-symbol test trials. She 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. 9).

In summary, the test performance of Participant 3 indicated that she selectively attended to the unchanged symbol (scissors) in the conflict compound although it was not confirmed by her response topographies. Her response topographies revealed that she did not selectively respond to the unchanged symbol in the conflict compound in contrast to the response topographies of Participant 1 and Participant 2.

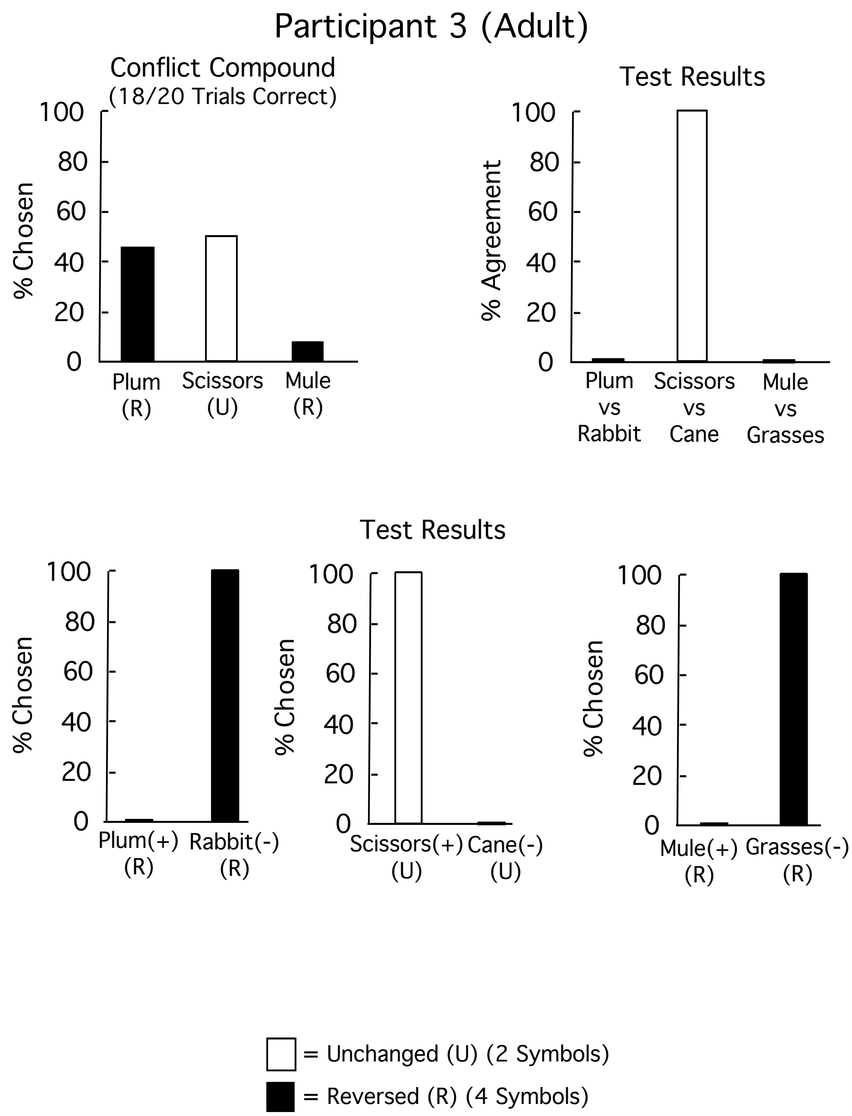


Figure 9. For Participant 3, (left graph) percentage each of the three S+ symbols were chosen during reinforced trials when criterion accuracy was achieved for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies 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.

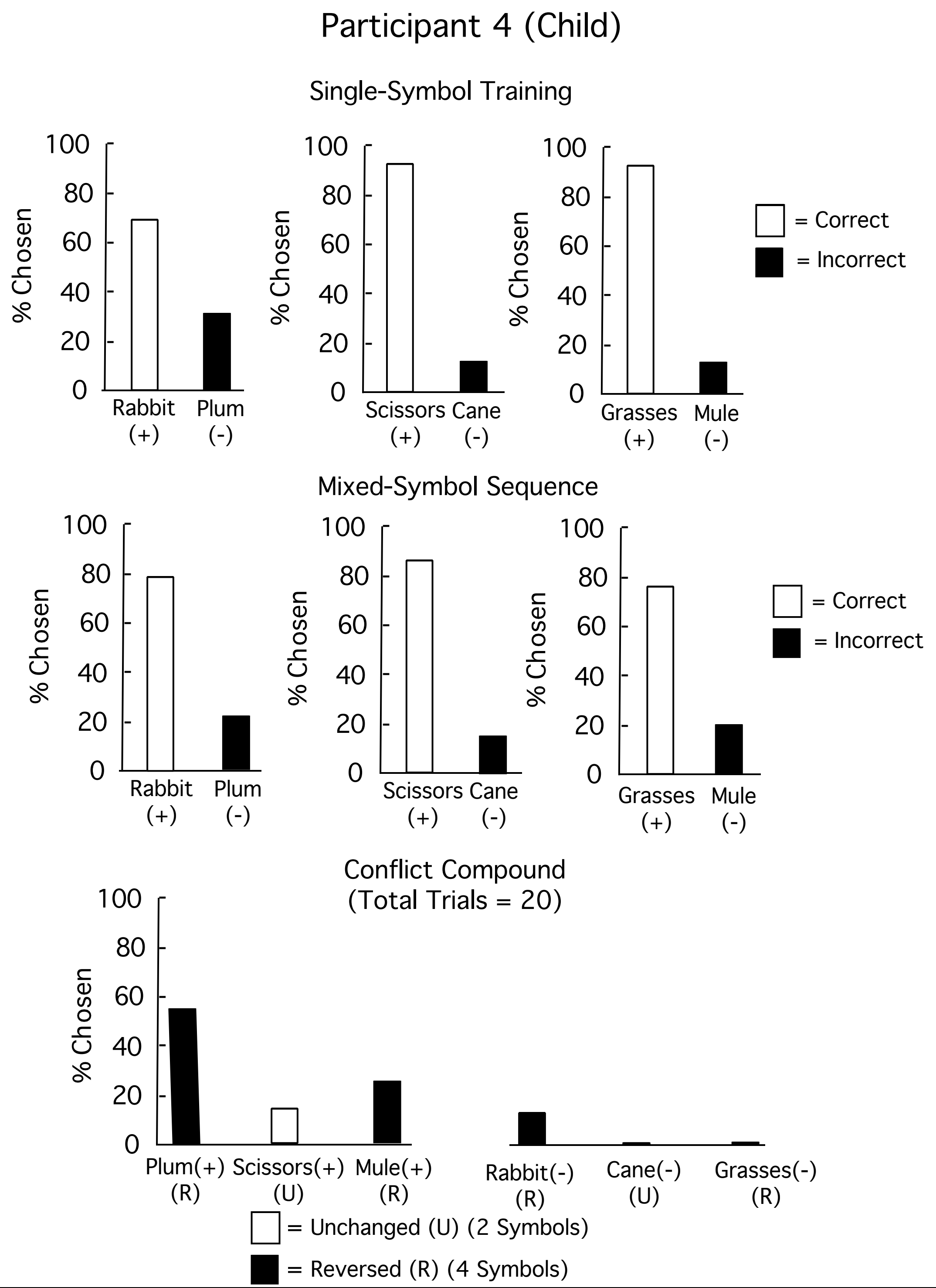


Figure 10. For Participant 4, percent accuracy for the three symbol discriminations during single-symbol training and during the mixed-symbol sequence. In addition, percentage S+ and S- unchanged symbols (white bars) and S+ and S- reversed symbols (black bars) were chosen when the conflict compound was originally presented.

Participant 4 (Child)

Single-symbol training. In the first phase, Participant 4 also learned the three separate single-symbol discriminations online and the prompts and reinforcement were also provided by the software (See Fig. 10). When the first single-symbol discrimination (rabbit+ vs. plum-) was presented, Participant 4 made eight errors (69% accuracy) and required 26 trials before achieving criterion accuracy. Participant 4 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. Participant 4 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 Participant 4 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 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, Participant 4 made eleven errors during the mixed-symbol sequence (See Fig. 10). 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. As a result of these errors, Participant 4 required 56 trials before he achieved criterion accuracy for the mixed-symbol sequence. Intermixing the three single-symbol discriminations in an unpredictable sequence disrupted initially their original criterion accuracy for Participant 4, which in contrast did not occur for the three older participants.

Conflict compound. When the conflict compound was presented, Participant 4 made two errors (90% accuracy) and required 20 trials to reach criterion accuracy (See Fig. 10). 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, Participant 4 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, Participant 4 selected the unchanged symbol (scissors) in two of the 18 correct trials (11%), a reversed symbol (plum) in 11 of the 18 correct trials (61%), and a reversed symbol (mule) in five of the 18 correct trials (28%) (See Fig. 11). Participant 4 did not shift his attention to the unchanged symbol (scissors) in the conflict compound. He responded primarily to reversed symbols (plum and mule) in the conflict compound, with two exceptions, when criterion accuracy was met.

Test results. The test performance of Participant 4, 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. 11). 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, and the other reversed-symbol pair was associated with a 67% level of agreement (See Fig. 11).

The original stimulus control of the unchanged symbol pair was disrupted following acquisition of the conflict compound since Participant 4 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. Participant 4 also responded to both reversed S+ symbols and reversed S- symbols during the reversed symbol test trials (See Fig. 11). Pairing stimulus-response relations with extinction in the conflict compound due to a reversal of their prior reinforcement contingencies disrupted the original stimulus-response relations, which did not occur for the three older participants.

In summary, both the response topographies and the test performance of Participant 4 indicated that he did not shift his attention to the unchanged symbol in the conflict compound.

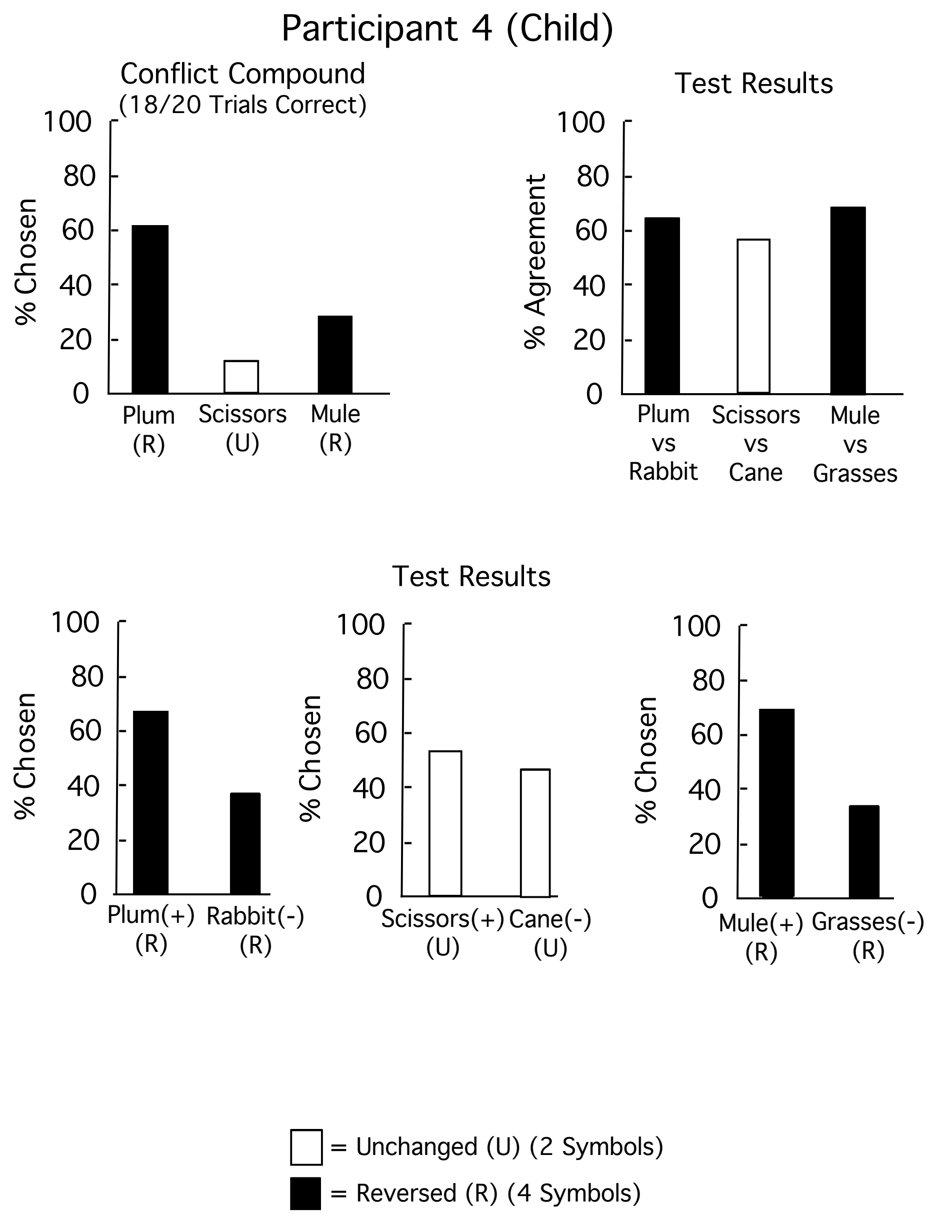


Figure 11. For Participant 4, (left graph) percentage each of the three S+ symbols were chosen during reinforced trials when criterion accuracy was originally achieved for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies of the conflict compound. The top symbols shown for 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.

Participant 4 (Child) (Extended Training)

Single-symbol training. In the first phase of extended training, Participant 4 was presented again with the same three separate single-symbol discriminations (See Fig. 12). The prompts and reinforcement were again provided by the software. Participant 4 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 Participant 4 achieved criterion accuracy in the first ten trials. In summary, Participant 4 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. 12). Only one error (89% accuracy) occurred for the rabbit+ vs. plum- discrimination. Participant 4 achieved 100% accuracy for both the scissors+ vs. cane- discrimination and the grasses+ vs. mule- discrimination. During extended training, Participant 4 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. 12).

Conflict compound. When extended training was provided for the conflict compound, Participant 4 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 Participant 4 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. 12). In the remaining 19 trials during extended training, Participant 4 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 symbol (scissors) in each of the 18 correct trials (100%) (See Fig. 13). Participant 4 shifted his attention to the unchanged 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, Participant 4 did not shift his attention to the unchanged symbol (scissors) in the conflict compound.

Test results. His test performance, which was based on less than 36 trials because of equipment malfunction, further confirmed because of extended training that Participant 4 shifted his attention to the unchanged symbol (scissors) in the conflict compound when criterion accuracy was achieved. This was concluded since only the unchanged symbol (scissors) exercised stimulus control in agreement (80% or higher) with the reinforcement contingencies of the conflict compound following extended training (See Fig. 13). The unchanged-symbol pair exercised an 83% level of agreement with the reinforcement contingencies of the conflict compound because Participant 4 selected the unchanged S+ symbol (scissors) in 83% of the unchanged-symbol test trials. Only a 33% level of agreement occurred, however, for both reversed S+ symbols (plum and mule) after extended training was provided since Participant 4 selected the reversed S- symbols (rabbit and grasses) in 67% of the reversed-symbol test trials (See Fig. 13).

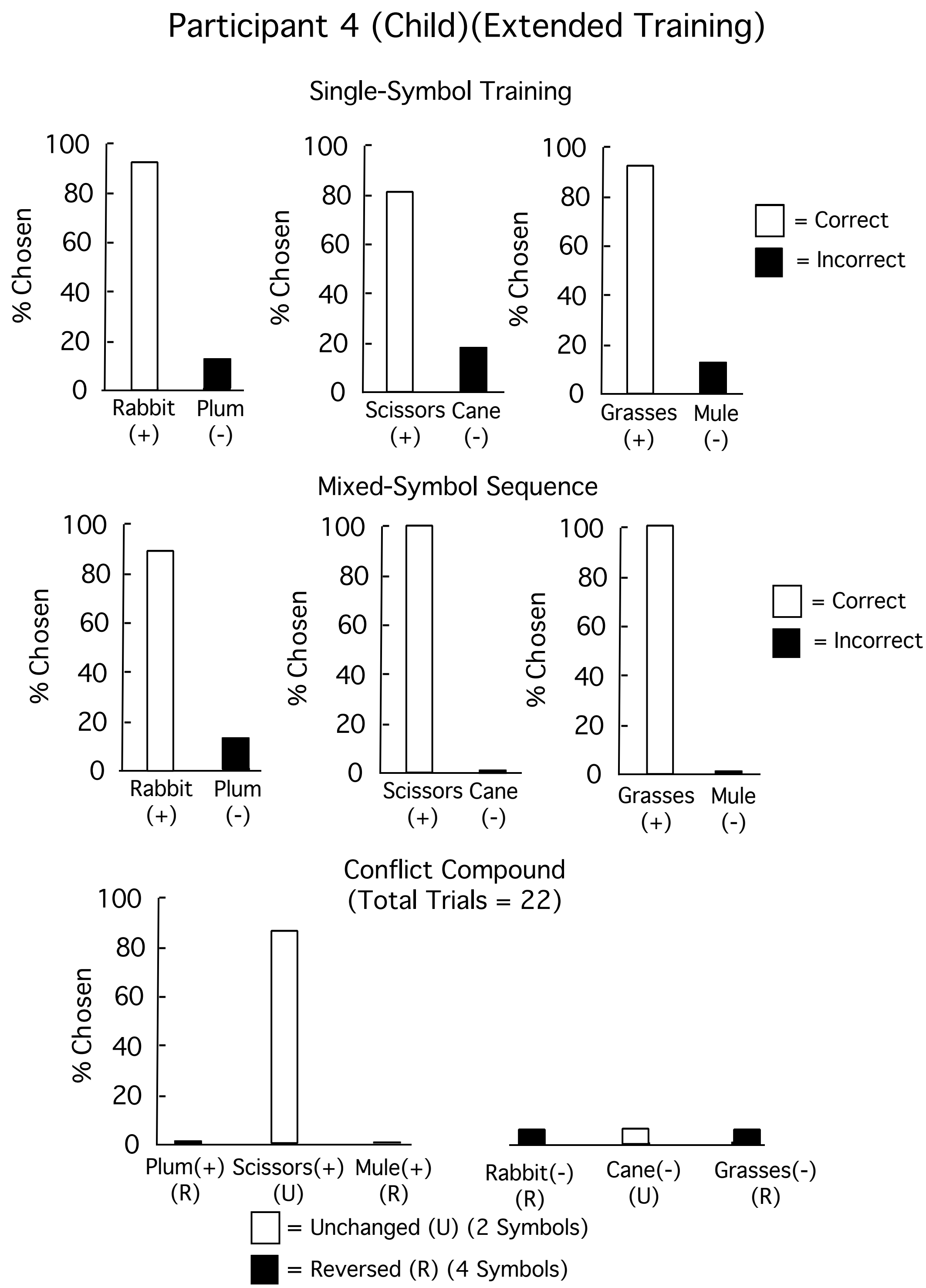


Figure 12. For Participant 4, percent accuracy for the three symbol discriminations when single-symbol training and the mixed-symbol sequence were presented a second time. In addition, percentage S+ and S- unchanged symbols (white bars) and S+ and S- reversed symbols (black bars) were chosen when the conflict compound was presented a second time.

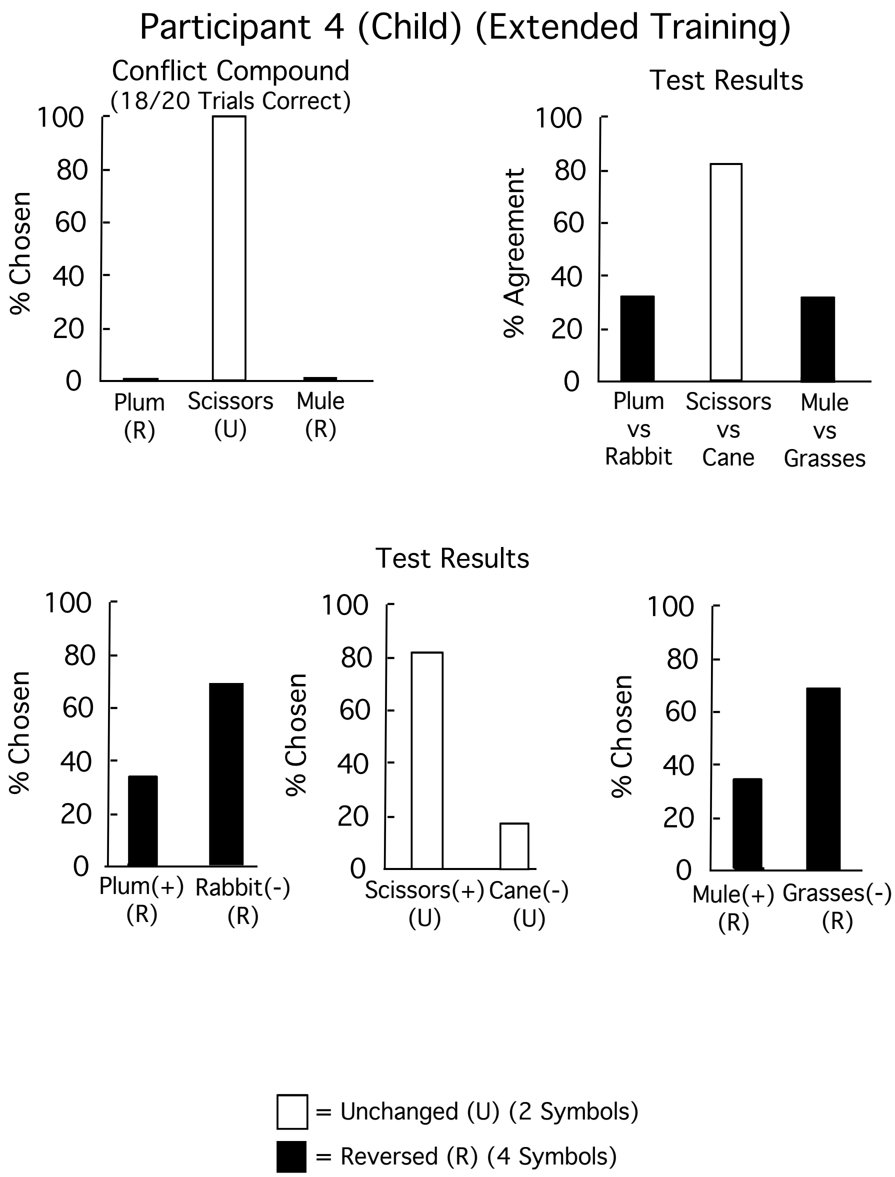


Figure 13. For Participant 4, (left graph) percentage each of the three S+ symbols were chosen during reinforced trials when criterion accuracy was achieved a second time for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies of the conflict compound following extended training. The top symbols shown for 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 following extended training. White bars and black bars indicate unchanged and reversed symbols, respectively.

When the conflict compound was presented again 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, however, disrupted. This was shown because Participant 4 selected the reversed S+ symbols (plum and mule) in 33% of the reversed-symbol test trials and 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. 13). In contrast, the test performance of Participant 4 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 Participant 4 revealed that he shifted his attention to the unchanged symbol in the conflict compound after only a few responses to the reversed S- symbols initially occurred.

Experiment 2

Method

Subjects

An adult 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 at a remote site, and the participant used an Apple iPhone.

General Procedure

Each session consisted of approximately 100 trials. A trial began when symbols, centered on two white illuminated backgrounds, appeared on the screen of the participant's Apple iPhone. The trial ended when the participant touched a symbol in either illuminated area. A 3-s intertrial interval followed when the screen was dark, and then the next trial began. Touching the correct symbol during training sessions resulted in a flashing screen, and a point was earned for each correct response. The total number of points accumulated was displayed in the upper right corner of the participant's screen. If an incorrect symbol was selected, reinforcement was not provided. During test sessions, reinforcement was provided regardless of which symbol the participant touched. Because a report was automatically generated following the session, the participant also received immediate feedback concerning his performance.

Single Symbol Training

In the first step, Participant 5 learned the same three separate visual discriminations online, which were composed of six different symbols, as did the previous four participants in the first experiment (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 Apple iPhone screen in a block of 20 trials, and the S+ symbol never appeared more than twice in succession in the same location. Prompts and reinforcement were also provided by the software (See Fig. 2).

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 three single-symbol visual discriminations. Response latency was defined as the amount of time that elapsed between the presentation of a symbol pair on the screen of the participant's Apple iPhone and his symbol selection.

Mixed-Symbol Sequence

In the second step, the three original symbol pairs were again presented in the same unpredictable mixed sequence that had also been presented in the first experiment to the previous four participants. 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 mixed-symbol sequence was presented to Participant 5 until the criterion of 28 out of 30 trials correct was met. Response accuracy and response latency were recorded throughout the mixed-symbol sequence.

Conflict Compound

The individual symbols were next combined to form a conflict compound after criterion accuracy was obtained for the mixed-symbol sequence. The conflict compound was created for Participant 5, as had also occurred for the previous four participants, 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). Prior reinforcement histories were again unchanged for only scissors and cane in the conflict compound while the prior reinforcement histories were reversed for the remaining four symbols. Plum and mule were paired with reinforcement in the compound and rabbit and grasses with extinction, which was the reverse of original single-symbol training. Response accuracy, response topography, and response latency were recorded during the presentation of the conflict-compound.

Test Conditions

After criterion accuracy (90% accuracy in a 20-trial sequence) was achieved for the conflict compound, the same test trials were presented to Participant 5 as were previously presented to the four participants in the first experiment. Thirty-six test trials were presented in which the same three symbol pairs were presented 12 times each in a mixed sequence. Reinforcement was also provided during the test trials regardless of which symbol Participant 5 selected.

The purpose of the test was to assess which symbols Participant 5 was attending to when he obtained criterion accuracy for the conflict- compound discrimination. This was again determined by calculating 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. Symbols associated with high percent agreement scores (80% or greater) were concluded to control responding in the conflict compound when Participant 5 attained criterion accuracy.

The symbol that Participant 5 selected each time the conflict compound appeared on the screen was also recorded with software, which 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 Adolescent 5 during the 36 test trials.

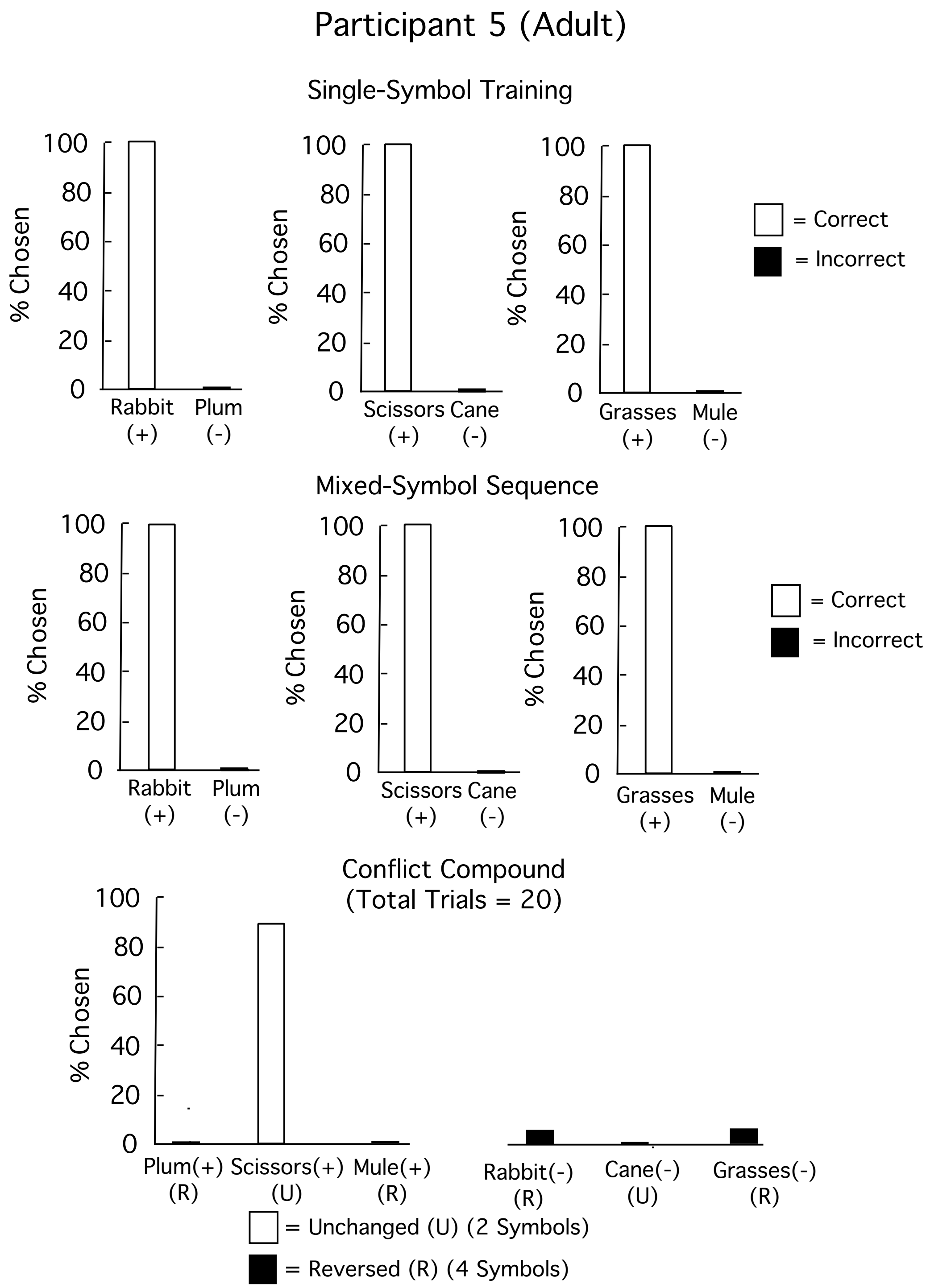


Figure 14. For Participant 5, percent accuracy for the three symbol discriminations during single-symbol training and during the mixed-symbol sequence. In addition, percentage S+ and S- unchanged symbols (white bars) and S+ and S- reversed symbols (black bars) were chosen when the conflict compound was presented.

Results

Participant 5 (Adult)

Single-symbol training. Participant 5 did not make any errors during single-symbol training and achieved, as a result, 100% accuracy for each of the three single-symbol discriminations (See Fig. 14).

Although his accuracy scores (100% accuracy) remained the same for all three discriminations throughout single-symbol training, his response latencies showed changes in stimulus control not revealed by the accuracy scores. For the first single-symbol discrimination where rabbit was the S+ symbol and plum was the S- symbol, the average response latency was 4.5 seconds (See Fig. 15). Initially, however, the response latencies for the first two trials in the first discrimination were 21.3 and 7.9 seconds respectively. The response latencies quickly decreased in subsequent trials and were between one and slightly above two seconds with a gradual decrease across trials.

The average response latency decreased to 2.3 seconds for the second single-symbol discrimination where scissors was the S+ symbol and cane was the S- symbol (See Fig. 16). The initial response latency of 5.8 seconds in the first trial of the second discrimination was also much lower than the 21.3 seconds latency recorded in the first trial of the first discrimination task. Response latencies also decreased in subsequent trials and, with one exception, varied between one and two seconds. In the sixth trial of the second single-symbol discrimination task, a 4.7 second response latency was recorded.

In the third single-symbol discrimination in which grasses was the S+ symbol and mule was the S- symbol, the average response latency was only 1.7 seconds (See Fig. 17). This was lower than the average response latencies of the previous two single-symbol discriminations. Although a response latency of 5.1 seconds occurred in the first trial of the third single-symbol discrimination, in subsequent trials the response latency varied between 1.2 and 1.5 seconds.

In summary, although the accuracy scores remained at 100% accuracy for all three single-symbol discriminations, the decreases in average response latencies which occurred for the single-symbol discriminations showed a slight improvement in stimulus control. This improvement in stimulus control indicated by the response latencies was not reflected by the participant's accuracy scores.

Mixed-symbol sequence. During the second phase when the three original single-symbol discriminations were presented in an unpredictable mixed sequence until the criterion of 28 out of 30 trials correct was achieved, Participant 5 did not make any errors (See Fig. 14). He again achieved 100% accuracy for each of the three single-symbol discriminations when they were intermixed and achieved criterion accuracy in the first 30 trials. Although intermixing the three single-symbol discriminations in an unpredictable sequence did not disrupt their original criterion accuracy for Participant 5, 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 only 1.5 seconds which was a decrease from the original average response latency of 4.5 seconds for the first single-symbol discrimination (See Fig. 15). This change in average response latency for the first single-symbol discrimination occurred when 100% accuracy was demonstrated in both single-symbol training and the mixed-symbol sequence. Although there was a small increase in response latency in the first two trials of the first single-symbol discrimination during the mixed-symbol sequence, the response latencies decreased to slightly above one second in the later trials.

The average response latency for the second single-symbol discrimination (scissors+ vs. cane-) during the mixed-symbol sequence was 1.9 seconds which was also a decrease from the original average response latency of 2.3 seconds for the second single-symbol discrimination (See Fig. 16). This decrease in average response latency for the second single-symbol discrimination also occurred when 100% accuracy was demonstrated in both single-symbol training and the mixed-symbol sequence. The average response latency (1.9 seconds) of the second single-symbol discrimination during the mixed-symbol sequence was, however, slightly longer than the average response latency (1.5 seconds) of the first single-symbol discrimination during the mixed-symbol sequence. This slightly longer average response latency for the second discrimination was mostly the result of the response latencies of three and four seconds recorded in the first and fifth trials of the second discrimination during the mixed-symbol sequence.

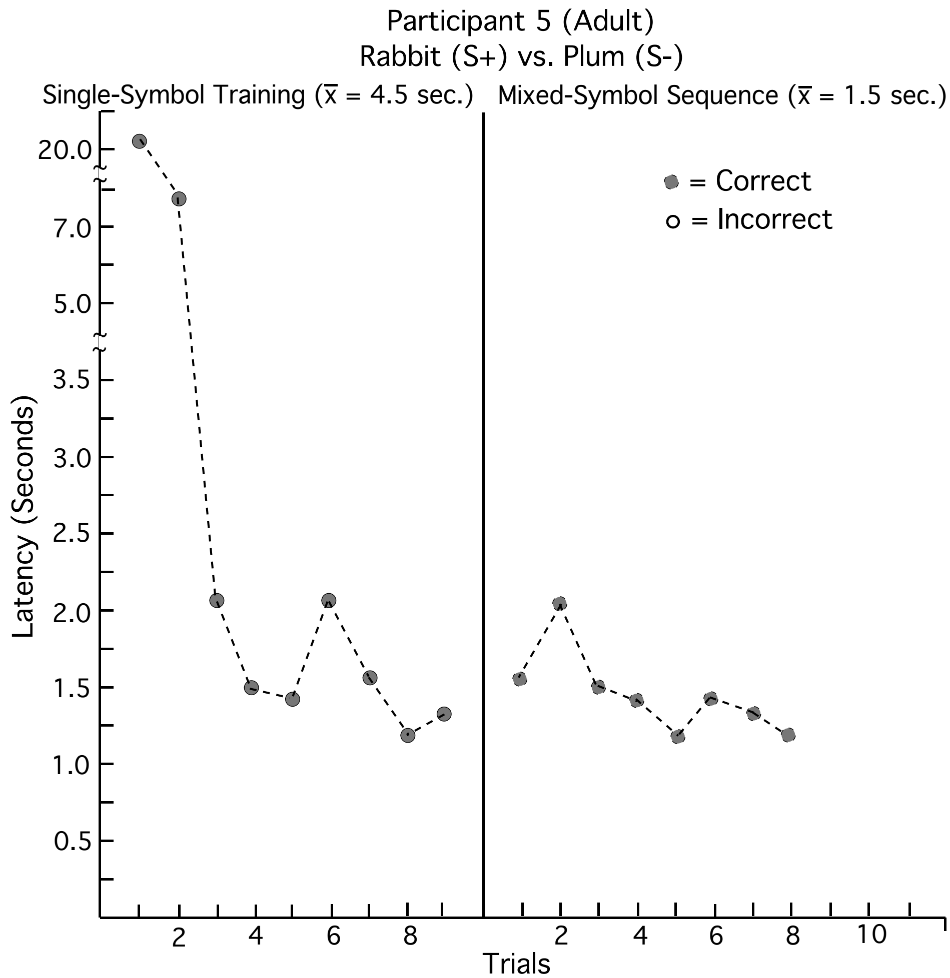


Figure 15. For Participant 5, response latency for rabbit (+) vs. plum (-) during single-symbol training and during the mixed-symbol sequence.

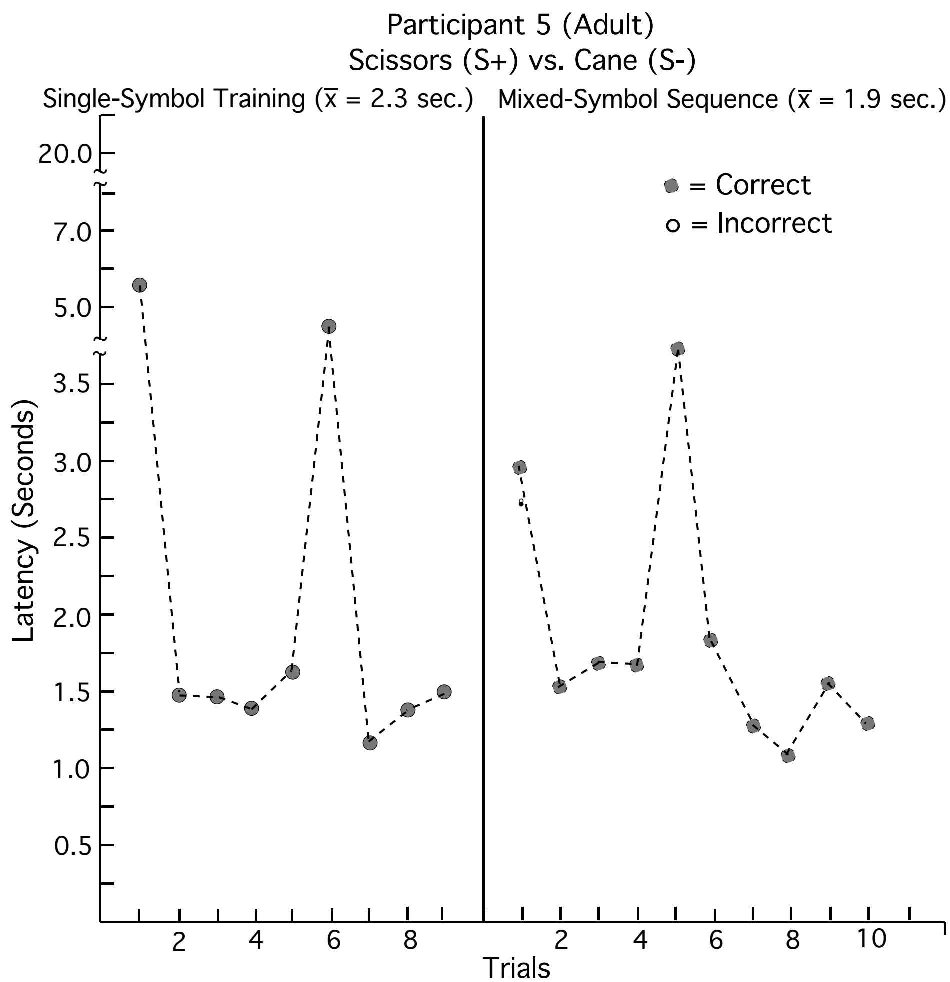


Figure 16. For Participant 5, response latency for scissors (+) vs. cane (-) during single-symbol training and during the mixed-symbol sequence.

In the third single-symbol discrimination (grasses+ vs. mule-), the average response latency during the mixed-symbol sequence was 1.5 seconds which was slightly less than the original average response latency of 1.7 seconds for the third discrimination (See Fig. 17). It was not comparable, however, to the extent of decrease of the average response latencies observed during the mixed-symbol sequences for both the first and second single-symbol discriminations. This smaller decrease in average response latency during the mixed-symbol sequence of the third discrimination was the result of a slight increase in response latency that occurred in most of the trials during the mixed-symbol sequence.

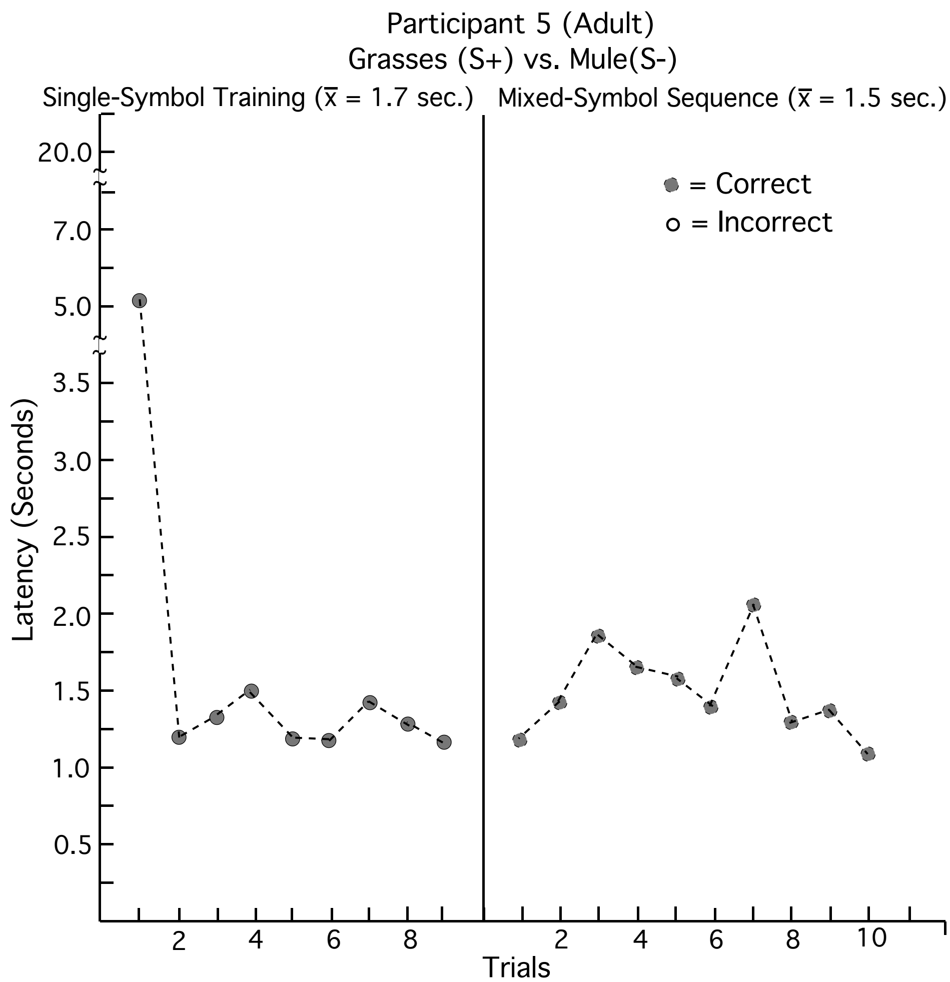


Figure 17. For Participant 5, response latency for grasses (+) vs. mule (-) during single-symbol training and during the mixed-symbol sequence.

In summary, the response latencies of Participant 5 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 single-symbol discriminations were intermixed. This was shown by the fact that the average response latency for all three single-symbol discriminations during the mixed symbol-sequence was less than their original average response latency. Stimulus control was not only not disrupted during the mixed-symbol sequence but for two of the single-symbol discriminations slightly improved.

<u>Conflict compound</u>. Participant 5 made only two errors (90% accuracy) when the conflict compound was initially presented and achieved, as a result, criterion accuracy in the first 20 trials (See Fig. 14). Both errors occurred because Participant 5 selected a reversed S- symbol in the second and third trials of the conflict-compound discrimination. Participant 5 made one error because he selected rabbit, and he made the second error because of selecting grasses, which were both reversed S- symbols. In the remaining 18 trials, Participant 5 selected the unchanged S+ symbol (scissors) in the conflict compound. When criterion accuracy was achieved, Participant 5 selected the unchanged S+ symbol (scissors) in each of the 18 correct trials (See Fig. 18), and he shifted his attention to the unchanged S+ symbol in the conflict compound after only two responses to reversed S- symbols initially occurred.

The response topographies of Participant 5 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. His response latencies, however, revealed changes in stimulus control not shown by his response topographies and response accuracy. The average response latency of Participant 5 for the S+ symbol (scissors) during the mixed-symbol sequence was 1.9 seconds (See Fig. 16). When the conflict- compound discrimination was presented, however, his average response latency for the unchanged S+ symbol (scissors) increased to 4.7 seconds (See Fig. 19). In the initial four trials of the conflict-compound discrimination, his response latencies for the unchanged S+ symbol (scissors) were 9.3 seconds, 5.4 seconds, 4.1 seconds, and 9.0 seconds, respectively. Similar long response latencies of 13.3 seconds, 6.8 seconds, and 9.3 seconds also occurred for the unchanged S+ symbol (scissors) in later trials of the conflict-compound discrimination (See Fig. 19). In contrast, the response latencies for the S+ symbol (scissors) during the mixed-symbol sequence were below two seconds, with two exceptions (See Fig. 16).

In summary, the response accuracy and response topographies of Participant 5 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 latencies, however, showed a reduction in stimulus control for the unchanged S+ symbol (scissors) in the conflict compound, which was not revealed by either his response accuracy or his response topographies. This reduction in stimulus control of the unchanged S+ symbol (scissors) in the conflict compound, demonstrated by the longer response latencies of Participant 5, 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 either his response accuracy or his response topographies.

<u>Test results</u>. The test performance of Participant 5 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. 18). The unchanged-symbol pair demonstrated a 100% level of agreement with the reinforcement contingencies of the conflict compound since Participant 5 consistently selected the unchanged S+ symbol (scissors) throughout the unchanged-symbol test trials. Because Participant 5 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. 18).

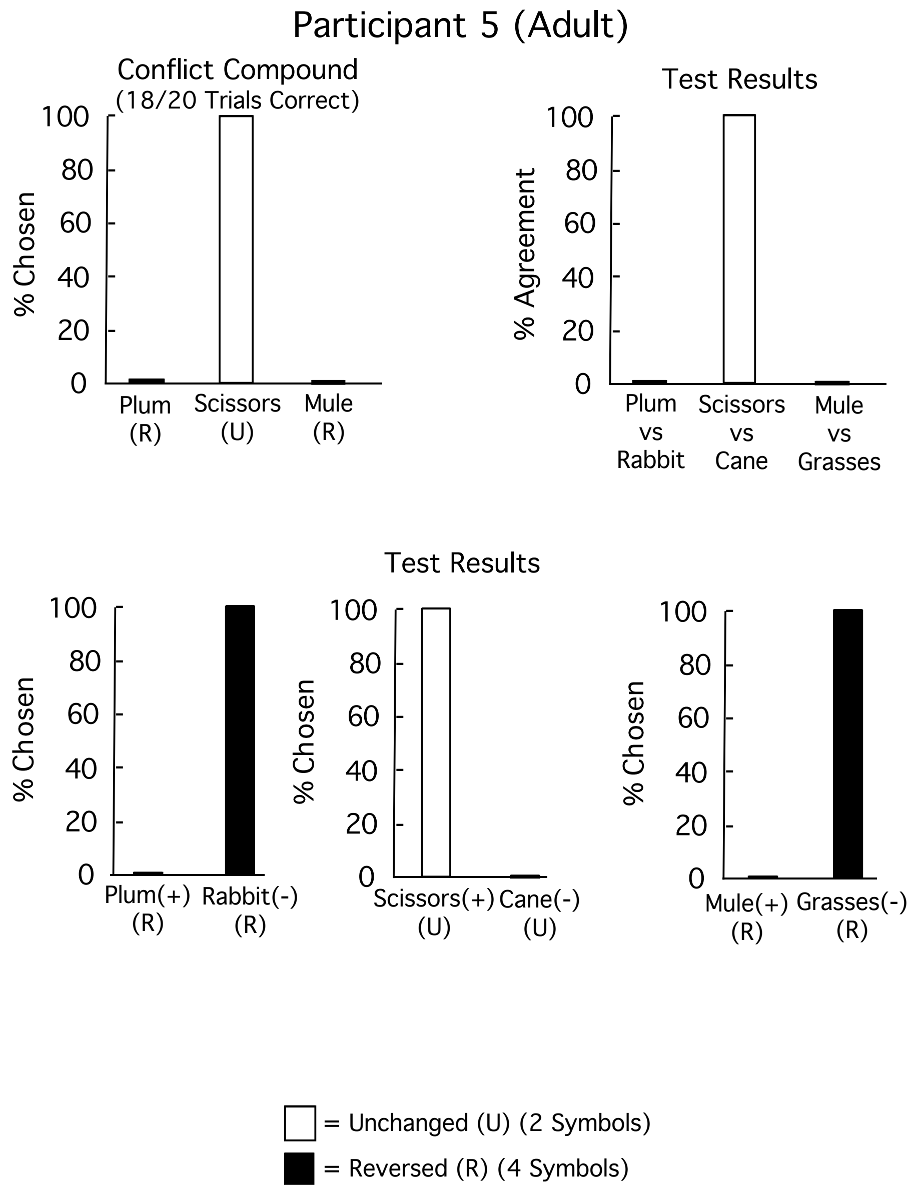


Figure 18. For Participant 5, (left graph) percentage each of the three S+ symbols were chosen during reinforced trials when criterion accuracy was achieved for the conflict compound and (right graph) percent agreement of responses during stimulus-element test trials with the reinforcement contingencies of the conflict compound. The top symbols shown for Participant 5 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.

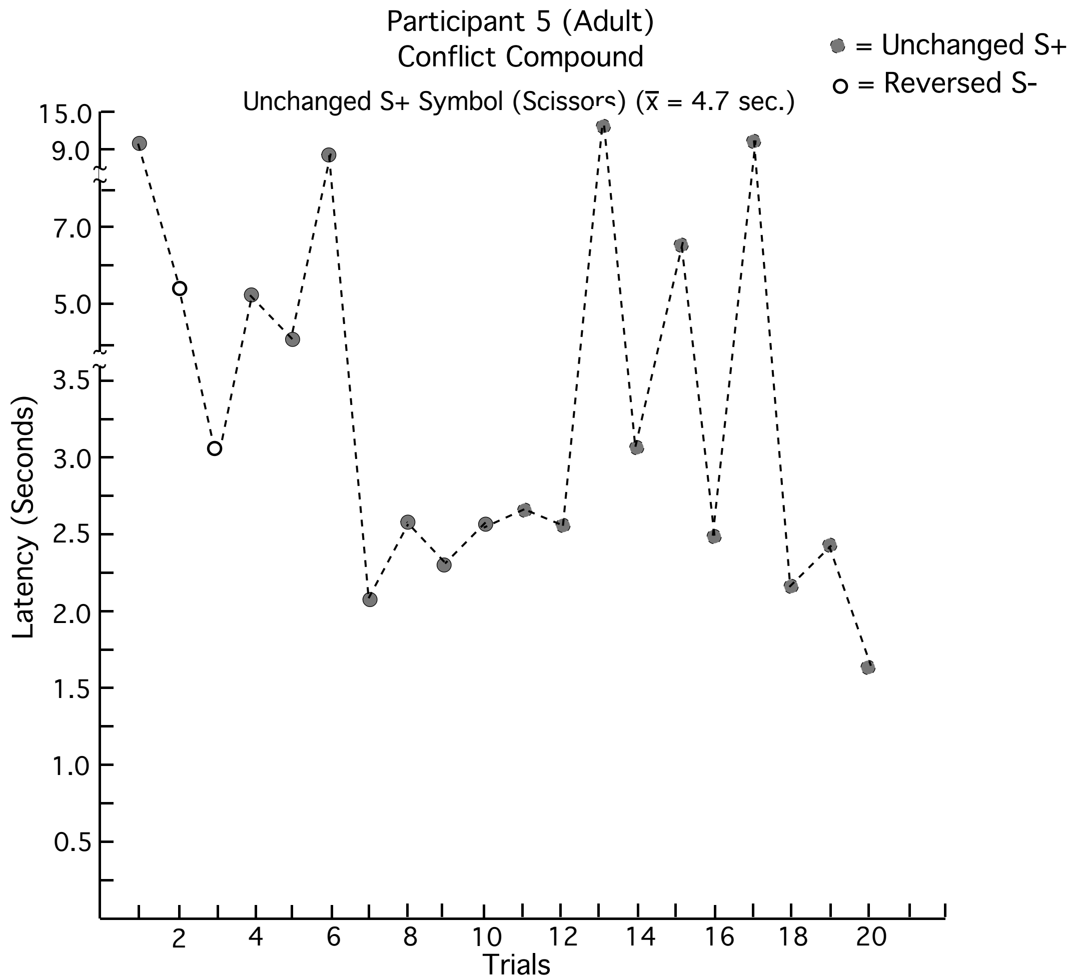


Figure 19. For Participant 5, response latency for unchanged S+ symbol (scissors) during presentation of the conflict compound.

The symbols selected during the test trials indicated 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. Participant 5 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. 18). 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.

The response latencies of Participant 5 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 a reduction of stimulus control in the conflict compound because of increased response latencies. The average response latency for scissors in the conflict compound increased to 4.7 seconds (See Fig. 19). During the unchanged-symbol test trials, however, the average response latency for scissors decreased to 1.4 seconds (See Fig. 20), similar to the average response latency (1.9 seconds) for scissors during the mixed-symbol sequence administered before the conflict-compound discrimination was presented (See Fig. 16). Although the increased response latencies of Participant 5 indicated the stimulus control of the unchanged S+ symbol (scissors) was reduced in the conflict compound, his decreased response latencies for scissors during the unchanged-symbol test trials revealed the original stimulus control for scissors remained intact.

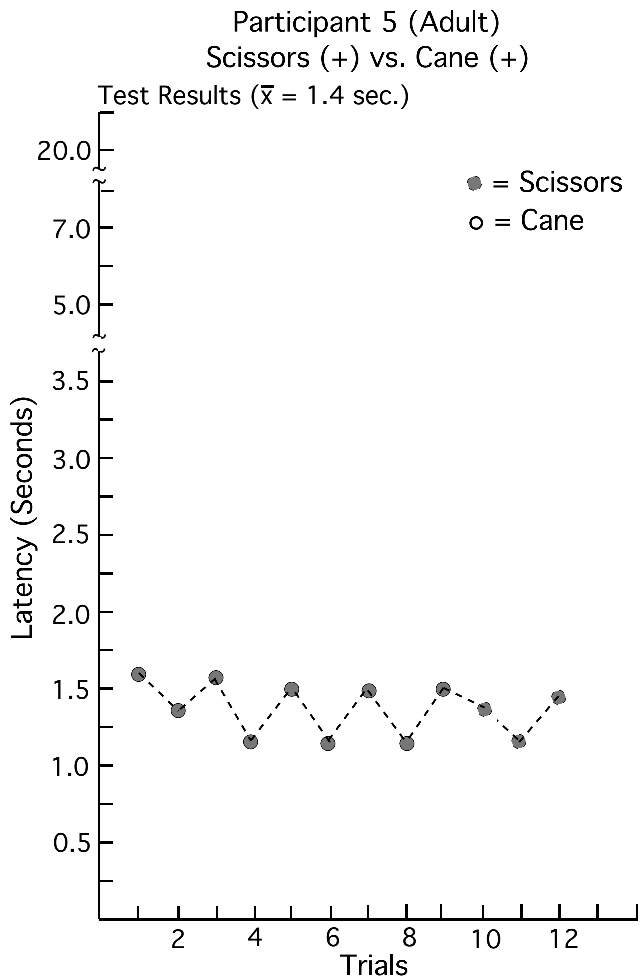


Figure 20. For Participant 5, response latency for scissors vs. cane during test trials.

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 (1.9 seconds) for rabbit during the reversed-symbol test trials (See Fig. 21) was comparable to the average response latency (1.5 seconds) for rabbit when it was a S+ symbol in the mixed-symbol sequence (See Fig. 15). The consistent selection of rabbit and the short response latencies 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.

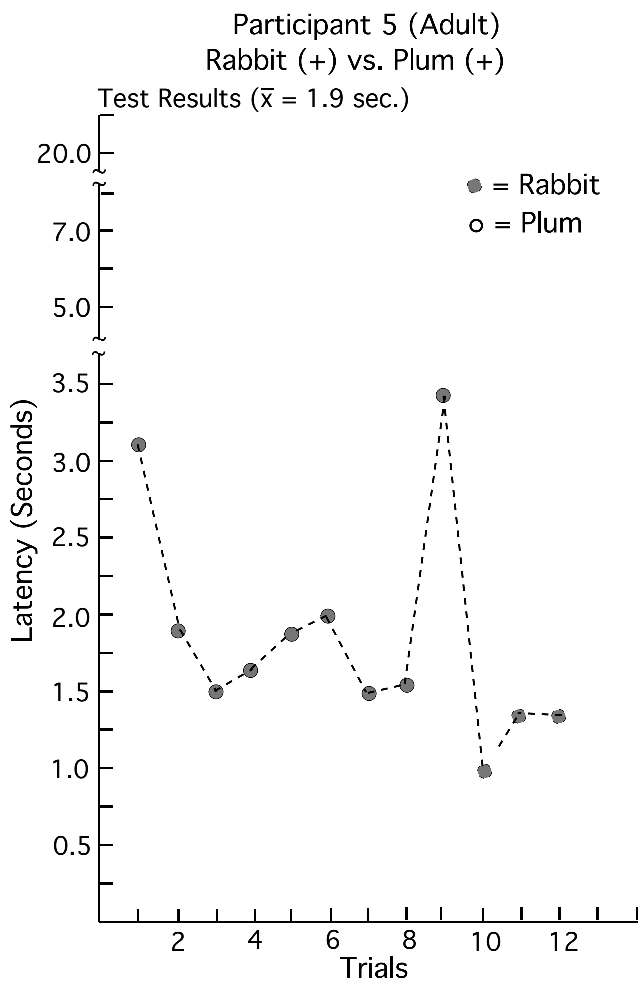


Figure 21. For Participant 5, response latency for rabbit vs. plum during test trials.

Grasses was also a reversed S- symbol in the conflict compound and it was also consistently selected during the reversed-symbol test trials. The average response latency (1.4 seconds) for grasses during the reversed-symbol test trials (See Fig. 22) was virtually identical to the average response latency (1.5 seconds) for grasses when it was a S+ symbol in the mixed-symbol sequence (See Fig. 17). The consistent selection of grasses and the short 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.

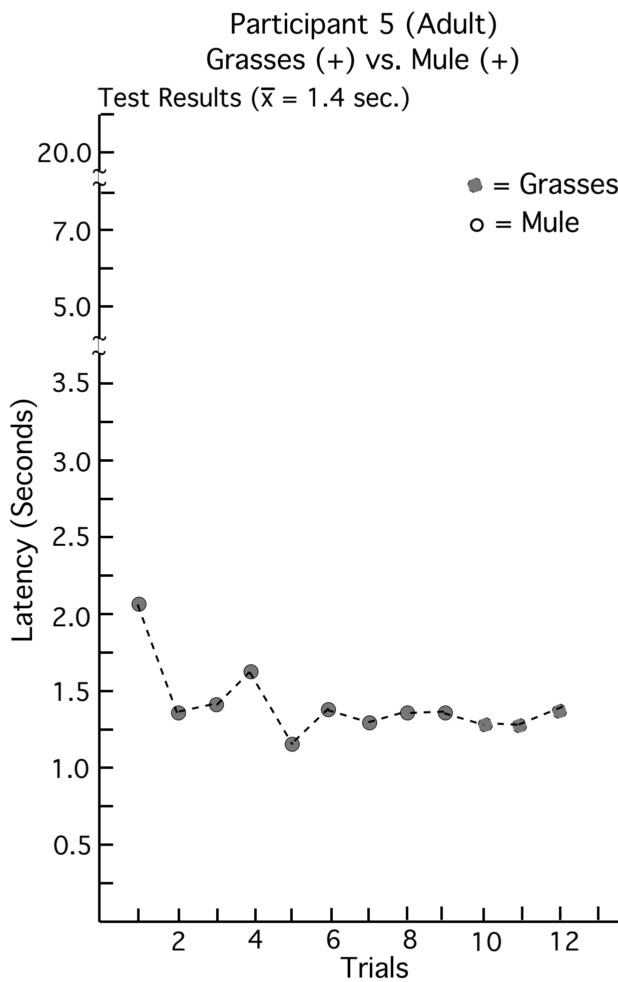


Figure 22. For Participant 5, response latency for grasses vs. mule during test trials.

Discussion

Establishing prior reinforcement histories for separate stimulus components was effective in determining which features of compound visual cues participants of differing ages 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 participants attended to a stimulus compound with conflicting prior reinforcement histories. 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 also revealed in how four participants of differing ages attended to the conflict compound by employing online multiple testing procedures, which were automatically administered by the software.

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. The two symbols with a reversed prior reinforcement history in the compound were ignored. This was shown because on reinforced trials when criterion accuracy was met, the two participants selected only the unchanged symbol in the conflict compound. Both participants also shifted their attention to the unchanged symbol in the conflict compound after only a few responses to the reversed S- symbols initially occurred.

In the test trials of both participants, the unchanged-symbol pair exercised a 100% level of agreement with the reinforcement contingencies of the conflict compound. In contrast, a 0% level of agreement occurred for both reversed-symbol pairs. This demonstrated that when the conflict compound was presented, the two stimulus-response relations paired with extinction (because their prior reinforcement contingencies were reversed in the compound) decreased in frequency without the original stimulus-response relations being disrupted. This supports Ray's (1969) position that a controlling stimulus-response relation may occur more or less frequently without disturbing the relation between the stimulus and response.

A third participant (adult), however, 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. If only the test trials had been administered, it would have been concluded that she selectively attended to the unchanged symbol in the conflict compound. Recording her response topographies, however, demonstrated the third participant responded to both the unchanged symbol and the reversed symbols in the conflict compound, which was not revealed by her test results. The importance of recording response topographies in addition to response accuracy to adequately determine how stimulus compounds are attended to confirms earlier investigations (Huguenin, 1987; 1997; 2000; 2004).

Finally, neither the response topographies nor the test performance of the fourth participant (a young child) indicated that he selectively attended to the unchanged symbol when he originally achieved criterion accuracy for the conflict compound. After extended training was provided, however, the fourth participant 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 initially occurred. The test performance of the fourth participant further confirmed following extended training that he selectively attended to the unchanged symbol. In summary, after extended training was provided, both the response topographies and the test performance of the fourth participant revealed that he shifted his attention to the unchanged symbol in the conflict compound. This supports earlier findings (Huguenin, 2000) which found extended training improved the effectiveness of prior reinforcement histories in determining which features of a visual compound that adolescents with developmental disabilities attended to.

In a second study, the response topographies and the test performance of a fifth participant (adult) also revealed that he selectively attended to the unchanged symbol (scissors) in the conflict compound while ignoring the reversed symbols. When criterion accuracy was achieved for the conflict-compound discrimination, he consistently responded to the unchanged symbol (scissors) in each of the 18 correct trials, and he shifted to the unchanged symbol after only two responses initially occurred to the reversed S- symbols. His test trials also confirmed that he selectively attended to the unchanged symbol (scissors) as 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.

His response latencies, however, revealed changes in stimulus control for the unchanged S+ symbol (scissors) when the conflict compound was presented, which were not shown by either his response topographies or response accuracy. The response accuracy and response topographies of the fifth participant revealed high levels of stimulus control for the unchanged S+ symbol (scissors) in the conflict compound. His response latencies, however, showed a reduction in stimulus control for the unchanged S+ symbol (scissors) when it appeared in the conflict compound. A reduction in stimulus control was demonstrated by the longer response latencies of the fifth participant for the unchanged S+ symbol (scissors) in the conflict compound due to the interfering effect of the reversed symbols. In contrast, shorter response latencies occurred for scissors in the mixed symbol sequence and during the test trials when scissors was presented alone. This interfering effect of the reversed symbols on reducing the level of stimulus control of the unchanged S+ symbol (scissors) in the conflict compound was not revealed, in contrast, by either his response accuracy or response topographies.

These results demonstrate the utility of incorporating response latency as an additional response measurement to provide a more fine-grained and sensitive analysis of attention to visual compounds. While response topographies and response accuracies summarized visual attention across sessions, response latencies expressed changes in visual attention within sessions which were not revealed by either response topographies or response accuracies. Recording response latencies could identify attentional disorders, such as distractibility or difficulties shifting attention, which have a higher incidence in autistic children (Patten & Watson, 2011) and which might not be revealed by other types of assessment.

In summary, stimulus-control procedures, which were fully automated and administered online were successful in assessing the visual attention of participants differing in age. Recording response topographies in addition to response accuracy revealed individual differences in how four participants attended to stimulus compounds. By recording response topographies, it was also possible to determine how quickly they shifted their attention in accordance with prior reinforcement histories when stimulus compounds were presented. In most cases, prior reinforcement histories associated with individual stimuli determined which stimulus elements the participants attended to and which stimulus elements they ignored even when the procedures were administered online at remote sites where the experimenter was not present.

These results demonstrate the feasibility of providing visual attention assessments online, requiring only parental supervision, to discover visual attention impairments, such as overselective attention, to identify children at risk for developing autism or other developmental disabilities. Because of the rapid increase in children diagnosed with autism (1 in 44 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 developmental levels are significantly reduced (Lupindo, Maw, & Shabalala, 2022). Providing visual attention assessments online would 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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Footnotes

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