Discrimination learning is an important component of much adaptive behavior and many academic skills; examples include following directions, responding to one's name when called, classification, reading, number identification, and many others. As Sidman (2010) noted, “tradition holds that [discrimination] learning must take place through trial and error” (p. 167). Trial-and-error discrimination training typically involves differential reinforcement contingencies; reinforcers follow responses to stimuli defined by the experimenter or teacher as correct (S+) and no reinforcers follow responses to stimuli defined as incorrect (S-). Accuracy is typically near chance level at the beginning of training and increases with continued exposure to the contingencies.

Discrimination learning, however, need not require errors. The possibility of learning discriminations with few errors was initially explored in the 1960s. Terrace (1963a) conducted two experiments in which pigeons were trained on red versus green successive simple discriminations. Initially, the S+ appeared alone. Because the S+ was the only available selection, responses to S- (errors) were not possible. The S- was then introduced gradually over trials by progressive increases in intensity and duration. The birds who received this procedure learned the color discrimination with few errors. After the red vs. green discrimination was established, Terrace (1963b) demonstrated that stimulus control could be transferred from the red and green colors to a vertical vs. horizontal line with few errors if (a) the lines were superimposed on the colors initially and (b) the red and green backgrounds were slowly faded out by diminishing their intensity over a series of presentations until they were no longer visible. Terrace termed this procedure superimposition and fading.

In Terrace (1963b), the red and green colors functioned as prompts. In the context of errorless learning, a prompt is a previously established discriminative stimulus that signals a high probability of reinforcement following some defined response(s). The use of a prompt in
superimposition and fading is usually based on the assumption that behavioral control by that prompt will eventually transfer to an initially neutral stimulus targeted to control responding (e.g., Doran & Holland, 1979). This transfer of control occurs at some point in the fading process as the prompt is gradually eliminated over successive teaching trials by changes in some physical dimension (intensity, distance, size, etc.).

Since the 1960s, the use of errorless learning procedures has expanded beyond the research laboratory to human applied settings, often with developmentally limited populations; for reviews, see Green (2001); Lancioni and Smeets (1986); and Mueller, Palkovik, and Maynard (2007). As evident in these reviews, however, the use of “errorless” learning procedures with humans often generates errors, and sometimes fails to establish the target discriminations. One possible explanation for failures, explored in the present study, concerns the simple versus conditional stimulus control requirements of the prompt in relation to simple versus conditional stimulus control requirements of the target discrimination.

Simple discrimination can be described by a three-term contingency in which a discriminative stimulus signals the availability of reinforcement following responding, whereas the absence of such stimulus signals the absence of reinforcement for the same responses. In simple discrimination procedures, the positive (S+) and negative (S-) functions of stimuli remain the same from trial to trial (e.g., red = S+, and green = S-). In Terrace (1963b), both the prompt (red vs. green) and target (vertical vs. horizontal line) discriminations were simple discriminations.

Conditional discrimination can be described by a four-term contingency in which the discriminative stimulus functions of a three-term contingency depend upon another stimulus, a conditional or contextual stimulus (Saunders & Spradlin, 1989; Sidman, 1986). In conditional discrimination the S+ and S- functions of the stimuli that control the defined response change, depending upon which conditional stimulus is presented. Matching to sample (MTS) is a conditional-discrimination procedure widely used in both research and education: A series of discrete trials presents an array of comparison stimuli, along with one sample stimulus that changes over trials. The S+ and S- functions of the comparison stimuli also change over trials, conditionally upon the sample for each trial. For example, given trials with red and green
squares as comparisons, on trials with the sample printed word "RED," the red square would be S+ and the green square S-, and vice versa on other trials with the sample "GREEN."

As in Terrace (1963b), many of the prompts used in superimposition and fading procedures with human participants require simple discrimination only; that is, the superimposed prompt always functions as S+. Examples include superimposed colors (e.g., Irvin & Bellamy, 1977) and a superimposed pointing finger (e.g., Schreibman, Charlop, & Koegel, 1982). Superimposition and fading, however, has been used to teach both simple and conditional target discriminations (Green, 2001). As explained above, simple and conditional discrimination training have different stimulus control requirements. When simple discrimination prompts are used to teach simple discrimination targets one could say there is a match between the stimulus control requirement of the prompt and the target discrimination. Following transfer of stimulus control from prompt to target, if the target stimulus continued to control responding in the same way as the prompt, then the teaching would be considered successful.

The use of prompts requiring simple discriminative control to teach conditional discrimination targets, however, would be successful only if the mismatch of stimulus control requirements by the prompt and by the target discrimination did not affect acquisition of new conditional discriminations. In conditional discriminations, however, a learner's responses must be under conditional and discriminative control of a combination of at least two stimuli, for example, the samples and correct comparisons on MTS trials. This requirement of relational stimulus control in a conditional discrimination is more complex than the requirement to respond successfully to a prompt that requires only simple discrimination (for a thorough treatment of this issue, see McIlvane, 2013).

If the issue of a match versus mismatch of stimulus control between prompts and target discriminations were significant, then the research literature should include more successful outcomes with matches than mismatches. A comparative survey of the literature, however, is complicated by many differences across studies in participant characteristics, discrimination difficulty, consequences, and learning criteria (Green, 2001; Lancioni & Smeets, 1986; Mueller et al., 2007). The literature includes no well-controlled study of prompts requiring simple versus conditional stimulus control for teaching conditional discriminations. I will present a study addressing this potential methodological problem in teaching discrimination.
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Method

Participants and Setting

Six typically developing children (mean age 7.7 years, range: 6-9 years) and three children diagnosed with an autism spectrum disorder (ASD; mean age 10.1 years, range: 7-13 years; Peabody Picture Vocabulary Test mental age equivalent scores of 4.1, 3.1, and 4.5) were recruited for the study.

Materials, Data Collection, and Design

All sessions were presented using a laptop computer connected to a touch screen monitor. A computer program managed trial presentation, prompt presentation and prompt fading, differential consequence delivery, and 3-s inter-trial intervals (ITIs). The program also recorded the sample and comparison stimuli and comparison stimulus locations for each trial, and the timestamps for responses to sample and comparison stimuli. Participants responded by touching the stimuli presented on the touch screen monitor.

An ABAB reversal experimental design was used for each participant. Two conditions alternated, with order of SD and CD condition (details below) presentation counterbalanced across participants.

Experimental Stimuli Used During Training and Probes

Four sets of six stimuli were used during the current study (Table 1). Stimuli were arranged in sets so that three arbitrary stimulus-stimulus relations could be taught within each set.

Training: SD Condition

This condition tested the effects of prompts requiring simple discriminative control. Blocks of 18 trials were presented. Each trial presented a sample stimulus in the center top of the computer screen. A non-differential observing response was required, touching the square in which the stimulus was presented, and then the sample stimulus was removed for 0.5 s and represented with three comparison stimuli on the bottom left, center, and right positions on the computer screen. During the steps in which color prompts were presented (fading Steps 1 through 4, details below), the sample stimulus and the correct comparison stimulus were
presented with the same color (blue, red, or green) and the incorrect comparison stimuli were black. Thus, the prompt required only simple discriminative control because the stimulus that was not black was correct on every trial. During the final step of the fading procedure (Step 5), the sample and the three comparison stimuli were all presented in the color black. Each of the three sample stimuli was presented six times within a block, and the order of presentation was randomly determined by the computer program. The positions of comparison stimuli were counterbalanced by the computer program, and each correct stimulus appeared in the same position twice.

**Training: CD Condition**

This condition tested for the effects of prompts requiring conditional discriminative control. Blocks of 18 trials were presented. Stimuli were presented in same positions as in the SD condition, and a non-differential observing response was also required. During the steps in which the prompts were presented, each comparison stimulus was always presented in blue, red, or green, with the color for each stimulus remaining the same on all trials. Each sample stimulus was always presented in the same color as the corresponding correct comparison stimulus, and thus the two incorrect comparison stimuli were presented in colors different from the sample. Thus, the prompt required conditional discriminative control because the color of the correct comparison stimulus was conditional upon the color of the sample and that color changed from trial to trial. All randomization of stimulus order and counterbalancing of stimulus positions were the same as in the SD condition.

**Errorless Procedures**

*Prompts and fading steps used on both SD and CD conditions.* A 5-step (within-stimulus and non-criterion-related) prompt procedure was used to teach the conditional discriminations. The prompt colors with respective hue, saturation and luminance (hsl) for Step 1 were the following: red (hsl: 0, 100%, 29%), blue (hsl: 120, 100%, 29%), and green (hsl: 240, 100%, 29%). Note that the colors were initially of same saturation and luminance values, but different hue values. Steps 2-4 of the fading procedure were implemented by adjusting luminance, with hue and saturation held constant. The visual effect of decreasing luminance was that the colors became darker. In Step 5, all stimuli were black.

The SD and CD conditions differed in the colors for the incorrect comparison stimuli during Steps 1-4. In the SD condition, only the sample and the correct comparison were
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presented with color prompts; the incorrect comparison stimuli were presented in black. In the CD condition, all stimuli were presented with color prompts during Steps 1-4. In Step 5 of both conditions, all stimuli were black, and consistent correct responses would indicate the transfer of stimulus control from color to form.

Criteria for advancing and backing up prompt levels. To advance: at least 15 correct responses within 18 consecutive trials and no more than one error with the same sample stimulus. To back up, one prompt step was two errors with the same sample stimulus at the current prompt step. The criterion to master Step 5 (all stimuli black) was a block of 21 trials (18 trials plus 3 probe trials, see below) with no more than one error with the same sample stimulus.

Probe Trials

Within every block of 18 trials, three Step-5 probe trials (i.e., all stimuli black) were presented, one for each sample stimulus. The probes were inserted at random points within the block. Probes served to evaluate whether the relations between sample and comparison stimuli had been learned, that is, whether stimulus shape (instead of color) controlled comparison selection (Doran & Holland, 1979). Responses to probe trials did not affect criteria to advance or back up prompt steps.

Results

Pre-experimental Phases

All participants screened were included in the study.

Transfer of Stimulus Control

Results of the probe trials may estimate the approximate point of the transfer of control from the prompt stimuli (colors) to the features selected by the experimenter to control selection, differences in the shapes of the arbitrary forms. Figures 1 and 2, and Table 2 present probe trials results.

Percentage correct in probe trials. For the six typically developing participants and one of the children diagnosed with ASD (Participant MJ), the percentage of correct responses in probe trials was always higher during CD conditions than during the SD conditions (Figure 1), suggesting that the prompts requiring relational stimulus control may be more effective in
teaching the conditional discriminations. The results from the first instance of each condition for Participants JC and BS, the other two children diagnosed with ASD, were different. Participant JC and BS scored a higher percent of correct responses in probes during the SD condition when first introduced to the training. During the replication with new arbitrary stimuli, both scored a higher percent of correct responses in probe trials with the CD condition, similar to the performance of the other children.

**Moment of transfer.** An analysis was conducted to try to estimate the approximate point at which stimulus control had shifted from color prompts to arbitrary forms. The moment of transfer (cf. Touchette, 1971) was defined as the number of trials before 6/6 correct responses in six consecutive probe trials or trials at fading Step 5 (all black stimuli; same as a probe trial). Figure 2 depicts the moment of transfer for each participant across all conditions. Note that each 18-trial block introduced three probe trials. A minimum of two blocks containing probe trials or six trials with all stimuli presented in black (Step 5) was required to reach this criterion.

Fewer trials were required to reach 6/6 consecutive correct responses on probe or Step 5 trials in the CD condition than the SD condition in 15/18 opportunities or for 8/9 participants. These results suggest that responses came under relational stimulus control by the forms sooner with the CD condition than with the SD condition. The results from one participant diagnosed with ASD, however, were different. JC required fewer blocks to reach the 6/6 criterion during probe trials in the SD conditions.

**Training Effectiveness**

All participants met the criteria to advance within the fading procedures with very few errors during the first four steps across both conditions. Accuracy scores during training from Steps 1 to 4 ranged from 94.4% to 100%, and on Step 5 it ranged from 36.7% to 100%. The majority of the errors occurred at the last step of the fading procedure, when all stimuli were presented in black.

Eight of nine of the participants learned the discriminations. MJ did not meet learning criterion during the first exposition to the SD condition. Participants were exposed to between 90 and 1008 trials during the discrimination training.
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Discussion

The results on probe trials indicated consistent differences across the two teaching conditions. The total number of correct responses on probe trials was higher during CD conditions than during SD conditions for 8 of 9 participants, suggesting that the prompts requiring relational stimulus control may have encouraged the initial transfer of control during earlier fading steps than the prompts requiring simple discriminative control.

These results suggest that there may be advantages if the prompt used to teach conditional discriminations is consistent with the stimulus-control requirements of the discrimination targets. A look at the literature, however, indicates that the prompts typically used to teach conditional discrimination usually require only simple discriminative control (e.g., Lancioni & Smeets, 1986). For example, if a teacher were using point prompts to teach relations among printed words and pictures in a MTS procedure, the same point prompt might be used on every trial. A simple discrimination is all that is required in order to respond effectively to the prompt: Given the point prompt with a comparison stimulus, select that stimulus. When the point prompt is presented with another comparison stimulus, select that other stimulus. There is no requirement to observe and attend to the sample or comparison stimuli – touching whichever comparison stimulus is presented with the point prompt is followed by reinforcing consequences. When prompts requiring simple discriminative control are used to teach conditional discrimination targets, results are often mixed (Aeschleman & Higgins, 1982; Touchette & Howard, 1984).

To summarize, the current study explored the use of a prompt requiring conditional discriminative control. It compared the effectiveness of an errorless learning procedure requiring simple discrimination with an errorless learning procedure requiring conditional discrimination. Data from probe trials indicated that conditional discrimination targets may be acquired faster when the stimulus control required by the prompt procedure matches the stimulus control required by the discrimination target.
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Table 1
*Experimental Stimuli*

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Table 2
*Accuracy during probe trials across both conditions*

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<td>130/247</td>
<td>73/221</td>
<td>81/97</td>
</tr>
</tbody>
</table>
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Figure 1: Percentage of correct responses in probe trials across participants and conditions.

Figure 2. Number of trials presented before the participant scored 6/6 correct responses on probe trials or trials at Step 5 of the fading procedure.