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Blocking of Stimulus Control in Children with Autism

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Abstract

The present study aimed to investigate the blocking of stimulus control in three children with autism. We used a go/no-go procedure in a standard blocking paradigm. In Phase 1, we established one of two sounds or colored squares as a discriminative stimulus for touching a tablet screen. In Phase 2, a colored square was added to the sound or a sound was added to the colored square in a stimulus compound. The discrimination training continued as in Phase 1. We subsequently tested discriminative control by each of the single stimuli separately and by the compounds. Finally, after testing with no programmed consequences, we reestablished the original discrimination and replicated the test of stimulus control. The results support previous experiments by demonstrating that the establishment of discriminative control by a second stimulus by adding it to a previously established discriminative stimulus in a compound was blocked by the earlier discrimination training in all three participants. We discuss procedural details that may be critical to avoid the blocking of stimulus control in the applied field, particularly with respect to the acquisition of skills that involve multiple stimuli, such as joint attention, social referencing, and bidirectional naming.

Keywords Go/no-go · Blocking · Stimulus overselectivity · Bidirectional naming · Joint attention · Autism

The phenomenon of blocking was first demonstrated in Pavlovian, or classical, conditioning (Kamin, 1969). Blocking refers to the fact that previously conditioning of a stimulus prevents conditioning of a new stimulus, which is presented simultaneously with the first. A standard blocking procedure has two acquisition phases: for example, an animal may be repeatedly exposed to a formerly neutral stimulus, say a light, immediately followed by an unconditioned stimulus (US), say food, until the animal salivates when the light is presented alone. At this point, the light has become a conditioned stimulus (CS1). After the same number of additional conditioning trials, with the light (CS1) and a tone (CS2) presented together in a compound stimulus prior to the US, the single stimuli involved and the compounds are tested separately and together for stimulus control (CS1, CS2, CS1+CS2). Test results typically show that the animal does not show increased salivation to the tone (CS2) when the tone is presented alone on test trials. The

previous pairings of CS1 and the US is then said to have blocked the establishment of stimulus control by CS2. Blocking in classical conditioning has been shown in experiments with rats (e.g., Blaisdell, Gunther, & Miller, 1999; Cheatle & Rudy, 1978; Fowler, Goodman, & DeVito, 1977; Mackintosh, 1975; Taylor, Joseph, Balsam, & Bitterman, 2008), pigeons (e.g., Mackintosh & Honig, 1970; Palmer, 1988; Williams, 1975), rabbits (e.g., Stickney & Donahoe, 1983), and humans (e.g., Arcediano, Matute, & Miller, 1997; Bergen, 2002; Delgado, 2016; Kimmel & Bevill, 1991; Martin & Levey, 1991).

Although blocking was first described in studies of classical conditioning, the effect has also been demonstrated in operant discrimination training, with rats (e.g., Seraganian & vom Saal, 1969; vom Saal & Jenkins, 1970), rabbits (e.g., Stickney & Donahoe, 1983), and humans, in children (e.g., Didden, Prinsen, & Sigafoos, 2000; Dittlinger & Lerman, 2011; Lyczak & Tighe, 1975; Otto, 2006; Singh & Solman, 1990) as well as in adults (e.g., Clough, Meyer, & Miguel, 2016; Rehfeldt, Dixon, Hayes, & Steele, 1998).

Research on the use of extra-stimulus prompts has aimed to evaluate whether the interference of pictures on the acquisition of reading skills was an instance of blocking by previously established discriminative stimuli in the form of corresponding pictures. The overall results from these studies were that

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the acquisition of sight-word reading was faster when the word was presented as a single stimulus than when presented in a compound with a picture (e.g., Didden et al., 2000; Dittlinger & Lerman, 2011; Otto, 2006; Singh & Solman, 1990; Wu & Solman, 1993). Stimulus control was achieved more clearly by the pictures that the participants could tact before the experiment started. In contrast, control by the added written words presented during the blocking condition (Condition A) was blocked. The results suggested that pictorial prompts should be applied with caution when teaching textuals (i.e., reading aloud) because they may inhibit rather than strengthen appropriate stimulus control (Didden et al., 2000; Dittlinger & Lerman, 2011; Singh & Solman, 1990; Wu & Solman, 1993). Thus, the transfer of stimulus control from the pictorial stimuli to the written words was impaired. These studies demonstrated that the picture prompts functioned as a blocking element and inhibited accurate textual responses. In fact, the number of correct textuals was higher in the presence of the written words alone than in the condition where pictorial prompts were used (Solman, Singh, & Kehoe, 1992; Wu & Solman, 1993).

Lyczak and Tighe (1975) investigated blocking in a series of sorting tasks, (discrimination of food and vehicles) with children aged 6–9. In all experimental conditions, an initial training phase established the sorting of stimuli according to one dimension (A), which was relevant to the solution (i.e., size, color or shape). In a second training phase, a second dimension (B) was equally relevant to the solution. Finally, they tested whether control by B had been blocked by the formerly established control of sorting by dimension A. Such blocking was only observed when the transition between training phases and between training and test was made inconspicuous by progressing across phases with minimal delays and no instructions that emphasized differences from the previous phases.

Researchers have suggested that blocking is likely related to stimulus overselectivity, in which some relevant properties of a compound stimulus fail to acquire stimulus control (e.g., Cengher, Budd, Farrell, & Fienup, 2018; Cipani, 2012; Farber, Dickson, & Dube, 2017; Lovaas, Schreibman, Koegel, & Rehm, 1971; Ploog, 2010). Such narrow attending may be maladaptive and is sometimes associated with children with autism (Dube et al., 2016; Lovaas et al., 1971). However, Dube et al. (2016) found no significant differences in overselective responding when comparing a group of children with autism with typically developing children, and children with Downs syndrome when these groups were matched according to developmental level.

Nevertheless, the blocking effect may have implication for teaching children with autism when a skill requires attending to multiple stimuli. For example, joint attention skills depend on simultaneous attending to multiple stimuli, such as the adult's gaze direction, pointing, and the spoken word "Look!" and an

object with multiple stimulus elements (e.g., color, shape, texture or function; Ploog, 2010). Likewise, Michael, Palmer, and Sundberg (2011) argued that in verbal behavior multiple control is the rule rather than the exception, and standard listener skills involve conditional discriminations, such as matching to sample, responding to different relations, or instructions, in which a three-term contingency is brought under the control of a conditional stimulus. Examples include responding to instructions (e.g., Sundberg, 2020), matching to sample, and bidirectional naming—where the establishment of listener skills result in the emergence of corresponding verbal skills or vice versa (Horne & Lowe, 1996). Research into the circumstances under which blocking occurs may have implications for how to arrange effective discrimination training to establish joint attention and bidirectional naming for children with autism. Moreover, such research may be useful with respect to refinement of standard procedures for establishing social conditioned reinforcers.

In a recent study, Vandbakk, Olaff, and Holth (2020) demonstrated blocking of stimulus control in rats using an operant conditioning procedure. In the first phase of a go/no-go procedure, either of two single stimuli, one auditory and one visual, was established as a positive discriminative stimulus (S+) for chain pulling, and the second as a negative discriminative stimulus (S- or S-delta). An unconditioned reinforcer (water) was produced contingent on chain pulling in the presence of the S+. In the second phase, a compound tone-light/light-tone stimulus was used the same way as the single stimulus in the previous phase. Following training, tests of stimulus control and conditioned reinforcer properties were conducted. The result showed limited stimulus control by the added stimulus, which had not been established as an S+ during the first phase. Moreover, the added stimulus did not show reinforcing properties when contingent upon a novel response. Thus, Vandbakk et al. (2020) supported previous research on the blocking effect in animals using an operant discrimination training procedure.

The authors of this article suggest that procedures that facilitate blocking of stimulus control may influence the establishment of stimulus control and conditioned reinforcers in applied settings. The present study aimed to replicate parts of Vandbakk et al. (2020) in an applied context. Thus, we investigated whether blocking could be demonstrated in children with autism during the establishment of stimulus control, using a standard operant discrimination procedure (e.g., Seraganian & vom Saal, 1969; Vandbakk et al., 2020; vom Saal & Jenkins, 1970).

Method

Participants

Three boys, aged 3–6 and diagnosed with autism, participated in the current study. Eric was 6 years old; Roy was 3, and Ted

was 4 at the time of the experiment. The participants' parents gave their informed consent for participation in the study, and the Norwegian research ethical committee approved the study. All participants received early intensive behavioral intervention in their public day care center. The participants had no additional health issues. All participants had acquired some vocal verbal behavior and basic social skills, such as saying "High-five" and "Thank you" appropriately to other persons.

Before the current experiment, verbal behavior was tested using the Assessment of Basic Language and Learning Skills-Revised (ABLLS-R; see Partington, 2006). However, only skill areas most relevant to cooperation and reinforcer effectiveness, visual performance skills, and verbal behavior were included in the assessment: (a) Cooperation and Reinforcer Effectiveness; (b) Visual Performance; (c) Receptive Language; (d) Motor Imitation; (e) Vocal Imitation; (f) Requests; (g) Labeling; (h) Intraverbals; (i) Spontaneous Vocalization; and (j) Syntax and Grammar; and (p) Generalized Responding. Scores for each child are shown in the Appendix. We considered acquired verbal behavior as the most relevant area related to the present research question. Hence, additional social skills, reading, spelling, math, and basic life skills were not assessed in detail, but all three children were able to play simple games with their peers, and self-help skills were age-appropriate.

Setting

The study was conducted in each child's day care center. All participants had a separate training room available with a table and two chairs. This training room was used during all experimental sessions. The researcher was either positioned next to the child (Eric) or across the table (Roy and Ted). Daily sessions were run on weekdays over 5 weeks.

Stimuli

During discrimination training and stimulus control tests, visual and auditory stimuli were used. Visual stimuli were colored squares presented on the monitors, whereas the auditory stimuli were tones produced by the computer speaker. The colors of the visual stimuli and the type of auditory stimuli were randomly selected from the Microsoft Office "wav" tones and its color panel. Table 1 provides an overview of the stimuli used in both training phases.

Assessment of Preferred Stimuli

To assess potential reinforcers, we used a multiple stimulus assessment without replacement (DeLeon & Iwata, 1996). Edibles were not used for Eric, whereas for the other two participants, raisins, grapes, and small pieces of gingerbread were delivered as immediate consequences of completing a session. Preferred video clips, as identified by the children's parents, were downloaded from YouTube. Titles of video clips are shown in Table 2. New similar video clips were identified during Phase 1 for Roy, to avoid saturation. For Ted, the video clips were saved in different folders to avoid that the same video clip was used twice in succession. Throughout the entire experiment, the duration of the preferred video clips was 8 s for all participants.

Apparatus

Three Acer Aspire Switch 10,1″ computers with a touch screen and operating system Windows 8 were used during the entire experiment, one computer for each participant. Each computer had a detachable screen, which functioned as a tablet with an integrated speaker. Experimental conditions and data recording was controlled by software developed in Microsoft Visual Basic 1.0, 2010 Express by the third author.

A 7.0 × 7.0 cm sized square in the middle of the screen was present throughout all training and test sessions and served as the main response key (as illustrated in Fig. 1). The background of the screen was light gray. All visual stimuli were presented by changing the color of the initially white square. The changed color was either an S^+ or an S^-. The number of touches on the main key on the computer screen was automatically recorded through the Visual Basic program in separate files and imported to an Excel file by the researchers. The experimenter could pause, restart, or close the program if necessary, by pressing specific keys on the keyboard.

Procedure

All training sessions were initiated by the presentation of the computer screen and a vocal instruction by the experimenter: "I will now show you something on the screen, pay attention." Either one of six quasi-randomly mixed sequences of S^+ and S^- presentations was selected for each session. The number of training trials per session was gradually increased from 6 to 20, whereas test sessions consisted of 24 trials. Regardless of the number of trials, the number of S^+ was always equal to the number of S^- trials.

The participants completed four to five sessions per day during Phase 1, and six to eight sessions during Phase 2. Each session lasted approximately 1–2 min. Between sessions, the participants were given a play break. The play breaks were arranged either in the teaching room or with peers in the daycare center. Experimental sessions were scheduled throughout the day at the daycare center between 9 A.M. and 5 P.M. The sessions were carried out as a part of the participants' regular instructional sessions, which were usually completed 1–2 hr before lunch and 1–2 hr after lunch.

Table 1 Overview of stimuli presented during Phases 1 and 2

Participants	Phase 1: Single stimuli		Phase 2: Compound stimuli	
	S_1^+	S_1^-	$S_1^+S_2^+$	$S_1^-S_2^-$
Eric	Purple Square	Yellow Square	Purple Square + Whoosh Sound	Yellow Square + Beep Sound
Roy	Whoosh Sound	Beep Sound	Whoosh Sound + Green Square	Beep Sound + Red Square
Ted	Green Square	Red Square	Green Square + Whoosh Sound	Red Square + Beep Sound

Note. S_1^+ and S_1^- were established first, and S_2^+ and S_2^- were added in the second phase

Phase 1 and Phase 2: Go/No-Go Discrimination Training The discrimination training was a go/no-go procedure, which entails that the S_1^+ and the S_1^- were presented alternately rather than simultaneously. The purpose of Phase 1 was to establish stimulus control over one response, touching the main key in the presence of S_1^+. The target responses were differentially reinforced in the presence of the S_1^+ (i.e., "go") by the immediate onset of a preferred video clip, described in Table 2. In the presence of the visual or auditory S_1^- (i.e., "no-go"), touch responses did not produce any programmed consequences. All participants started with two 6-trial sessions; three S^+ and three S^- trials. The number of trials gradually increased up to 20 over successive sessions. Responses to the main key within the 5.2-s duration of the S^+ (the discriminative stimulus) led to the onset of the preferred video clip (the reinforcer).

Phase 2 involved the same type of go/no-go training as Phase 1. However, the discrimination was between two stimulus compounds rather than between single stimuli. On successive trials, either a novel *auditory* S_2^+ was added to the previously established *visual* S_1^+, and another novel auditory S_2^- was added to the previously established visual S_1^- (for Ted and Eric) or novel *visual* stimuli, S_2^+ and S_2^- were added to the formerly established *auditory* S_1^+ and S_1^-, respectively (for Roy; see Table 1). Responses in the presence of the S_1^+ and the added stimulus (S_2^+) were followed by reinforcement. The reinforcement schedule was gradually thinned from continuous reinforcement to variable ratio (VR) 5. The number of trials in Phase 2 was yoked to the number of trials necessary to acquire stimulus control in Phase 1.

Prompting Prompts were (1) pointing to and/or physically guiding touches to the monitors; (2) physically obstructing responses in the absence of S^+, including in the presence of S^-; and (3) pointing to and/or physically guiding touches on the trial-initiation key. The obstruction of touches on the main key in the absence of S^+ in Phase 1 was accomplished by the researcher putting her hand in front of the tablet's screen whenever the child moved its hand toward it. The prompts were faded across trials. Additional prompts and praise were used with Roy only: vocal prompts used were instructions such as "Wait" and "Listen." General vocal praise from the researchers, such as nods, smiles, "Great job with the tablet." "Nice sitting on your chair," and "You are doing great," were presented intermittently. Roy received intermittent praise for working on the tablet throughout the experiment.

Limited Hold At first, the duration of both the visual and the auditory stimuli was 5.2 s. However, the duration of the stimuli was shortened for Roy and Ted during training in Phase 1. Responding to S^+ within the time limit (i.e., the limited hold) interrupted the duration of the stimulus and resulted in a preferred video clip playing on the tablet screen. In contrast, responses to the main key in the presence of S^- or during the Intertrial Interval (ITI) had no programmed consequences other than initiating a reset delay as described below.

Reset Delay To avoid the adventitious reinforcement of touching the square in the absence of the S^+, we used a reset delay: if the participants touched the main key during the ITI or in the presence of S^-, the next trial was postponed by a given number

Table 2 Video clips used during the experiment

Eric	Roy	Ted
Sponge Bob	Trucks	"Join the dance 2014"
Larva	Garbage trucks	"Gummi bear"
Despicable Me	Children song game	"Until Dovre falls"
Ice Age	Children music	"What does the fox say"
Ed	Trains	"Gangnam style"
Edd and Eddy	Motorcycles	"Tarzan and Jane"
Monster University	Cars (Disney)	"The lazy song"
Ninja Turtles	Fantorangen (Norwegian)	
How to Train Your Dragon		

Note. For Ted, the clips were music videos

Fig. 1 An illustration of the placement of the white and the blue square on the screen
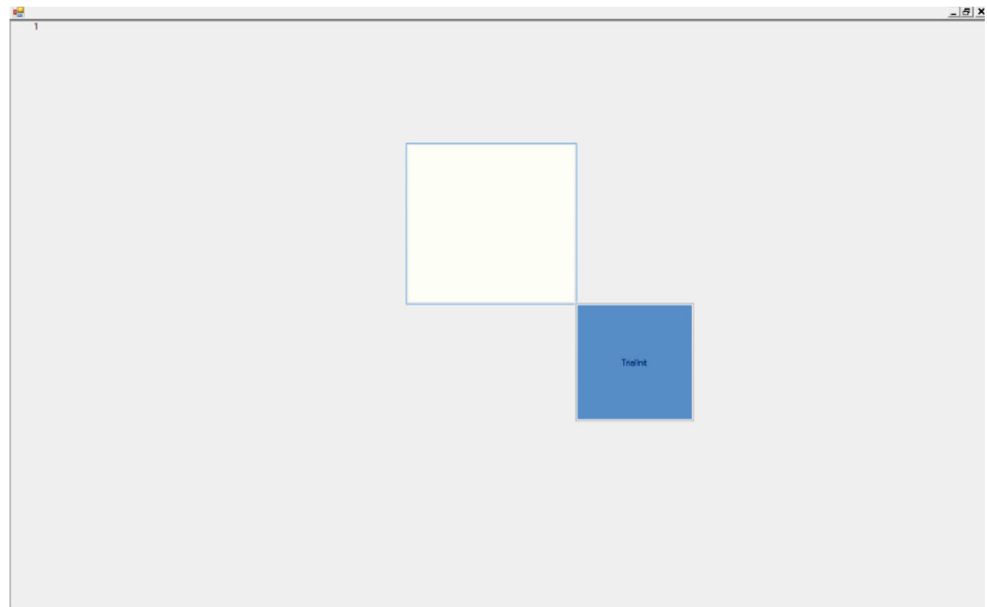
Note. A picture of the screen of the computer showing the placement of the white square and the placement of the blue square, which the participant could press to proceed to the next trial, a trial initiation response.

of s. The reset delay was gradually increased from 6 s until stimulus control was reached according to the criteria.

Trial-Initiation Response As soon as a trial ended, a blue square (5.0 × 5.0 cm) appeared on the screen (see Fig. 1), and the participant could initiate the next trial by touching it (e.g., Iversen, 1998). When the trial-initiation option was introduced, the previous automatic ITI was removed. Hence, the duration of ITI depended on how fast the participants touched the trial-initiation response button (the blue square). The trial-initiation response option was introduced from Session 13 for Eric, Session 21 for Roy, and Session 33 for Ted. The participants were trained by the experimenter prompting a response to the blue square (e.g., by pointing to it).

From Continuous to Intermittent Reinforcement Continuous reinforcement (fixed ratio 1; FR 1) was used for the establishment of stimulus control in the initial sessions. Across successive sessions in Phases 1 and 2, the schedule of reinforcement was thinned from FR1 through VR3 and VR4, to VR5, with a range of four, so that the number of responses required to produce the reinforcer varied between three and seven.

Stimulus Control Criterion The original stimulus control criterion was that responses to the main key occurred in the presence of the S^+ and zero responses in the presence of S^- and in the absence of stimuli on 100% of the trials across two successive 20-trial sessions. However, the mastery criterion was softened for Roy to 90% mastery across two 20-trial sessions.

Phases 3 and 5 were tests of stimulus control, whereas Phase 4 was the reestablishment of stimulus control as the final training sessions in Phase 2.

Phases 3 and 5: Tests of Stimulus Control by Simple and Compound Stimuli During a 24-trial test session, the six stimuli (i.e., each of the single stimuli [S_1^+, S_2^+, S_1^-, and S_2^-] as well as the two compounds [$S_1^+S_2^+$ and $S_1^-S_2^-$] were presented in a quasi-randomized order: (1) the visual or auditory S^+ established during Phase 1; (2) the visual or auditory S^- established during Phase 1; (3) the visual or auditory stimulus added to the initial S^+ in Phase 2; (4) the visual or auditory stimulus added to the initial S^- during Phase 2; (5) compound$^+$ stimulus, consisting of the visual S^+ with an auditory stimulus added or vice versa, and (6) compound$^-$, consisting of the visual S^- and an auditory stimulus added, or vice versa. Each of the stimuli was repeated four times.

During the test of stimulus control, responses to the main key produced consequences (the preferred video clips; see Table 2) to maintain responding only in the presence of the compound consisting of the original S_1^+ and the added S_2^+. The video clips were contingent on responses according to a VR 5 schedule. The presentation of the compound $S_1^-S_2^-$ was considered as a control condition, in which responses to the two stimuli presented simultaneously were never reinforced. Likewise, responses to either S presented alone were never followed by any programmed consequences.

Responses to the main key in the presence of either of the six stimulus conditions were recorded for later analysis of whether stimulus control was established. Blocking would be

demonstrated to the extent that touch responses to the main key were more frequent in the presence of the initial S^+ than in the presence of the stimulus added during Phase 2 and in the presence of the S^- stimuli. The primary dependent measure was the number of responses to the main key (i.e., touches on the square) in the presence of different single and compound stimuli. Stimulus control was measured by relative number of responses in the presence of the different stimulus conditions.

Results

In Phase 1, discrimination of single stimuli, the stimulus control criterion of 100% accuracy in two successive 20-trial sessions was achieved after a total of 900 training trials (Sessions 49–50) for Eric, and after 1,038 trials (Sessions 62–63) for Ted. For Roy, the stimulus control criterion of 90% mastery in two consecutive 20-trial sessions was met after a total of 850 training trials (Sessions 55–56). During the first eight sessions Roy emitted more responses in the absence of stimuli (up to 89 responses), than in the presence of both S_1^+ and S_1^-. Therefore, during Sessions 9–12, we focused on training the discrimination between the S_1^+ and absence of stimuli, rather than discrimination between the two training stimuli. From Session 13, discrimination training for Roy continued by including S^- trials as for Eric and Ted.

Touching the trial-initiation key was prompted in the session it was introduced for Roy and Ted, whereas Eric touched the key spontaneously. When the trial-initiation response option was introduced, the number of responses to the main key (i.e., responses in the absence of S_1^+ and S_1^-) immediately dropped and stayed low for the rest of the experiment for Eric (from Session 13) and Ted (from Session 33). A reduction in the number of responses to the main key was less clear for Roy.

During Phase 2, go/no-go training with compound stimuli, the mastery criterion was achieved in fewer trials than in Phase 1. Eric reached the mastery criterion after four 20-trial sessions, Roy mastered the discrimination after three 20-trial sessions, and Ted after two 20-trial sessions. However, the participants were exposed to an equal number of trials as in Phase 1. The number of responses in the presence of the S_1^+, in the presence of the S_1^-, and in the absence of stimuli (during the ITI) in Phase 1 are shown in the left part of Fig. 2, whereas the number of responses in the presence of the compounds ($S_1^+S_2^+$ and $S_1^-S_2^-$) as well as in the absence of stimuli during Phase 2 are shown in the right part.

In Phase 3, Test 1 of stimulus control by simple and compound stimuli, all three participants consistently emitted more responses on the four S_1^+ trials than on the corresponding four S_2^+ trials (Fig. 3, left panel). Thus, blocking of stimulus control was demonstrated in all participants following previous discrimination training with simple stimuli in Phase 1 and with compound stimuli in Phase 2. In the presence of the

single stimuli S_1^- and S_2^-, and the compound $S_1^-S_2^-$, two of the participants made no responses at all, whereas one (Roy) emitted relatively few responses.

During Phase 4, the reestablishment of stimulus control was achieved in two 20-trial sessions. In Phase 5, Test 2 of stimulus control by simple and compound stimuli, all participants emitted fewer responses in the presence of S_2^+, which was added in Phase 2, than in the presence of S_1^+, which was introduced during Phase 1 of the discrimination training. Thus, the demonstration of blocking was replicated. Figure 3 (right panel) shows the results from the replication of the stimulus control test (Phase 5). As in the first test, the number of responses in the presence of the single stimuli S_1^- and S_2^-, and the compound $S_1^-S_2^-$, was zero or near zero for two of the participants, whereas one (Roy) emitted a few responses in the presence of S_2^-.

During each of the four reinforced compound $S_1^+S_2^+$ trials in each of the two test phases, all participants emitted four to six responses, which was the maximum number because the opportunity to respond ended with the presentation of a preferred video clip. In general, the second test confirmed the results of the first test. In particular, the higher number of responses in the presence of the four S_1^+ trials than on the corresponding four S_2^+ trials was consistent across the tests.

Discussion

The purpose of the present study was to investigate whether blocking of stimulus control during operant discrimination could be demonstrated in children with autism. All three participants responded more frequently in the presence of the first conditioned stimulus than in the presence of the added stimulus. Thus, control by the added stimulus was blocked. Replication of the stimulus control test showed the same consistent result: The S_1^+, which was established during the first phase of the discrimination training, was still effective, whereas S_2^+, which was added during the second phase, was not.

The results of the present study are in accord with the results of previous studies that have demonstrated blocking of discriminative control in animals (e.g., Vandbakk et al., 2020; vom Saal & Jenkins, 1970) and in humans. However, results of previous experiments with humans have varied, and so have the procedures used in those experiments. The studies with human participants have been concerned with specific tasks, such as the use of extra-stimulus prompts in reading instruction (e.g., Didden et al., 2000) or new stimuli in compounds with stimuli that have already formed equivalence classes (e.g., Rehfeldt et al., 1998), or sorting tasks (e.g., Lyczak & Tighe, 1975). In the study reported by Lyczak and Tighe (1975), the participants demonstrated blocking only during the condition with no specific cueing of the successive phases of training and test. Blocking was observed when the three phases appeared more continuous, as in animal studies,
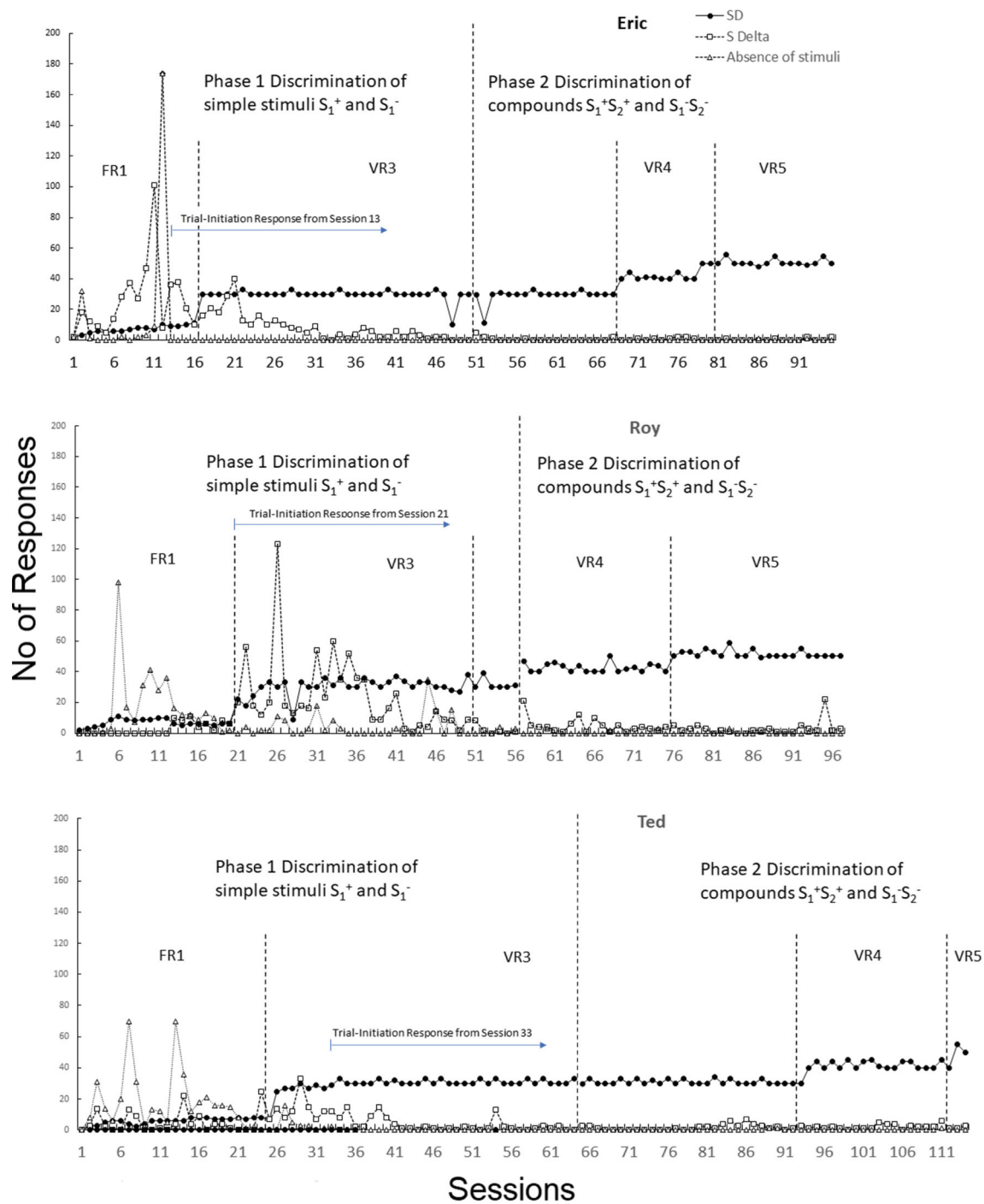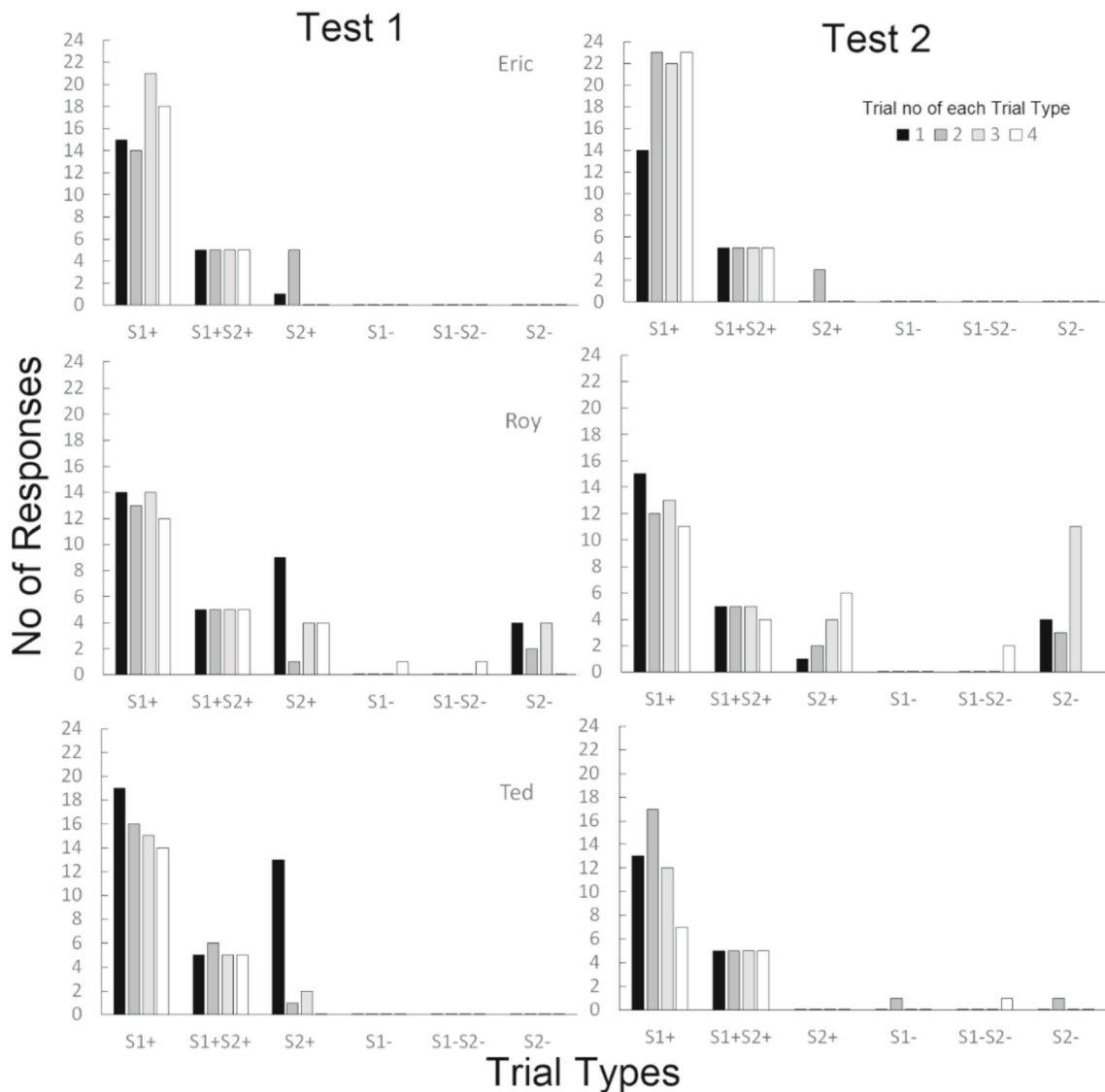
Note. The number of responses is shown on the y axis and session numbers are marked on the x axis. FR = Fixed Ratio and VR = Variable Ratio. The session number at which the Trial-Initiation Response Option was introduced is indicated for each participant.

Fig. 2 Successive discrimination training during Phase 1 and 2

without phases being signaled. The easily discriminable transition between the training phases could have indicated the beginnings of new training phases and, thus, explain the failure of a blocking effect of the previous training phase.

The purpose of giving phase-specific verbal instructions has been to prevent a declining response rate in the absence of continuous feedback. For example, the children have been told that "the rule of the game has changed," and that they "will receive

Note. The tests measured the number of responses in the presence of S_1^+ and S_2^+-, S_1^- and S_2^-, and in the presence of the compound $S_1^+S_2^+$ and $S_1^-S_2^-$. Except in the presence of $S_1^+S_2^+$, where responses were reinforced according to a VR5 schedule, the tests were carried out in extinction. The black bars (1) represent responses during the first of each trial type, the dark grey bars (2) indicate responses during the second, light grey bars (3) represent responses during the third, and the white bars (4) indicate responses during the fourth and final trial of each type.

Fig. 3 Tests of stimulus control

the reinforcer at the end of the test session." Also, participants have been told to do as they did in the previous phase, during the discrimination training (Lyczak & Tighe, 1975). These procedural variables probably counteracted blocking. Some other previous blocking experiments with children have avoided the problem of extinction by providing feedback, such as verbal praise, on each response during baseline and posttest (e.g., Didden et al., 2000; Singh & Solman, 1990). An obvious problem with such continuous reinforcement during the test is that the test itself may establish discriminative control that did not derive from previous training. A strength of the present experiment is the use of an intermittent schedule of reinforcement to promote a high rate of

responding during the later tests, where touching the main key was reinforced exclusively in the presence of the compound $S_1^+S_2^+$. The purpose of stretching the schedule of reinforcement during training from FR 1 to VR 5 was to prepare for response maintenance throughout the test phases while avoiding verbal instruction as well as reinforcement of the crucial test trials, S_1^+ and S_2^+. The VR 5 schedule of reinforcement implied that the participants had to touch the compound stimulus on the average five times before the responses produced the reinforcer. Therefore, during the stimulus control tests, the results show 20–21 responses in the presence of the compound $S_1^+S_2^+$ for each participant. These trials were randomly interspersed

between the other five trial types. Without this intermittent reinforcement, the participants' behavior during the stimulus control tests might have extinguished rapidly during the tests. However, despite reinforced responding to the compound stimulus, the stimulus control tests of the two stimuli separately showed an explicit control by S_1^+, but not by the later added S_2^+.

The go/no-go discrimination implies control by the negative as well as by the positive discriminative stimulus. For all participants, the establishment of the go/no-go discrimination took from 850 to 1,038 trials to reach the criterion of 90%–100% accuracy in two successive sessions. Although responses to the main key in the presence of S_1^+ occurred immediately following the startup instruction, *not* responding in the absence of S_1^+, including in presence of the S_1^-, took more trials to establish. A history of tablet use may explain the speed with which responding to the main key on the tablet was established, as well as slowness of refraining from responding in the absence of S_1^+. It may be presumed that once responding is established, its removal in the presence of the negative discriminative stimulus (in this case, the S_1^-) requires differential extinction or punishment in the presence of that stimulus. Three features of the procedure may have worked to eventually produce the required go/no-go discrimination: First, the reset delay prevented the adventitious reinforcement of responding to the main key in the absence of S_1^+. Second, the limited hold and the intermittency of reinforcement may both have sharpened the control by the S_1^+ by hindering discriminative control by the reinforcing consequences. Third, the introduction of the trial-initiation option seemed to effectively reduce the number of responses to the main key during ITIs by providing an alternative.

Once control by the negative S_1^- (as well as by the positive S_1^+) is established, an intriguing question is whether the negative control by the later introduced S_2^- will be blocked (as well as the positive control by S_2^+). Such blocking of control by the negative S_2^- was indicated in the case of one participant only: Roy responded more frequently in the presence of S_2^- than in the presence of S_1^- during both tests. It is possible that some apparent blocking of control by the S2- in the case of Roy was predictable from the fact that he responded more frequently than the other two participants to the S⁻ stimuli throughout most of the training. It is also possibly relevant that only Roy was first introduced to auditory stimuli (as S_1^+ and S_1^-) and then to visual stimuli (as S_2^+ and S_2^-), whereas the other two participants (Eric and Ted) were first exposed to visual stimuli (as S_1^+ and S_1^-) and next to auditory stimuli (as S_2^+ and S_2^-). Roy, who was exposed to auditory stimuli first, also showed slightly less blocking than the participants who were exposed to visual stimuli first. However, it must be listed as a limitation of the present experiment that it included the reverse introduction of auditory and visual stimuli for one participant only. Thus, order effects of visual and auditory stimuli were thoroughly investigated neither within nor across

participants. Possible order effects, along with the extent to which blocking of negative control by a new stimulus is predictable from the strength of the original S⁻ control should be investigated in future research.

Cengher et al. (2018) found stimulus prompting more effective than response-prompting procedures and suggested that blocking or overshadowing may shed light on the difference. Often, stimulus prompts consist of highlighting a trait of a stimulus with no specific prior conditioning history, then gradually fading that trait (e.g., emphasize the color blue on a sight word and gradually fading the text until the individual says "Blue" in the presence of a blue card). In contrast, response prompts typically have a conditioning history (e.g., vocal instructions, physical guidance, or adding a picture to facilitate the reading of words) and thus have discriminative properties. Thus, response prompts may inhibit the establishment of stimulus control of a second S⁺. An alternative variant of the superiority of stimulus-prompting procedures (or intra-stimulus prompts) over response prompt (or extra-stimulus prompts) procedures is overshadowing. Unlike blocking, overshadowing does not depend on a prior conditioning history. When two stimuli are presented together, one stimulus may acquire control stronger or more quickly than the other (e.g., a picture may be more salient than a visible word in a sight-word reading task).

Stimulus overselectivity has been widely accepted as a hindrance to the establishment of stimulus control in children with autism (e.g., Lovaas et al., 1971). On the other hand, Dube et al. (2016) found that stimulus overselectivity reflects mental age rather than the diagnosis of autism. Stimulus overselectivity, whether autism-specific or not, is still a problem that may require specific attention whenever it occurs. Hence, it is important to investigate the conditions under which stimulus overselectivity occurs and to find applied solutions to such blocking of stimulus control.

Whether problems of restricted stimulus control are called stimulus overselectivity, differences in stimulus salience, selective attention, overshadowing, or blocking, the key to solving the problem, we presume, lies in changing the contingencies. It is fortunate that stimulus overselectivity and blocking may be reduced by teaching an overt precurrent ("observing") response to the S⁺ (Doughty & Hopkins, 2011), as well as by teaching conditional discrimination from the beginning of a procedure, rather than following a simple discrimination (Green, 2001). Moreover, Farber et al. (2017) suggested that differential observing responses (e.g., different tacts to sample stimuli) during matching-to-sample resulted in less overselectivity than nondifferential observing responses, where the response to the sample is the same on every trial, in children with autism (e.g., Reed, Altweck, Broomfield, Simpson, & McHugh, 2012). Differential observing responses verify the discrimination of stimulus features that differ among the samples (e.g., by tacting the sample stimuli). Therefore, in cases where blocking has been demonstrated,

the effect of establishing differential observing responses to each sample should be investigated.

Blocking of conditioned reinforcers is shown in pigeons (e.g., Palmer, 1988) and rats (e.g., Vandbakk et al., 2020), and is strongly indicated in children with autism (e.g., Lovaas et al., 1966). In applied contexts, it is likely that the conditioning of a new stimulus as a reinforcer will sometimes fail: for example, if a smile already functions as a reinforcer, establishing "Great!" as a reinforcer might be hampered or blocked if it appears in a compound with the smile. Such blocking of conditioned reinforcers may become a significant problem for children with autism, because without a range of effective social conditioned reinforcers, social skills and other complex skills are not likely to develop (e.g., Du, Broto, & Greer, 2015; Eby & Greer, 2017; Ferster, 1961; Greer & Du, 2015; Lepper & Petursdottir, 2017; Lugo, Mathews, King, Lamphere, & Damme, 2017; Schmelzkopf, Greer, Singer-Dudek, & Du, 2017). Therefore, the identification of obstacles for the successful establishment of commonly effective social reinforcers may be fundamental to the learning of important skills by children with autism (Dozier, Iwata, Thomason-Sassi, Worsdell, & Wilson, 2012; Eby & Greer, 2017; Lovaas et al., 1966; Rodriguez & Gutierrez, 2017), including tacts (Eby & Greer, 2017), joint attention (Isaksen & Holth, 2009; Jones & Carr, 2004) and complex verbal behavior, such as bidirectional naming (Olaff & Holth, 2020). In future research with children with autism, a possible blocking of standard social consequences as conditioned reinforcers should be investigated. Paving the way for effective conditioning of social reinforcers might prepare for the natural environments to automatically shape relevant verbal and social skills, including bidirectional naming and joint attention, and thus reduce the need for contrived intensive skill training (Holth, 2012).

The present experiment demonstrated blocking during the tests of stimulus control. To the best of our knowledge, the current study is the first that explicitly used an operant blocking paradigm with participants with autism. However, replications are needed to investigate the scope and the limits of blocking by earlier discrimination training. Problems with the establishment of novel stimuli as conditioned reinforcers as well as problems of stimulus overselectivity in children with autism may boil down to blocking and overshadowing. Future research on blocking and overshadowing as well as effective interventions to overcome these problems may benefit people with autism.

Data Availability The data generated during the present experiment are available from the first and the third author on request.

Compliance with Ethical Standards

Ethical Approval In advance, the Norwegian Center for Research Data approved the present experiment.

Informed Consent to Participate and for Publication Informed consent was obtained from all participants' caregivers, as well as from the managers of the kindergartens the participants attended.

Conflict of Interest The authors declare that there is no conflict of interest.

Appendix

Table 3 Summary of the description of the participants according to age, diagnosis, standard Vineland scores and ABLLS-R scores, and verbal description

Participants	Age	Diagnosis	ABLLS-R scores—% mastery of verbal behavior domains
Eric	6:0	Childhood autism	Cooperation and reinforcement effectiveness: 91.1%
			Visual Performance: 100%
			Receptive Language: 98.9%
			Motor Imitation: 100%
			Vocal Imitation: 98.2%
			Requests: 100%
			Labeling: 95.7%
			Intraverbals: 96.1%
			Spontaneous vocalizations: 100%
			Syntax and Grammar: -90.4%
			Generalized Responding: -100%

Table 3 (continued)

Participants	Age	Diagnosis	ABBLS-R scores—% mastery of verbal behavior domains
Roy	3:0	Childhood autism	Cooperation and reinforcement effectiveness: 66%
			Visual Performance: 30%
			Receptive Language: 48%
			Motor Imitation: 27%
			Vocal Imitation: 54%
			Requests: 31%
			Labeling: 22%
			Intraverbals: 15%
			Spontaneous vocalizations: 75%
			Syntax and Grammar: 36%
			Generalized Responding: 58%
Ted	4:0	Childhood autism	Cooperation and reinforcement effectiveness: 85%
			Visual Performance: 55%
			Receptive Language: 25%
			Motor Imitation: 24%
			Vocal Imitation: 20%
			Requests: 7%
			Labeling: 1%
			Intraverbals: 0%
			Spontaneous vocalizations: 14%
			Syntax and Grammar: 0%
			Generalized Responding: 17%

Note. ABLLS-R is an acronym for Assessment of Basic Language and Learning Skills, Revised and is summarized as percent achievement per skill domains at intake in the study

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