The Role of Observation on Selection and Rejection Control by Some Discriminative Compounds

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Thesis for the master's degree in Psychology with emphasis in Research in the field:

Decision Making and Choice

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September 2021

Abstract

Title: The Role of Observation on Selection and Rejection Control by Some Discriminative Compounds

Studies with rats and pigeons have found control by some components of S+ visual compounds. Varying measures can reveal control by other S+ components, and even by S- components via rejection. Studies with humans have replicated these results, suggesting observation as a measure of stimulus control. A within-individual design of concurrent fixed-ratio schedules examined how direct observation correlates to selection or rejection control in 15 adult humans. During acquisition, nine participants were reinforced for choosing a red circle or a triangle, and punished for choosing a green circle or a square. The second phase reversed the contingency. Following each training, 5 participants were asked to choose between the components presented individually in multiple combinations. For the other 4 participants, 4 tests were included that opposed each component with a novel stimulus. A variation with 3 participants substituted green for blue and red for yellow, randomized the components' topographical presentation, and included tests with novel stimuli. A final variation with 3 participants replaced the shapes and colors with multidirectional straight lines. Two categories of learners emerged in acquisition. The "fast learners" focused on colors, with observing durations under 10 seconds in acquisition. Tests revealed weak control by colors, or no control at all. The "explorers" observed the components proportionally and over 10 seconds each in acquisition. Tests revealed control by both S+ components via selection, and by both S- components via rejection. Compound patterns hindered acquisition, but not reversion.

Key words: Compound stimulus, Eye movements, Stimulus control, Selection control, Rejection control, Humans.

Resumen

Title: El Papel de la Observación en el Control por Selección y Rechazo de Compuestos Discriminativos

Estudios con ratas y palomas han hallado control por algunos componentes de estímulos visuales compuestos S+. Medidas variadas pueden revelar control por otros componentes S+, e incluso por componentes S- vía rechazo. Estudios con humanos han replicado estos resultados, sugiriendo la observación como una medida del control de estímulos. Un diseño intra-sujeto con programas concurrentes de razón fija examinó cómo la observación directa se correlaciona con el control por selección o rechazo en 15 adultos humanos. Durante la adquisición, nueve sujetos fueron reforzados por responder ante un círculo rojo o un triángulo, y castigados por elegir un círculo verde o un cuadrado. La segunda fase revirtió la contingencia. Luego de cada entrenamiento, 5 sujetos debían elegir entre los componentes presentados individualmente en múltiples combinaciones. Para los otros 4 sujetos, se incluyeron 4 pruebas que contraponen cada componente con un estímulo novedoso. Una variación con 3 sujetos cambió el verde por azul y el rojo por amarillo, aleatorizó la topografía de la presentación de los componentes e incluyó las pruebas con estímulos novedosos. Una última variación con 3 sujetos cambió las formas y colores por líneas rectas multidireccionales. Emergieron dos clases de respondientes en la adquisición. Los “aprendices veloces” se enfocaron en los colores, con duraciones de observación inferiores a 10 segundos en la adquisición. Las pruebas revelaron control débil de los colores, o ausencia de control. Los “exploradores” observaron los componentes proporcionalmente y por encima de 10 segundos cada uno en la adquisición. Las pruebas revelaron control por ambos componentes S+ vía selección, y por ambos componentes S- vía rechazo. Los patrones compuestos dificultaron la adquisición, pero no la reversión.

Palabras clave: estímulos compuestos, movimientos oculares, control de estímulos, control por selección, control por rechazo, humanos.

A great deal of attention has been paid to how consequences reinforce behavior. And they do. Paradoxically, though, way more behaviors can easily be explained appealing to events that precede behavior (Baum, 2005). Control exerted by antecedent stimuli upon the probability of occurrence of behavior is known as stimulus control (Skinner, 1953).

Response rate has traditionally been the measure of stimulus control. For instance, in one classical study on stimulus control, Reynolds (1961) reported control over pecking-rate by just one S+ component of a S+ compound. Reynolds reinforced two pigeons for responding to some shape-color compound on an operant go/no go discrimination. Other combinations were not reinforced. One of the contingencies delivered food to the pigeons for responding to a white triangle on a red background, while responding to a white circle on a green background did not. Further non-contingent testing presenting all components individually and simultaneously revealed that, whereas one pigeon chose the S+ shape, the other chose the S+ color. Reynolds concluded that only one of the components had been “attended” by the participants. Although one of Reynolds’ pigeons chose color and the other chose shape, evidence has been provided that color is a more salient feature of stimuli than shape (Terrace, 1966), which might lead to higher control by color across several conditions (Kendall & Mills, 1979).

Following studies employing various testing methods have found that more than just one S+ component could gain control over responding during extinction tests, depending on how the components are arranged. For instance, Kendall and Mills (1979) reinforced shape-color compounds in pigeons. Once established the discrimination, pigeons were presented non-contingent combinations of the components separately, by pairs. The pigeons chose the compound in the first place, color in second, and shape last. Kendall and Mills showed that testing measures other than the one employed by Reynolds would lead to various degrees of control by the components alone and combined.

In other testing methods, recombining the S+ and S- components would reveal control by both S+ components. For instance, Farthing and Hearst (1970) reinforced 12 pigeons for responding to a vertical white line on a blue background. During extinction tests, the pigeons were presented "elements" and "compounds." Color showed widespread control. The line-tilt dimension revealed control through "compound" trials but not in "elements" trials. Hence, the authors concluded that attributing no control to an element might be a failure of assessment, not of control.

Besides response rate, the number and duration of eye fixations has been proposed as an alternative method of assessing stimulus control (Spence, 1956; Blough, 1966; Wyckoff, 1969; Dinsmoor, 1985). Wyckoff (1969), for instance, set a pedal that allowed pigeons to see non-discriminative stimuli, and for a second group the stimuli played the discriminative function. While pigeons from the first group dismissed standing on the pedal, pigeons from the second group not only stood on the pedal for longer, but reportedly learned the discrimination that the red light correlated with the receipt of food. A third group of pigeons kept on discriminating once reversal took place. Wyckoff concluded that the time spent on the pedal—functionally analogous to observing—varied as a function of the contingent relation between color and food.

Similar results have been found in humans. One of the recent studies on stimulus control by Perez, Endemann et al. (2015) found that three human participants tended to choose, in non-contingent tests, the components of compound stimuli that they had fixated on the most during training sessions. First, they established a discrimination for responding upon a compound stimulus of a red circle and a triangle, and did not reinforce responding upon a green circle and a square—similar to those employed by Reynolds (1961), but separated, and yet compound. In extinction, they tested responses to each component similar to Reynolds, but added tests that compared every pair of S+ and S- components. Also, one test recombined the S+ and S- color and shape, resulting in a green triangle and a red square. A second phase reversed the contingency and tested control. Although one S+ component was the highest fixated, the second highly fixated component was S- in all cases. Some preferred color, others shape. Control was also attained by S+ components not fixated at all. Control by non-observed components might be due to a peripheral vision effect.

However, selecting a S+ component that has not been observed during acquisition could be in fact rejection of the S- component of the comparison (Carrigan & Sidman, 1992). Mixed select-reject controlling relations could also have occurred at the same time. Reject control can be assessed by replacing the S+ component of the comparison by a novel stimulus (Carrigan & Sidman, 1992). Selection of novel would allow the conclusion of rejection of S+.

The studies above suggest that a). more than just one S+ component of compound stimuli stand a chance to demonstrate control over responding if correctly assessed, both in pigeons and humans; b) some S- components can attain more visual attention than weak S+ components in humans; c) some S+ components non-fixated at all can attain control over responding.

Considering these findings, the present study aimed to a) replicate the finding that more than just one S+ component gains control over responding, by testing arrangements similar to those of Perez, Endemann, et al. (2015); b) assess the relation between duration of direct—non-peripheral—observation, and response rates and latencies in extinction; since Perez et al. found that some participants chose non-observed S+ components; c) establish and assess select and reject relations to determine whether results like those of Perez et al. where non-observed S+ were chosen corresponded rather to rejection of the S- component.

Select and reject relations are expected to be found as a function of observation rates. One recent study by Perez and Tomanari (2020) manipulated selection and rejection control in a matching-to-sample task and found that rejection control is linked to higher observation rates to the S- components, and selection control is linked to higher observation rates to the S+ components.

Also, to assess direct observation, the stimuli were hiden *behind* a dark layer during discrimination training; the participants could only see the stimuli upon hovering over the dark layers (e.g., Perez et al., 2015; also see McIlvane, 2013).

Four experiments evaluate this goal in different stages. Experiment 1 sought to replicate the three major findings by Perez, Endemann, et al. (2015). These results were a) the controlling relation displayed during the extinction sessions could not be reliably predicted by the shape-color aspect of the controlling components; b) the component highest fixated during acquisition of the discrimination gained the highest control over responding during extinction; and c) in some cases, the weaker S+ component gained control over responding during extinction. All experimental conditions employed by Perez et al. were identical in Experiment 1, except that visual contact assessment was measured by covering the components and making them visible only when the mouse pointer hovered over (Perez et al., 2015; McIlvane, 2013).

Experiment 2 consisted of the same phases and comparative tests as Experiment 1 but added 4 tests after Test 5 and before Test 10—recombination—in which it compared each component separately against a novel stimulus, a white circle (e.g., Carrigan & Sidman, 1992). If the component was selected and is observed during acquisition, it is assumed to control responses by selection. If the novel stimulus is selected and the compared component was observed during acquisition, the component is assumed to control by rejection.

Experiment 3 consisted of the same phases and comparative tests as Experiment 2 but used yellow instead of red and blue instead of green. It also randomized the location of the colors and shapes so that the participant could not predict where any component would appear. This served several purposes: to encourage equal visual search among the components, to decrease control by stimulus topography, and to increase control by contingency and by the formal aspects of the components.

Finally, Experiment 4 changed the colors and shapes to diagonal and axial line patterns inside circles. The contingency conditions, topographic randomization, reversal, testing, and phasing were identical to Experiment 3. The goal was to measure the effect of more neutral formal aspects of the components on the observational response at acquisition, on response rate, on average latency, and on the type of control-by selection or by rejection.

General Method

The general participants, and setting and equipment specifications apply to all experiments unless exceptions are noted.

Participants

Fifteen adult participants. They all manifested being naïve in the task, and none of them reported to suffer from any color discrimination-related disease. They read and signed an informed consent. At the end of each session, the experimenter answered any question the participants might have about the experiment and the participants were debriefed.

Setting and Equipment

Due to Covid-19 pandemic lockdown restrictions during 2020, all sessions were conducted remotely, with the experimenter at his home and the participants from their respective locations. Each session took around 30 minutes, between 8 a.m. and 5 p.m. The participants were asked to dispose of a room with a chair and a table, along with a computer monitor, a keyboard, and a mouse—or a laptop. They remained 60 cm away from the computer screen. By request of the experimenter, the participants isolated themselves in the private room to avoid any distractions and wore a headset to listen to the auditory feedback. Each participant received via e-mail the executable version of the experiment and ran it directly on their personal desktop computer or laptop. The experiment was programmed in Visual Basic 6.0, and the stimuli were created in Microsoft PowerPoint. The program presented the stimuli, the auditory feedback and recorded the participant responses, the mouse-dragging and the mouse-over.

Experiment 1

Experiment 1 aimed to replicate Perez, Endeman, et al. (2015) major conclusions: a) control evidenced in extinction covariates with the participants' observing responses during training; b) the controlling relations vary from participant to participant, some preferring colors, and other shapes; c) the weaker S+ controls portions of the responses during testing. In the first place, results helped analyze whether responses during extinction tests correspond to the observational patterns registered during acquisition and reversal, and which component's formal aspects are involved in the participants' preference. We also aim to demonstrate the control exerted by components other than the strongest—mostly fixated—S+ and to unravel the role of the observational response.

Since the duration of fixations to each component were measured differently from Perez et al. and participants responded from their homes due to the pandemic-related mobility and social distancing restrictions, Experiment 1 cannot be conceived as a perfect replication. Nonetheless, conditions were maintained as much as possible.

Method

Participants

Five adult participants, VP, YC LH, CG, and SP, volunteered to participate in the experiment.

Procedure

All four experiments consisted of acquisition and its testing in phase 1, and reversion and its testing in phase 2. Before the experiment started, the participants read out loud and then clarified any doubts regarding the following instructions (originally in Spanish):

> "This experiment consists of several phases and your task will be to accumulate points consecutively that will allow you to advance to the next phase, until you reach the end. You will know that you got a point when, when you click, you hear a high-pitched sound; a low-pitched sound, on the other hand, will let you know that you lost the points you had accumulated. Make sure you always click only on what you think will get you the point, even if you don't hear a sound after the click. Do you have any doubts? Repeat in your own words what you should do, let the researcher know that you have no doubt."

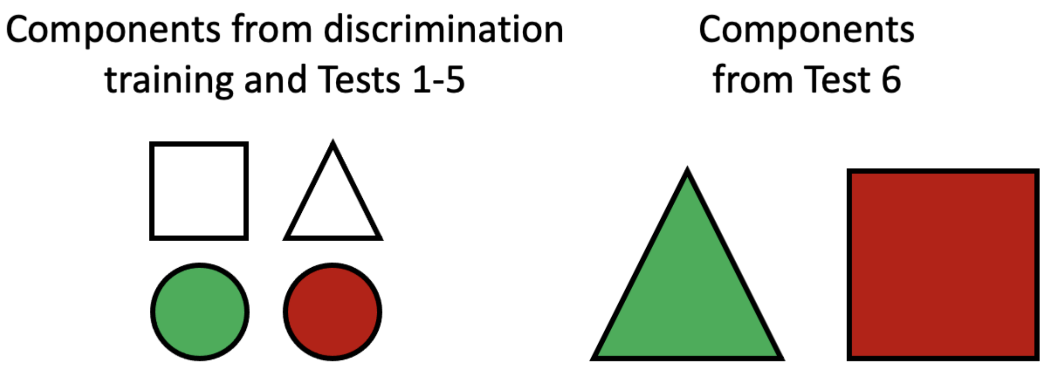
Stimuli

The stimuli during training and tests 1-5 were a square, a triangle, a red circle, and a green circle, all sized .52 cm*.52 cm; stimuli during Test 6 were a green-filled triangle and a red-filled square, sized 1.05 cm*1.05 cm (Figure 1). All components and presentation-areas proportions were relative to the participant's computer screen dimensions. Original proportions by Perez, Endemann, et. al. (2015) was maintained as follows:

- Component size: .52 cm×.52 cm (1,05 cm×1,05 cm for Test 6).
- Distance between components displayed in the same presentation-area: 7.95 cm.
- Distance center-to-center for the presentation-areas: 21,55 cm.
- Maximum size of each presentation-area: 9,92 cm×9,92 cm.

Figure 1

Components of Experiment 1



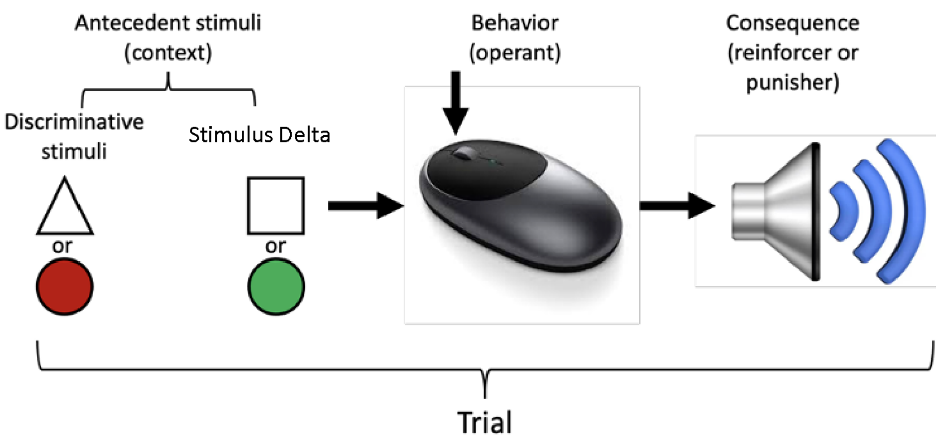
Note. On the left, the components employed during training sessions and tests 1-5. On the right, stimuli employed during the tests 6—recombination of the original components.

Procedure

Phase 1 started with a training session consisting of a Fixed-ratio-1 simultaneous discrimination task that required the participants to produce as many beeps as they could. The beep was contingent on clicking either the white triangle or the red circle, and added one point to the beep score counter—henceforward referred to as S+—both enclosed into the outlined square of the resentation area. A dissonant 'buzz' sound was contingent on clicking either a square or a green circle in another presentation-area, and reset the beep score counter—henceforward referred to as S-.

Figure 2

Example of a Single Trial During Discrimination Training



Note. A beep was contingent on clicking the triangle-red compound, while a dissonant 'buzz' was contingent on clicking the square+green compound. Phase 2 reverted the contingency.

Both shapes appeared always on the upper-middle of the presentation-area, whereas the colors did so on the lower-middles. The presentation-areas were randomly located in either of the two left-right upper corners of the screen on each trial (Figure 3). Between trials meddled a 0.5-second intertrial interval, which turned the screen blank before the next trial arrived. Every trial set the mouse-pointer back on the center of the screen to prevent clicking based on pointer-stimulus proximity. The dissonant buzz restarted the beep counter. The steady-state criterium was set twelve (12) consecutive beeps, which signaled the discrimination accomplishment, ended the training session, and started the stimulus control Tests. During testing, the stimuli were individually presented and occupied the center of each presentation-area. Although responses during Tests were not reinforced, the participants were asked to keep on producing the beeps.

Each test consisted of 12 trials in which the responding rate and response latency to each separate stimulus tested in extinction were recorded to assess individual stimulus control. The stimuli were distributed across the tests as follows:

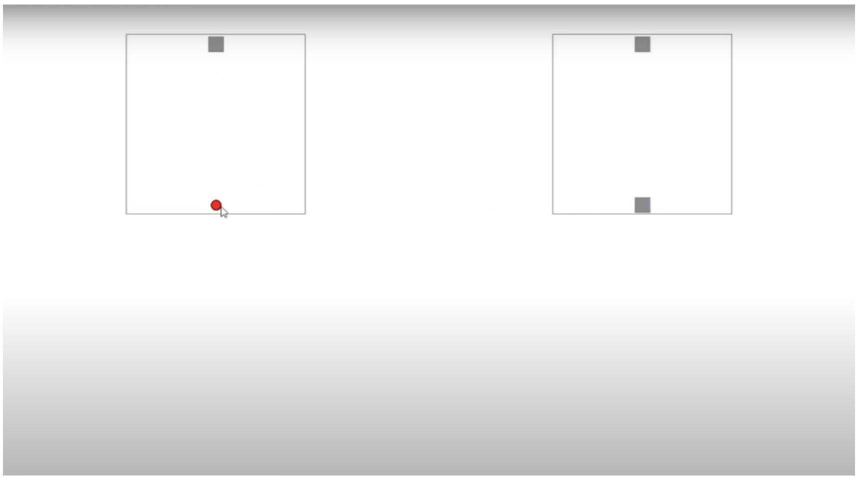
- Test 1 presented all four stimuli separately in a single presentation-area, placed in every corner of the screen each (see Figure 3). All locations randomized for each trial, up to three consecutive coincidences on the same corner for any stimulus.

- Tests 2-5 presented each S+ component against each S- component in a presentation-area each, placed on the upper corners of the screen. Locations randomized for each trial, up to three consecutive coincidences on the same corner for any stimulus.
- Test 6 presented the green triangle vs the red square, recombination of the S+ shape with the S- color, and vice versa. Each recombined compound in each upper corner of the screen, locations randomized for each trial, up to three consecutive coincidences on the same corner for any stimulus.

Once the sixth test of phase 1 ended, phase 2 began, which reverted the contingency of acquisition in phase 1. The beep was already contingent on clicking either the square or the green circle, and the dissonant sound buzzed upon clicking either the red circle or the triangle. All other conditions of phase 2 were identical to phase 1.

Figure 3

Distribution of the Presentation Areas and Components



Note. The figure shows an example of the presentation areas and the compounds' components unveiled upon mouse hovering. Proportions were maintained across different screen sizes.

In both phases, test 1 resembled Reynolds' (1961) extinction tests by presenting all four components separated and simultaneously. Phases 2-5 resembled the extinction tests of Perez, Endemann et al. (2015), which aimed to demonstrate control by components that test 1 would not succeed to identify. Test 6 resembled Test 6 of the same study, in which the shape and color components from S+ and S- were recombined to compare responses to those of test 1 (Perez, Endeman, et al., 2015; See also Farthing and Hearst, 1970).

Table 1

Components and Contingencies Programmed in Experiment 1

	Phase	Training		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Consequence		S+	S-	None	None	None	None	None	None
Stimuli	1	red, triangle	green, square	red, green, triangle, square	triangle, square	triangle, green	red, square	red, green	green triangle, red square
Consequence		S+	S-	None	None	None	None	None	None
Stimuli	2	green, square	red, triangle	red, green, triangle, square	triangle, square	triangle, green	red, square	red, green	green triangle, red square

Note. From left to right are presented the succeeding training and extinction tests with the respective components. The upper portion shows phase 1 and the lower portion shows phase 2.

Visual Contact Assessment

Dark layers were superimposed to all components during the training sessions. When the mouse-pointer hovered over the dark areas, the layers withdrew to allow the participants to see the components placed *behind* them. The dark layer resumed covering the component as soon as the mouse pointer abandoned the stimulus area. Each observation duration measure resulted from subtracting the beginning time to the final time. The possible peripheral vision effect reported by Perez, Endeman, et al. (2015) could not take place in this procedure because the components could only be seen one at a time, allowing us to ensure which components were being observed. Both frequency and duration of observation could be emulated by just the mouse pointer movements. Covering the components with layers entailed a topographically different but functionally similar response to that of observation, just as in Wyckoff's (1952) method to measure the pigeon's observing responses.

Results and discussion

Participants in Perez, Endemann et al. (2015) observed each component for up to 10 seconds. Participants in Experiment 1 of the present study took longer, up to 50 seconds—LH to red, in phase 1 (Figure 4a). This difference might be because Perez et al. kept all components always visible during each trial, whereas the present study only allowed participants to see one component at a time when the mouse pointer hovered over it. This fact, in part, confirms the peripheral vision hypothesis put forward by Perez et al., that the formal aspects of the components could be seen indirectly by the participants, facilitating the discrimination of the components with higher saliency. Furthermore, it proves that the peripheral vision effect may facilitate task learning by requiring less observation time for participants to acquire discrimination.

Three participants—LH, CG, and YC—observed all components above a 10-second threshold, the others took below this time. LH and CG produced significantly more responses during phase 1 acquisition than the other participants. Additionally, LH and CG observed each component longer than the other participants in phase 2. In view of the long durations and high response rates to all components exhibited by LH and CG, they will be characterized in the present experiment as 'explorers', whereas YC, VP, and SP, will be characterized as 'fast learners' (Table 2). It's worth noting that these two learner types emerged naturally in the results, not as a product of a methodological variation of observation as independent variable.

Table 2.

Characterization of the participants, according to their exploratory pattern.

Participant	Learner type
LH	Explorer
CG	Explorer
SP	Fast learner
VP	Fast learner
YC	Fast learner

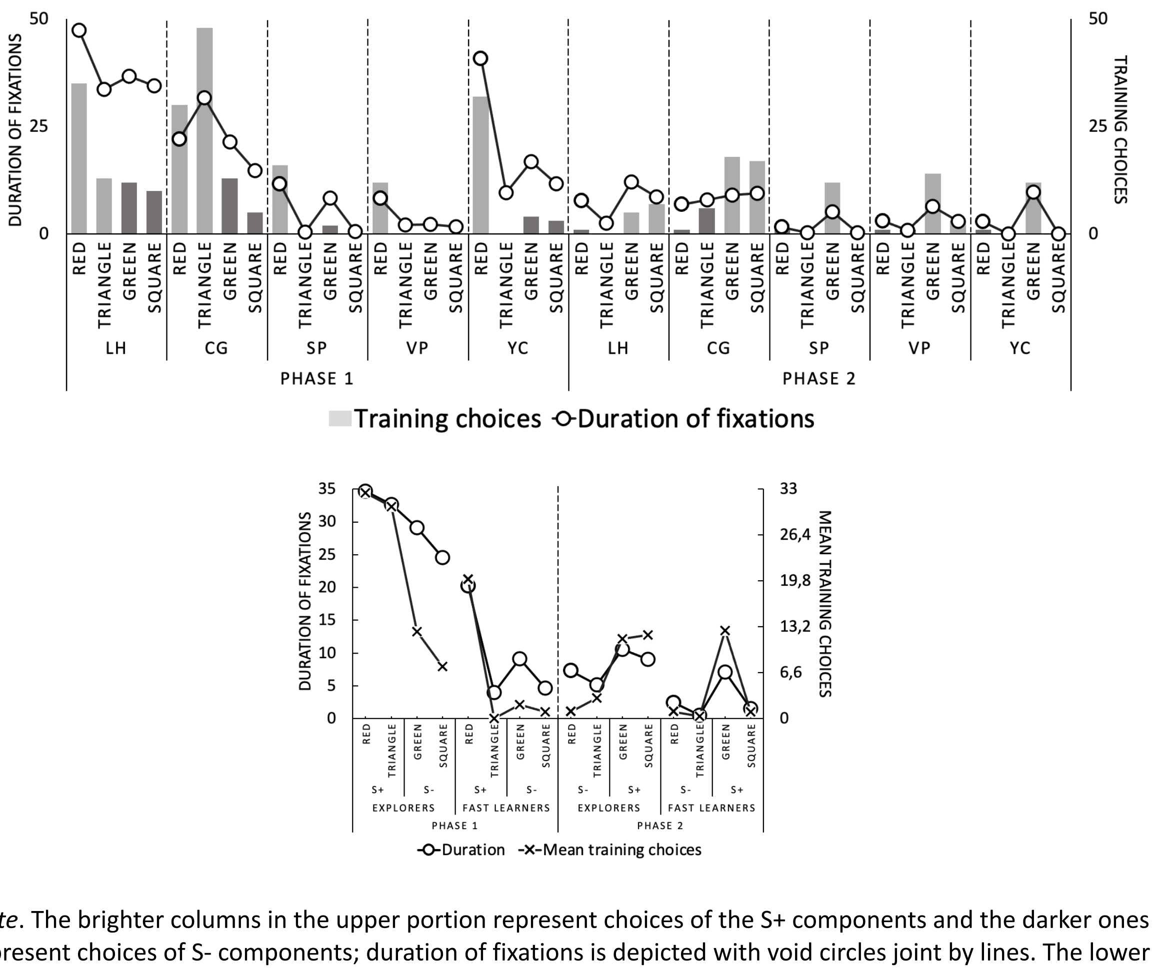
Note. The left column shows each one of the participants of Experiment 1, the right column shows the respective characterization based on observation durations. Explorers observed each component above 10 seconds on average, whereas Fast Learners did so under 10 seconds each. The same characterization applies for phase 2.

During acquisition and reversal, explorers observed S+ components longer than S- ones—except LH with the triangle in phase 1. In contrast, fast learners observed almost exclusively colors, which turned into horizontal saccades in the lower halves of the presentation areas—like Perez, Endeman, et al. (2015) participants—recording fewer clicks than any of the explorers (Figure 4a). The most-observed components were generally those that gained the most responses during training.

Averaging the duration of fixations and responses to each component during training, and grouped by learner type, explorers looked longer and chose both S+ components more often than S- components in training of both phases (Figure 4b). Fast learners, on the other hand, observed and chose colors—including color S- —more than shapes.

Figure 4

A Comparison between Duration of Fixations and Choices during Discrimination Training



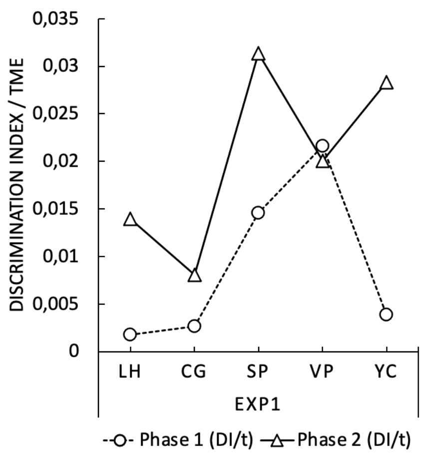
Note. The brighter columns in the upper portion represent choices of the S+ components and the darker ones represent choices of S- components; duration of fixations is depicted with void circles joint by lines. The lower portion shows the same comparison, discriminated per learner type. Explorers correspond to LH and CG, and Fast learners are SP, VP and YC.

Discrimination index—DI—was calculated for each participant in each phase, which consists of dividing the number of successes by the sum of success and failure. In addition, because observation time is to be compared to controlling relations formed, each DI was divided by the time that each participant took to reach the steady state. This ID/t operation generates a performance index—hereafter 'PI'—that relates each participant's number of errors and successes to the time taken up to reach the stability criterion. Because time plays the denominator in the operation, longer time lapses derive in lower PI scores. Thus, the higher the PI, the better the performance in training.

In all cases—except for VP—the PI was higher in phase 2 than in phase 1, and in all cases it was higher for fast learners than for explorers, when compared by phase (Figure 5).

Figure 5

Performance during Discrimination Training per Participant



Note. The performance index—PI —was obtained upon dividing the discrimination index by the time taken to reach the steady-state criterion of 12-consecutive beeps.

LH and CG—explorers—controlling relations exhibited during testing were predicted by the time looking at each component during acquisition, except LH in tests 2 and 3 of phase 1 (Figure 6a and 6b). In both phases, they clicked almost exclusively on the S+ components, demonstrating that the explorers were able to discriminate between the components that correlated with the consequence and those that did not. Explorers maintained a more observational-exploratory pattern that, while excruciating and apparently poorer in performance, was reflected on higher stimulus control scoring. Both the stronger and the weaker S+ components displayed control, just as reported by Perez, Endeman, et al. (2015). Just that in this case, both S+ components displayed control from test 1 in both phases (unlike Perez et al., 2015).

As to fast learners, observational responses predicted choices of SP in phase 2, roughly half of the tests of phase 1 (Figure 6c). SP seemingly reflects control other than shaped by the contingency, but rather easily predicted by the observing responses, especially from phase 2. Nonetheless, SP responded identically in all tests of both phases except test 1, suggesting another dimension of stimulus control in play, and that might be previously socially shaped green over red, conventional stimulus control. VP's choices were only predicted by observational behavior in test 1 of phase 1, else responding as a matter of chance (Figure 6d). YC's observational behavior could not predict choices during testing in Test 2 of both phases—which compared shapes—test 3 of phase 1, and test 4 of phase 2 (Figure 6e). Note that clicking consistently the triangle in test 2 of phase 2 while not having observed it again during training of phase 2 has three important implications: a) a failure to reverse leads to a continuation of control established during phase 1; b) the need of fixating and clicking on components during training in order for those components to attain control; c) the stimuli were not discriminated as compounds—control was not attained by compounds, but by components. Had the compounds played the discriminative function from the beginning, the square would have attained control in test 2 due to reversion of the contingency. On the contrary, participants from Perez, Endeman, et al. (2015) who did not observe shapes in phase 2 succeeded to reverse during testing. This fact highlights the importance of indirect peripheral observation, which was not featured in this experiment but was in Perez, Endeman, et al. (2015).

Fast learners explored just enough to fall under control by the stronger S+—customarily the S+ color. They learned fast, but seemingly addressed the components as four individual stimuli rather than as two compounds, as from responses during testing. For instance, SP chose red above the others in test 1 of phase 1 but chose only green when pitted against red and did exactly so in phase 2. VP made no mistakes during phase 1 but distributed their responses randomly among all the stimuli during all tests except test 1 of phase 1. YC overlooked shapes and therefore in test 2 in both phases showed low or no level of control by the respective shape reinforced.

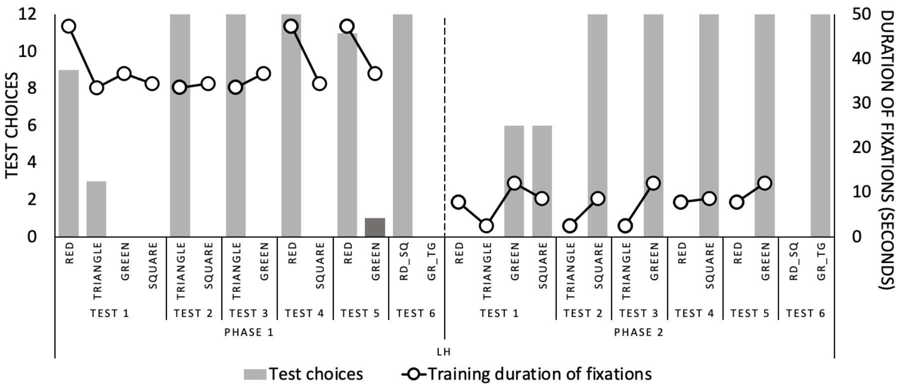
There's a chance, though, that even for fast learners, all tests did display a controlling relation, but control might not always be attained by the S+ component, but by the S- component, via rejection. Actually, both types of control might be working in a single test, either rejection or selection, chiefly by explorers. In the present study, only one possible case of control by rejection was recorded, SP in comparison test 2 of phase 1, where he consistently clicked on the triangle without having observed it. However, the hypothesis of rejection towards the square is not fully supported, as it received very little observation. The preference for the triangle may be due to a learning experience prior to the experiment.

Control by the S+ component persists in fast learners when its correlation with consequence is reversed and goes unnoticed. SP and YC consistently chose the S- triangle, and VP chose it half of the time, in comparison test 2 of phase 2, despite not having observed it during training. One reason for this systematic pattern in the fast learners is that, having not observed the S- triangle during phase 2 training, they failed to reverse the contingency associated with the triangle and the square, except SP, who did not observe the triangle in any phase. This shows that the fast learners discriminated the components individually, rather than as composites, which proves the failure in reversal and persistence by choosing unobserved S- components that in the past were S+ observed.

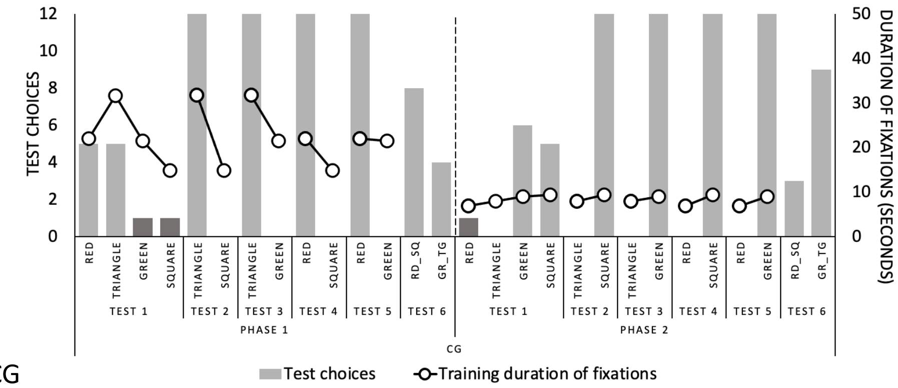
Figure 6f shows that, grouped by phase and by learner type, explorers fixated for longer and discriminated correctly, whereas fast learners focused on colors and failed to discriminate the relationship between components and consequence.

Figure 6

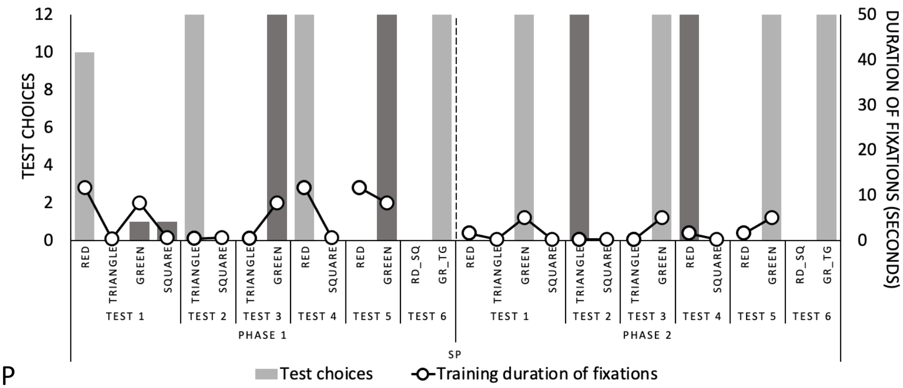
Comparison of Test Choices and Duration of Fixations throughout Discrimination Trainings



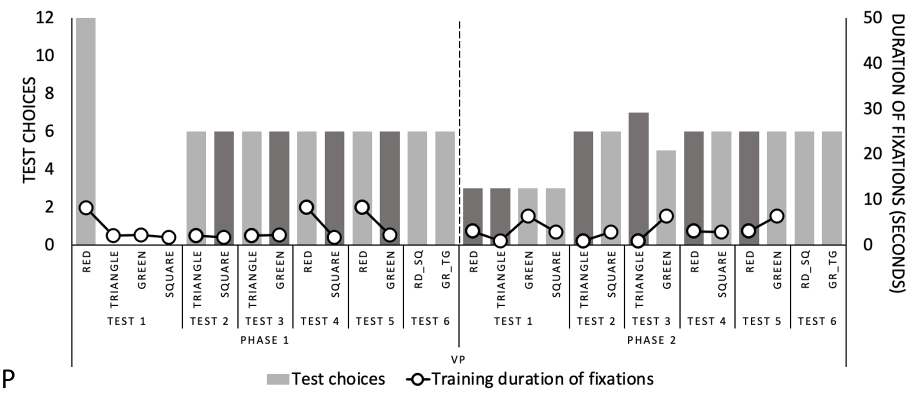
a. LH



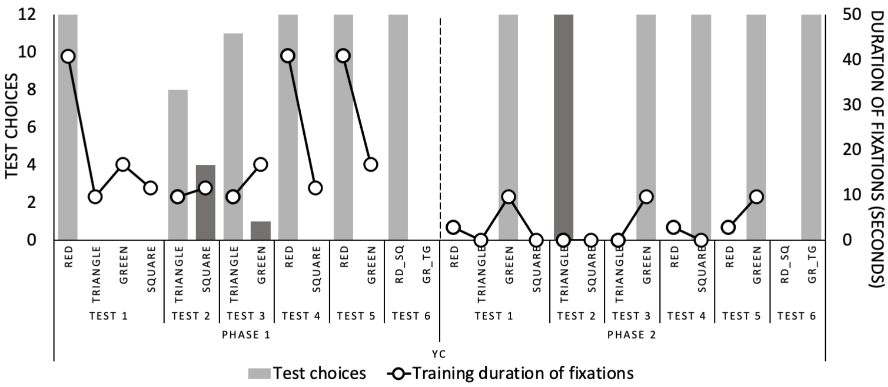
b. CG



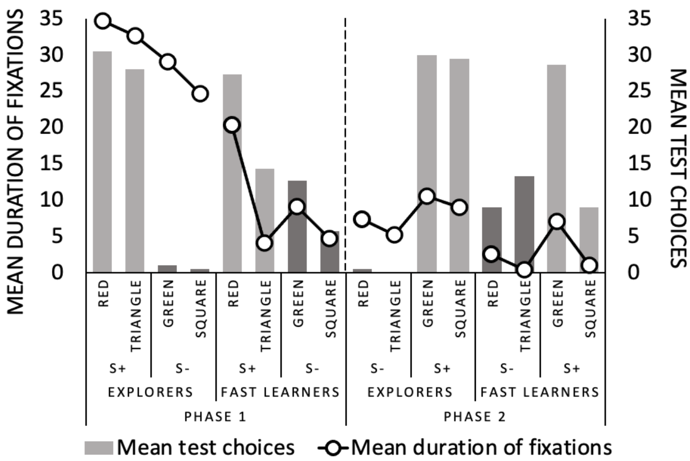
c. SP



d. VP



e. YC



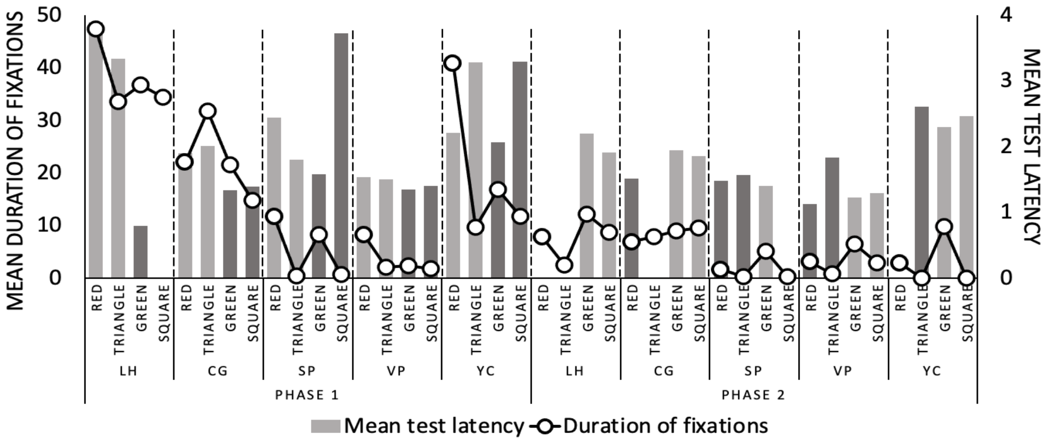
f.

Note. Parts a-e compare the test choices and the duration of fixations throughout discrimination training per participant. Part f shows the same comparison, grouped by learner type.

Figure 7 shows that, in all cases, explorers recorded longer average latencies when choosing S+ components than S- ones, whereas fast learners tended to do the opposite—except for VP and YC in phase 1. Although it could be inferred from the above that larger training observations correlate with higher latencies toward S+ components in testing, it is premature to conclude it, as the differences in some cases are subtle.

Figure 7

Comparison of the Total Duration of Fixations and the Mean Test Latency



Note. Brighter lines represent latencies of S+ components, and dark ones represent latencies of S- ones. Duration of fixations is represented by lines. The comparison is discriminated by phase and by participant.

A comparison one-by-one of the conclusions reached by Perez et al. and this experiment is disclosed below:

a) Observing responses predicted reliably the testing choices, as in Perez et al., but only for explorers—LH and CG—. Fast learners, in turn, chose inconsistently—YC—based on extraneous contingencies—SP—or simply as a matter of chance—VP. This pattern persisted until phase 2, where explorers, again, took longer to acquire the discrimination but displayed control accordingly, unlike fast learners.

b) In Perez, Endeman, et al. (2015), participants fixated on color or shape idiosyncratically. In the present study, this pattern was reflected by explorers only, who switched their visual attention from shapes to colors, from phase to phase—LH turned from fixating mainly on colors in phase 1 to fixating mainly on both S+ in phase 2, and CG fixated more on the S+ shape in phase 1 and on both S+ equally in phase 2. Fast learners, in turn, fixated more and for longer on colors than shapes, always. The above implies that visual exploration fosters predictability of control by the discriminative function of the compound, while lack of it enhances control by colors—in some cases, regardless of the contingency, as for SP.

c) Perez, Endeman, et al. (2015) reported control by both S+ components during testing, but only by the stronger S+ in test 1. In the present study, only explorers chose systematically both S+ components, but this control was reflected even in tests 1, unlike Perez et al. The conclusion about even control by both S+ components apply only awkwardly for those who fixated on components the less—fast learners, who chose the less fixated S+ only when fixated and clicked during training, like YC in test 2 of phase 2, who failed to reverse due to lack of visual contact and clicks.

Just as in Perez, Endeman, et al. (2015), one participant seemingly displayed rejection control—SP in the comparative test 2 of phase 2. However, because both components compared in the test—triangle vs. square—were systematically dismissed in both phases, both had virtually the same chance to be rejected, and so control might have been established prior to the experiment.

Altogether, Explorers of the present study showed the same discrimination, but not the same observation patterns as those of Perez, Endeman, et al. (2015); fast learners showed the same observation patterns, but not the same discrimination.

Since conclusions from this study are restricted to the method employed to assess visual contact, the above supports the conclusion that only through enough visual exploration participants from this study approached the conclusions about observation to those of Perez, Endeman, et al. (2015). The single results from this study comparable to methods that allow indirect observation is through patterns displayed by explorers, who better resemble Perez et al.'s results. Although some relations could be attributed to the component's formal aspects regardless of the contingency, there stands a chance that the same relations were established throughout previous reinforcement history—as for SP's preference for green and for triangle.

Suggestions for future research regarding the results is disclosed in the general discussion of this study.

Experiment 2

Experiment 2 was primarily intended to test the hypothesis of whether the components used in Experiment 1 controlled responses via selection or rejection, by means of a method proposed by Perez, Endeman, et al. (2015), in which the components used during training are individually compared against a novel stimulus (also see Carrigan & Sidman, 1992). Consistent responses toward the training component would indicate control by that component, while consistent responses toward the novel stimulus imply rejection toward the component of that comparison. To assess this, experiment 2 consisted of a replication of experiment 1, except that it added four tests in each phase, trials 6, 7, 8, and 9. Test 6 in each phase compared the square versus the novel stimulus, test 7 did the same for the triangle, test 8 for red, and test 9 for green. Tests 1 through 5 were identical in both experiments, and test 10 was identical to test 6 in experiment 1.

Method

Participants

Four adult participants BC, TM, AA, and YJ, volunteered to participate in the experiment.

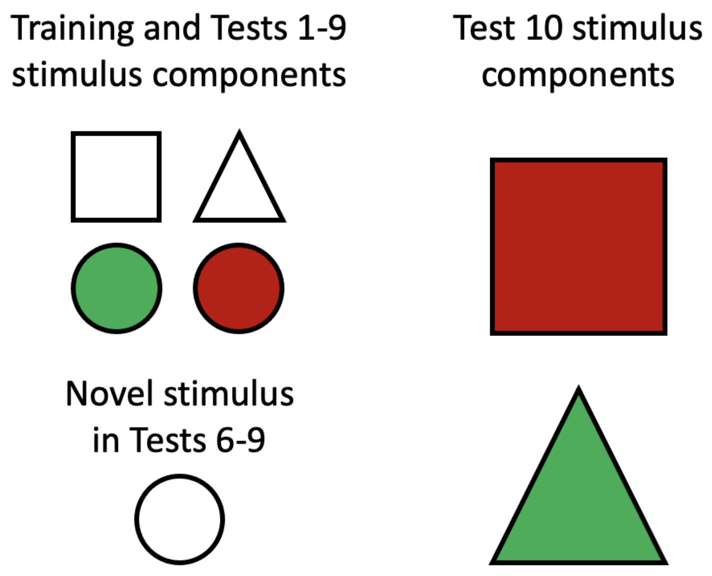
Stimuli

The stimuli during training and tests 1-9 were a square, a triangle, a red circle, a green circle, and a blank circle, all sized .52 cm*.52 cm. Stimuli during test 10 were a green-filled triangle and a red-filled square, sized 1.05 cm*1.05 cm each (Figure 8). All components and presentation-areas proportions were relative to the participant's computer screen dimensions. Original proportions by Perez, Endemann, et. al. (2015) were maintained as follows:

- Component size: .52 cm×.52 cm (1,05 cm×1,05 cm for test 10).
- Distance between components displayed in the same presentation-area: 7.95 cm.
- Distance center-to-center for the presentation-areas: 21,55 cm.
- Maximum size of each presentation-area: 9,92 cm×9,92 cm.

Figure 8

Components and Stimuli of Experiment 2



Note. On the left, the components and novel stimuli employed during training sessions and tests 1-9. On the right, stimuli employed during the tests 10—recombination of the original components.

Procedure

Phase 1 started with a training session consisting of a Fixed-ratio-1 (FR1) simultaneous discrimination task that required the participants to produce as many beeps as they could. The beep was contingent on clicking either the white triangle or the red circle, and added one point to the beep score counter—henceforward referred to as S+—both enclosed into the outlined square of the presentation area. A dissonant 'buzz' sound was contingent on clicking either a square or a green circle in another presentation-area, and reset the beep score counter—henceforward referred to as S-.

Both shapes appeared always on the upper-middle of the presentation-area, whereas the colors did so on the lower-middles. The presentation-areas were randomly located in either of the two left-right upper corners of the screen on each trial, just as in Experiment 1. Between trials meddled a 0.5-second intertrial interval, turning the screen blank before the next trial arrived. Every trial set the mouse-pointer back on the center of the screen to prevent clicking based on pointer-stimulus proximity. The dissonant buzz restarted the beep counter. The steady state criterium was set twelve (12) consecutive beeps, which signaled the discrimination accomplishment, ended the training session, and started the stimulus control tests. During testing, the stimuli were individually presented and occupied the center of each presentation-area. Although responses during tests were not reinforced, the participants were asked to keep on producing the beeps.

Each test consisted of 12 trials in which the responding rate and response latency to each separate stimulus tested in extinction were recorded to assess individual stimulus control. The stimuli were distributed across the tests as follows:

- Test 1 presented all four stimuli separately in a single presentation-area, placed in every corner of the screen each. All locations randomized for each trial, up to three consecutive coincidences on the same corner for any stimulus.
- Tests 2-5 presented each S+ component against each S- component in a presentation-area each, placed on the upper corners of the screen. Locations randomized for each trial, up to three consecutive coincidences on the same corner for any stimulus.
- Tests 6-9 presented each S+ and S- component against the novel stimulus, in a presentation-area each, placed on the upper corners of the screen. Locations were randomized for each trial, up to three consecutive coincidences on the same corner for any stimulus.
- Test 10 presented the green triangle vs the red square, recombination of the S+ shape with the S- color, and vice versa. Each recombined compound in each upper corner of the screen, locations randomized for each trial, up to three consecutive coincidences on the same corner for any stimulus.

Once the tenth test of phase 1 ended, phase 2 began, with the training session reverted to the contingency running in phase 1. The beep was already contingent on clicking either the square or the green circle, and the dissonant sound buzzed upon clicking either the red circle or the triangle. All other conditions of phase 2 were identical to phase 1.

Table 3

Components and contingencies programmed in Experiment 2

	Phase	Training		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
Consequence		S+	S-	None	None	None	None	None	None	None	None	None	None
Stimuli	1	red, triangle	green, square	red, green, triangle, square	triangle, square	triangle, green	red, square	red, green	square, novel	triangle, novel	red, novel	green novel	green triangle, red square
Consequence		S+	S-	None	None	None	None	None	None	None	None	None	None
Stimuli	2	green, square	red, triangle	red, green, triangle, square	triangle, square	triangle, green	red, square	red, green	square, novel	triangle, novel	red, novel	green novel	green triangle, red square

Note. From left to right are presented the succeeding training and extinction tests with the respective components. The upper portion shows phase 1 and the lower portion shows phase 2.

Visual Contact Assessment

Gray layers were superimposed to all components during the training sessions. When the mouse-pointer hovered over the dark layers, those withdrew to allow the participants to see the components placed *behind* them. The dark layer continued covering the component behind as soon as the mouse pointer abandoned the stimulus area.

Results and discussion

BC maintained a constant PI throughout acquisition and reversal, AA improved in reversal, TM decreased in reversal, and YJ significantly improved in reversal (Figure 9a). Unlike experiment 1, the PI in Experiment 2 showed no participants consistently outperforming or underperforming each other during the acquisition of the discrimination. Only AA observed every component above 10 seconds in phase 1 acquisition. YJ also recorded long durations but not equally distributed among components and observed the triangle only 6 seconds (Figure 9b). Since all other participants recorded durations below 10 seconds, only AA will be characterized as 'explorer' in phase 1 (Table 4).

Table 4.

Characterization of the participants, according to their exploratory pattern.

Phase	Participant	Learner type
1	AA	Explorer
	BC	Fast learner
	TM	Fast learner
	YJ	Fast learner

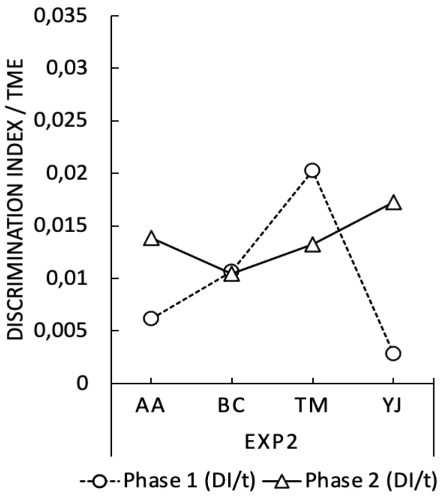
2	AA BC TM YJ	Fast learner Explorer Explorer Explorer

Note. The left column shows each one of the participants of Experiment 1, right column shows the respective characterization based on observation durations. Explorers observed each component above 10 seconds on average, whereas Fast Learners did so under 10 seconds each.

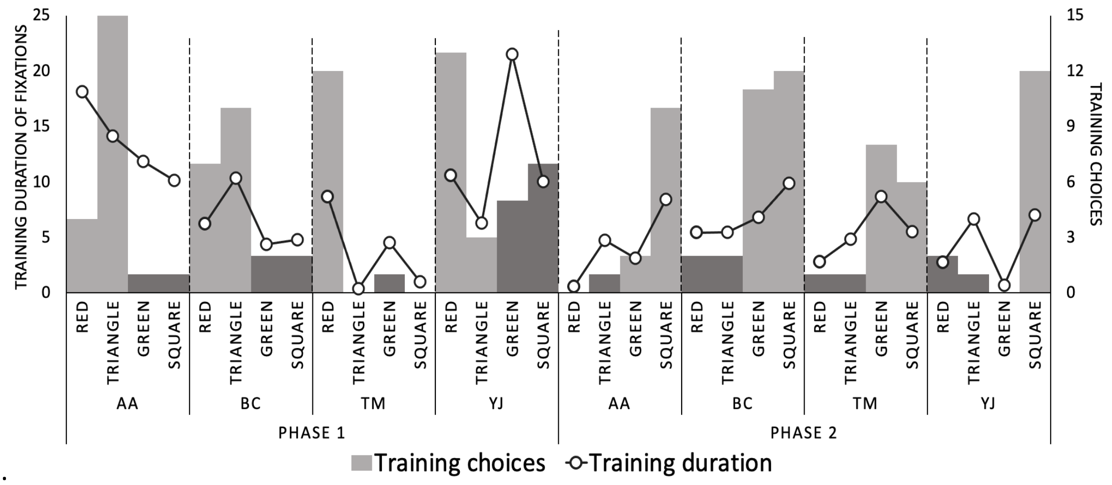
In phase 2, only BC and TM observed proportionally and chose all components during reversal, so they were characterized as Explorers in phase 2. Unlike Experiment 1, explorers recorded the lowest PI during training. YJ exhibited the lowest PI in phase 1, but she cannot be classified as explorer due to a poor discrimination in testing. It follows from the above that PI during training does not necessarily predict the observational pattern those participants hold. Another difference with Experiment 1 is that in Experiment 1, the explorers and fast learners in both phases were the same, while in this experiment the explorers and fast learners in phases 1 and 2 are different, because their observation patterns changed from one phase to the other.

Figure 9

Performance and a Comparison of Duration of Fixations and Training Choices



a.



b.

Note. Part a show the PI of each participant in each phase, which divides the discrimination index by the time it took them to reach the steady state. Part b contrasts the duration of fixations and responses during training; brighter columns represent choices to S+ components during training, whereas darker columns represent S- ones.

In phase 1, the explorer—AA—consistently chose the S+ components when those were presented in extinction along with the S- components in tests 1 through 5 of both the acquisition and reversal. Moreover, AA always chose the S+ components when compared against the novel stimulus, and always selected the novel when it was compared against the S- components. Now, in test 9 of phase 2, AA chose the novel stimulus more than the S+ color. This may be because AA barely observed the colors during reversal and did not click on red, which may have led to less forceful control by the S+ color of the reversal. It follows from the above that, as in Experiment 1, only those who observed each component for over 10 seconds during acquisition correctly discriminated both S+ components, but this control weakens when they lower their visual scanning or do not click all components in reversion of phase 2. As from tests 6 through 9 of phase 1 for AA, she fell under control of the S+ components via selection, but also fell under control by the S- components via rejection (Figure 10a). In tests 6-9 of phase 2, AA correctly rejected both S- components but only selected consistently the S+ shape, probably due to lack of visual contact during reversion. AA choosing the novel stimulus over the green on test 9 of phase 2 suggests that tests 3 and 5 of phase 2 show more of a rejection relationship toward red and the triangle, rather than selection of green. Test 10 in both phases confirmed choices of AA in tests 1, where she tended to prefer shapes. While AA's observation pattern in phase 2 does not resemble that of the standard explorer that she herself had shown in phase 1, she recorded very similar control to the explorers, except for test 9. AA is an exceptional case where a fast learner records very similar control to the explorers, but it possibly relates to her long observations during phase 1 that allowed her to revert correctly.

BC recorded fixation durations below 10 seconds in acquisition, which was reflected in weak control of both S+ components in test 1. Such control was further diluted in subsequent phase 1 tests, where he responded randomly. On reversal, BC recorded slightly longer and proportional durations than at acquisition, especially toward the S+ components, which were sufficient for him to correctly discriminate all S+ and S- components, except that he showed no rejection toward the S-shape in test 7. From the above it follows that, in tests 1, 2, and 3 of phase 2, BC was selecting the S+ components, but was not rejecting the triangle, only red. BC chose randomly in test 10 of both phases, so that no privileged control by any component can be drawn.

TM fixated mainly on colors during acquisition, leading to falling under control only by the S+ color, as can be seen in the novel stimulus tests, where TM selected red and green—the only components that he observed during acquisition—but rejected the triangle and square—which he scarcely observed (Figure 10c). TM confirms that short observation during training leads to falling under control by the most observed components only, even if these did not correlate with the delivery of the beeps. Now in reversion, TM switched to explorer by observing slightly more all components, which led to a stable control by both S+ components. Test 10 of both phases confirms that TM fell mainly under the control of the most observed components, the colors.

YJ fixated on all components in phase 1, mainly the colors. Although choosing only red in test 1, she favored green against the triangle and chose it sometimes against red, showing that, like fast learners in Experiment 1, her responses are highly dependent on color observation rather than contingency. YJ seems to have rejected square in phase 1, probably due to the number of failed clicks toward it during training. YJ reversed her pattern of observation from colors to shapes in reversal, which may explain why she preferred the square in test 1. However, like the phase 1 tests, YJ demonstrated control based almost exclusively on observation rather than contingency, as she selected in all cases only those stimuli observed during training, almost regardless of their relation to the consequence, and rejected the green—which she did not observe during training.

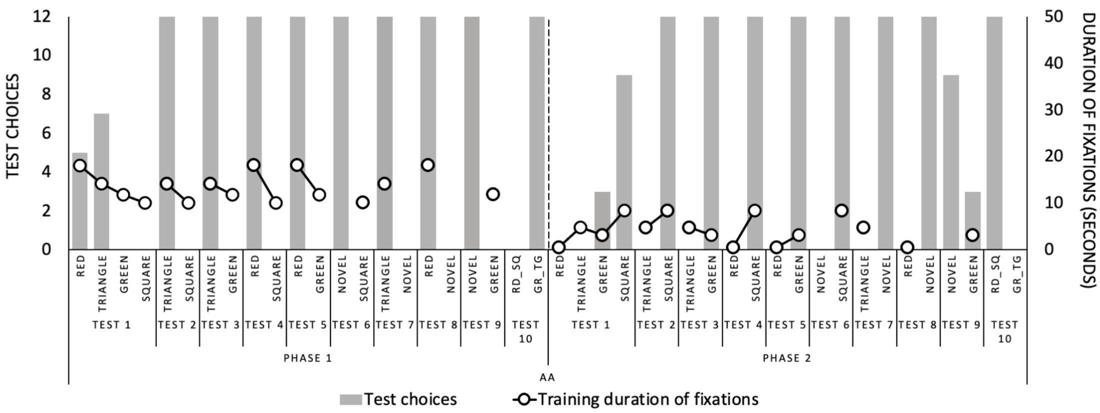
Tests 6-9 show that explorers—AA in phase 1, and BC and TM phase 2 —fell under control by both S+ components via selection—except AA in test 9 of phase 2—and fell under control by both S- components via rejection control—except BC in test 7 of phase 2.

Fast learners, in contrast, grouped, showed no pattern in tests 6-9, choosing randomly—BC, phase 1—, selecting the highly observed colors and rejecting the less observed shapes—TM, phase 1—, or selecting either only the strong S+ while rejecting the rest, or only the former highly fixated S+ while rejecting the rest—YJ, phase 1 and phase 2, respectively.

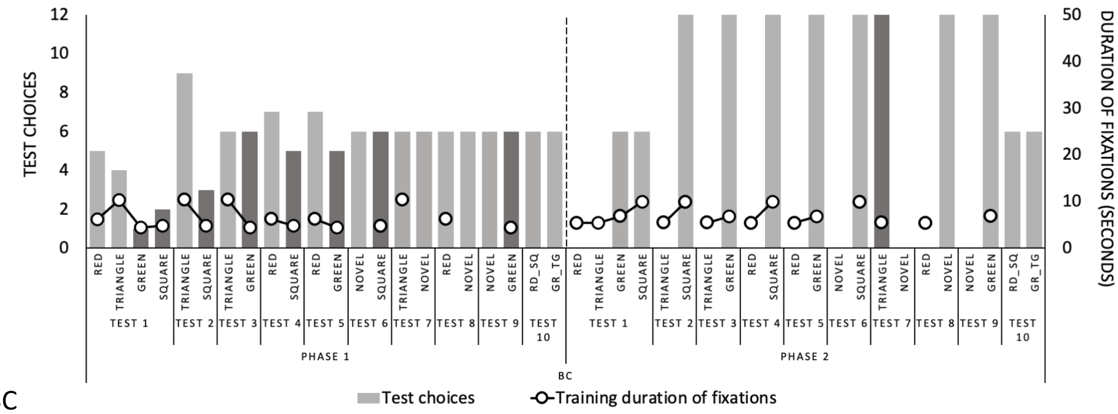
Although perfect discrimination is mostly exhibited by explorers, one fast learner discriminated perfectly in phase 2, whereas an explorer did not reject one S- component in the same phase. Because AA played as explorer in phase 1 and BC played as fast learner in phase 1, it is likely that some of the former control remained in phase 2, which explains the unexpected relation between learner type and discrimination.

Figure 10

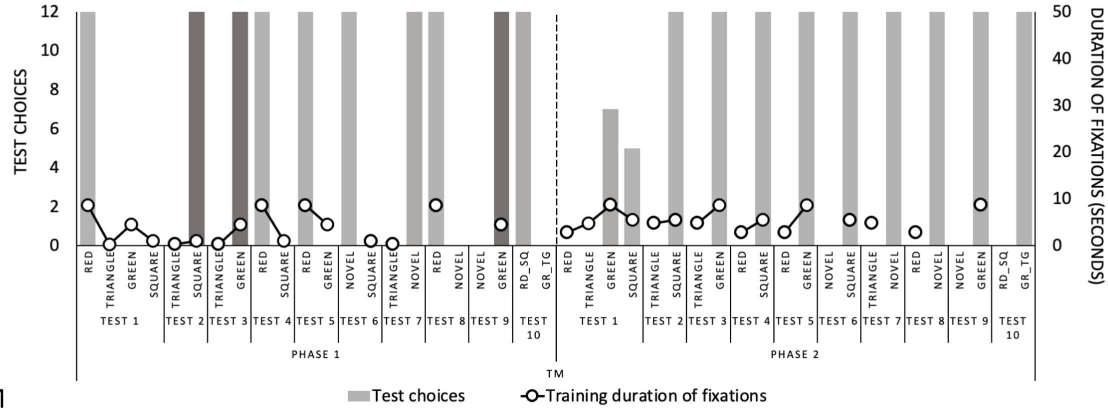
Comparison of Test Choices and Duration of Fixations throughout Discrimination Training



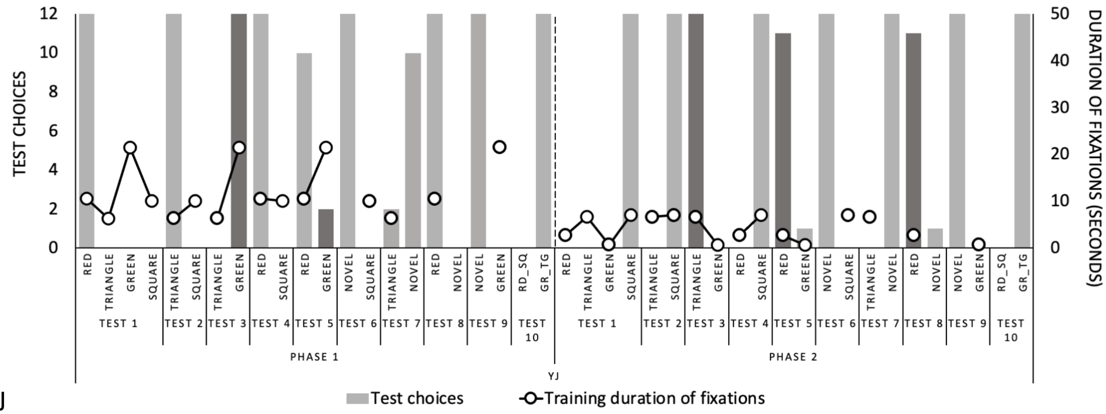
a. AA



b. BC



c. TM



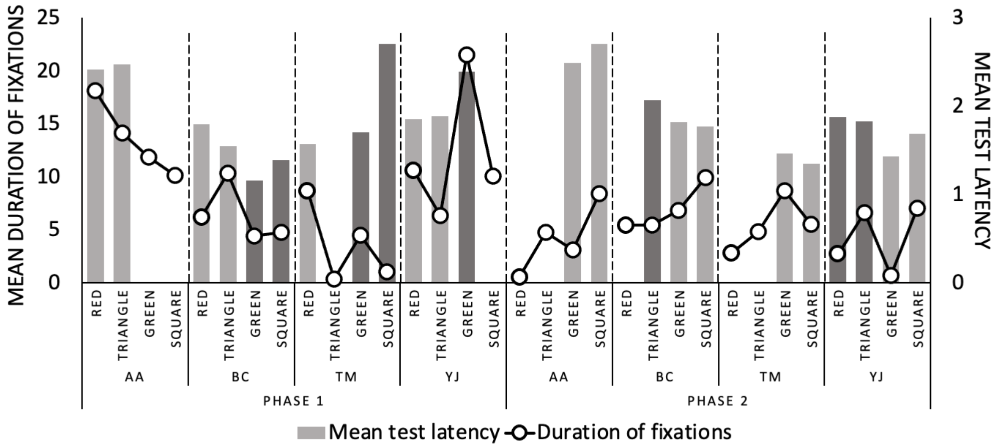
d. YJ

Note. The comparison is discriminated by participant. Brighter columns represent components correlated with the beeps during training, and dark ones correlated with the dissonant sound.

In terms of the analysis of component control over latency across tests, the explorer—AA registered longer latencies than fast learners in both phases, except in comparison with TM latency to square in phase 1 (Figure 11). Figure 11 shows that only for the explorer longer latencies correlated with perfect discrimination and with longer fixation durations in phase 1. In all cases where S- components were selected, latency was longer than with S+ components, except for BC in phase 1. However, these differences are subtle and do not correlate with observational patterns, so it cannot be concluded that the duration of fixations in training has any effect on latency in testing.

Figure 11

Comparison of Duration of Fixations and Mean Test Latency



Note. Brighter columns represent latencies of S+, and darker ones represent latencies of S-. Points and lines represent duration of fixations.

Experiment 2 confirms the findings from Experiment 1, namely, that the duration of fixations during acquisition and reversal directly influences the response rate to each component during extinction tests. The longer the distributed observation of all components during training, the better the discrimination, which results in greater control over both S+ components via selection, while increasing control by both S- components via rejection. As the observation time decreases—generally, under 10 seconds for phase 1 and slightly less in phase 2—the discrimination also decreases, resulting initially in exclusive control by the strongest S+—the longest fixated—weak or no control by both S+ components in tests 2-5, and no control by selection or rejection in tests 6-9, as well as incongruence between choices of tests 1 and 10 in both phases. Latencies were slightly longer towards S- components in both phases, but the data is not conclusive.

Experiment 3

Experiment 3 set out three goals through three variations on Experiment 2: (a) to randomize the location within the presentation-areas that placed statically colors at the bottom and shapes at the top, to stimulate exploratory patterns in participants; (b) decrease the number of trials per test by half, to look over whether the same control patterns observed in Experiments 1 and 2 can be derived with less trials and, by making it shorter, to make it less exhausting for participants who complained about the length of the application; and (c) vary the colors used in each compound stimuli to determine whether there is a type of foreign control by the colors green and red that was not being controlled in Experiments 1 and 2. Yellow and blue took over red and green, respectively. As in Experiment 2, testing with the novel stimulus to assess selection or rejection control was included. All other conditions were identical to Experiment 2.

Method

Participants

Three adult participants, FD, JF, and XA, volunteered to participate in the experiment.

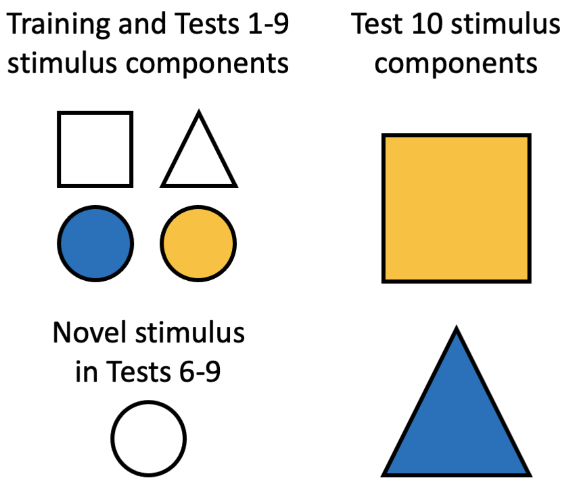
Stimuli

The stimuli during training and tests 1-9 were a square, a triangle, a yellow circle, a blue circle, and a blank circle, all sized .52 cm*.52 cm. Stimuli during test 10 were a blue-filled triangle and a yellow-filled square, sized 1.05 cm*1.05 cm (Figure 12). All components and presentation-areas proportions were relative to the participant’s computer screen dimensions. Original proportions by Perez, Endemann, et. al. (2015) was maintained as follows:

- Component size: .52 cm×.52 cm (1,05 cm×1,05 cm for test 10).
- Distance between components displayed in the same presentation-area: 7.95 cm.
- Distance center-to-center for the presentation-areas: 21,55 cm.
- Maximum size of each presentation-area: 9,92 cm×9,92 cm.

Figure 12

Components and Stimuli of Experiment 3



Note. On the left, the components and novel stimuli employed during training sessions and tests 1-9. On the right, stimuli employed during the tests 10—recombination of the original components.

Procedure

Phase 1 started with a training session consisting of a Fixed-ratio-1 (FR1) simultaneous discrimination task that required the participants to produce as many beeps as they could. The beep was contingent on clicking either the white triangle or the red circle, and added one point to the beep score counter—henceforward referred to as S+—both enclosed into the outlined square of the resentation area. A dissonant 'buzz' sound was contingent on clicking either a square or a green circle in another presentation-area, and reset the beep score counter—henceforward referred to as S-.

The presentation-areas were randomly located in either of the two left-right upper corners of the screen on each trial, just as in Experiment 1 and 2, and the components within each presentation area were also randomized vertically, so that neither the participants nor the experimenter could know in advance where each shape or color would appear on the screen. Between trials meddled a 0.5-second intertrial interval, turning the screen blank before the next trial arrived. Every trial set the mouse-pointer back on the center of the screen to prevent clicking based on pointer-stimulus proximity. The dissonant buzz restarted the beep counter. The steady state criterium was set twelve (12) consecutive beeps, which signaled the discrimination accomplishment, ended the training session, and started the extinction tests. During testing, the stimuli were individually presented and occupied the center of each presentation-area. Although responses during tests were not reinforced, the participants were asked to keep on producing the beeps.

Each test consisted of 6 trials in which the responding rate and response latency to each separate stimulus tested in extinction were recorded to assess individual stimulus control. The stimuli were distributed across the tests as follows:

- Test 1 presented all four stimuli separately in a single presentation-area, placed in every corner of the screen each. All locations randomized for each trial, up to three consecutive coincidences on the same corner for any stimulus.
- Tests 2-5 presented each S+ component against each S- component in a presentation-area each, placed on the upper corners of the screen. Locations randomized for each trial, up to three consecutive coincidences on the same corner for any stimulus.
- Tests 6-9 presented each S+ and S- component against the novel stimulus, in a presentation-area each, placed on the upper corners of the screen. Locations were randomized for each trial, up to three consecutive coincidences on the same corner for any stimulus.
- Test 10 presented the blue triangle vs the yellow square, recombination of the S+ shape with the S- color, and vice versa. Each recombined compound in each upper corner of the screen, locations randomized for each trial, up to three consecutive coincidences on the same corner for any stimulus.

As the last test of phase 1 ended, reversal of phase 2 began. The beep was now contingent on clicking either the square or the blue circle, and the buzz upon clicking either the yellow circle or the triangle. All other conditions of phase 2 were identical to phase 1.

Table 5

Components and contingencies programmed in Experiment 3

	Phase	Training		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
Consequence		S+	S-	None	None	None	None	None	None	None	None	None	None
Stimuli	1	yellow, triangle	blue, square	yellow, blue, triangle, square	triangle, square	triangle, blue	yellow, square	yellow, blue	square, novel	triangle, novel	yellow, novel	blue, novel	blue triangle, yellow square
Consequence		S+	S-	None	None	None	None	None	None	None	None	None	None
Stimuli	2	blue, square	yellow, triangle	yellow, blue, triangle, square	triangle, square	triangle, blue	yellow, square	yellow, blue	square, novel	triangle, novel	yellow, novel	blue, novel	blue triangle, yellow square

Note. From left to right are presented the succeeding training and extinction tests with the respective components. The upper portion shows phase 1 and the lower portion shows phase 2.

Visual Contact Assessment

Gray layers were superimposed to all components during training. When the mouse-pointer hovered over the hidden areas, the layers withdrew to allow the participants to see the components placed behind them. The dark layer kept on covering the component behind as soon as the mouse pointer abandoned the stimulus area.

Results and discussion

Participants JF and FD performed faster during discrimination reversal in phase 2 than during acquisition in phase 1, while XA performed better in acquisition than in reversal. Participants' PI levels under exposure to colors other than green and red were not different from the levels recorded in experiment 2 but did fall slightly below the PI of participants in phase 2 of experiment 1, especially when comparing fast learners in experiment 1 versus participants in experiment 3 (Figure 13a). The above suggests that discrimination may benefit from colors associated with everyday contingencies, but only in later phases of the experiment. However, it is speculative since PI in Experiment 2 does not confirm it, and the one single difference between experiments 1 and 2 is in the tests with novel. The lowest PI was shown by FD in phase 1, with an overall higher average duration of fixations than the other participants (Figure 13b - left), and a much higher duration per stimulus (Figure 13b - right). Additionally, FD invested more than twice as many responses to achieve steady state during acquisition (Figure 13c), so FD will be characterized as the 'explorer' in phase 1, whereas FD - phase 2, JF - both phases and XA - both phases, will be characterized as 'fast learners' (Table 4).

Table 4.

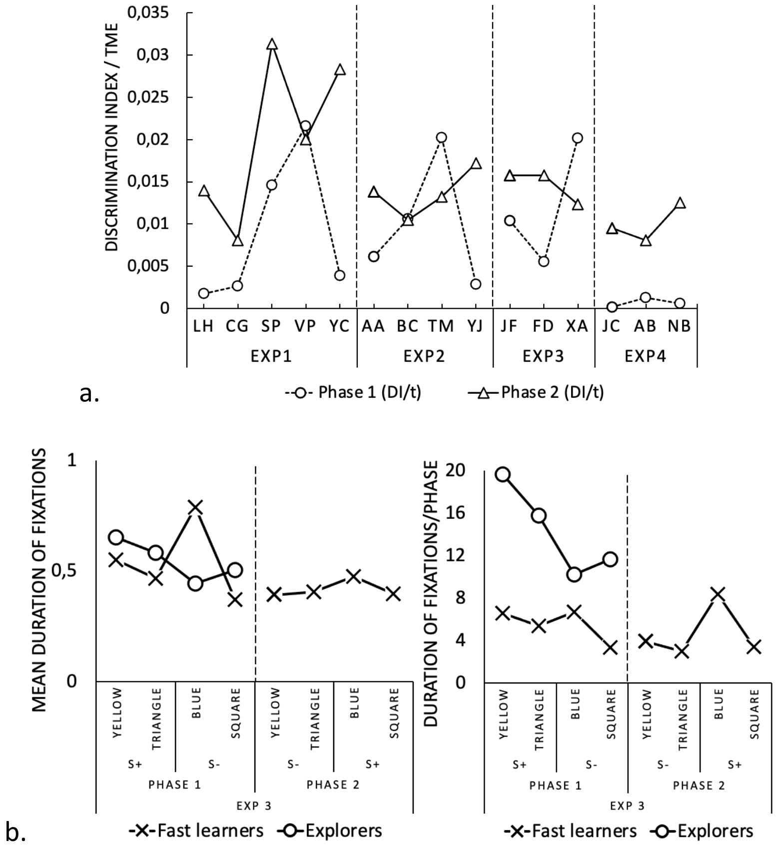
Characterization of the participants, according to their exploratory pattern.

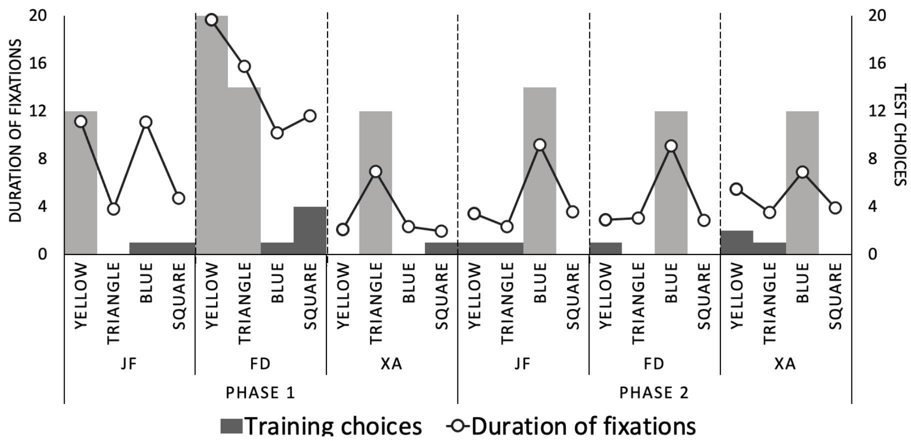
Phase	Participant	Learner type
1	JF	Fast learner
	FD	Explorer
	XA	Fast learner
2	JF	Fast learner
	FD	Fast learner
	XA	Fast learner

Note. The left column shows each one of the participants of Experiment 1, right column shows the respective characterization based on observation durations. Explorers observed each component above 10 seconds on average, whereas Fast Learners did so under 10 seconds each.

Figure 13

Performance, Duration of Fixations and Duration Compared to Training Choices





c.

Note. Part a show the PI of each participant in each phase. Part b relates the time spent observing each component during training, first averaged by response, and then averaged by the number of explorer and fast learner participants. Part c compares the duration of fixations and training choices.

JF gazed primarily on colors, which reflects on his responses to them in testing, almost independently of the correlation between color and consequence—in, say, tests 1, 3, 5, and 9 of phase 1 (Figure 14a). Possibly the lack of enough visual contact with the components caused JF to pick the square over the triangle in test 2 of phase 1, in addition to the fact that JF never chose the triangle during training. Just as in the previous experiments' fast learners, JF's responses were easily predicted by his observational pattern regardless of the contingency, except in test 1 of both phases, where he chose the most observed S+ color. In phase 2, JF fixated much more on blue, but, except for test 1, he chose yellow at every opportunity, even against blue and even in test 10. JF failed to reverse in the 1-on-1 tests, probably due to lack of visual contact in phase 2 training. Tests with the novel stimulus in both phases show that JF rejected both forms and only the color S+ controlled his responses via selection, even in phase 2, where he rejected the new color S+.

FD, in general, fixated for longer on all components during acquisition than during reversal, also more than the other participants in both phases (Figure 14b). FD also observed more both S+ components, leading to a perfect discrimination which reflected in control by both S+ during phase 1 tests—with slight exception in test 7. In test 10 FD favored the component most observed during acquisition and most chosen during tests, the S+ color. However, FD had a similar pattern of observation to JF on reversal, leading to strong control by the S- shape—he failed to reverse shape—and preference toward yellow, despite showing a preference for blue in test 1. Even in test 10 of phase 2, FD revealed control by yellow. Tests with novel stimuli show that only in phase 1 FD selected both S+ components and rejected both S- components. However, like JF, FD rejected the S+ shapes and color in the phase 2 novel stimulus tests, and instead selected the S- color, which forcefully controlled responses in both phases, except in test 10 of phase 2.

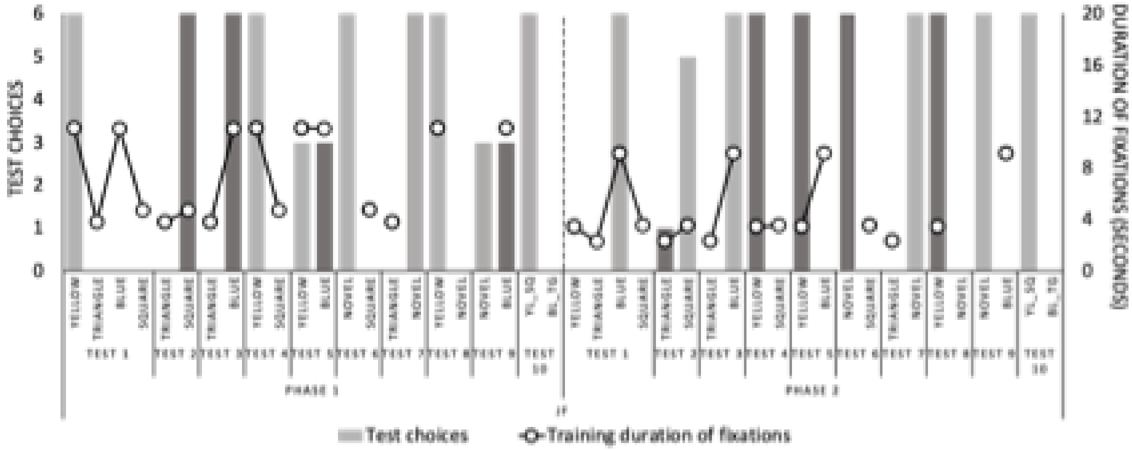
As for XA, she gazed primarily at the triangle in phase 1 and selected it in test 1, but in the absence of the triangle, she always selected only both S- components (Figure 14c). In tests 6-9, XA selected only the components, never the novel stimulus, suggesting that both the triangle and the S- components controlled via selection, not rejection. The triangle, as the most observed component, prevailed in test 10. Already in reversal, mainly colors gained XA's visual attention, especially the S+ color, chosen in all cases except in test 10. No other component consistently gained control in testing. In fact, XA rejected all other components against the novel stimulus. As a fast learner, XA shows that low observation lapses during training correlate with low discrimination, in which only one S+ component controls responses—usually the S+ color—and the other components are no or hesitantly chosen.

The explorer fixated on each component over 10 seconds, and all responses were biased toward both S+ via selection—tests 7 and 8—while both S-components were systematically rejected—tests 6 and 9 (Figure 15a). Fast learners, on the other hand, in general, observed each component below 10 seconds and distributed their responses randomly during phase 1 tests, except in tests 1 and 8, where they chose the S+ color and, to a lesser extent, the S+ shape. In phase 2, fast learners mainly observed the color S+, but they only chose it consistently in phase 1, not in the 1-on-1 comparisons, not even against the S- color—which may have retained control from phase 1—nor against the novel stimulus.

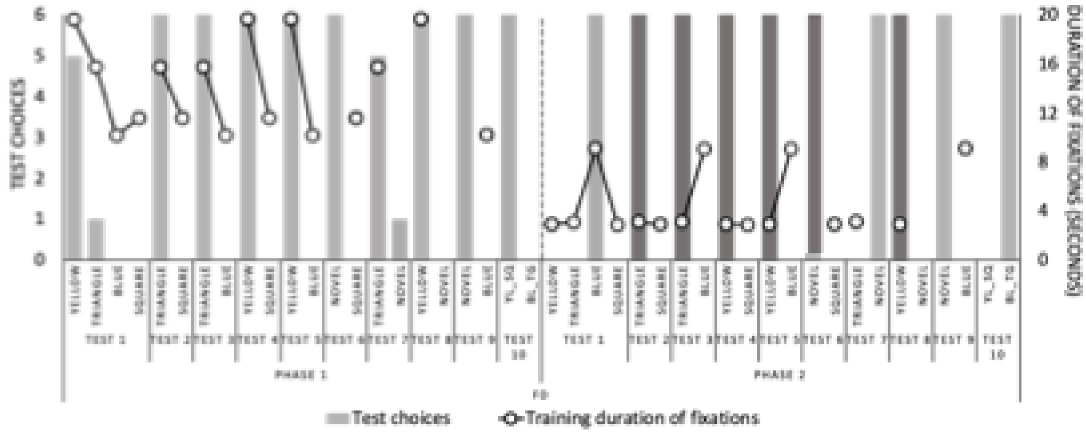
Tests 6-9 reflect three main patterns: a) high durations do correlate with selection control by the S+ components, and rejection control by the S- components—FD, phase 1; b) low durations do correlate with selection toward the most observed S+ component, and rejection or no control by the other components—JF, phase 1; XA, phase 2; and c) low durations in phase 2 training do correlate with selection of the most observed component in the former phase—acquisition—and rejection toward the other components—JF, phase 2; FD, phase 2.

Figure 14

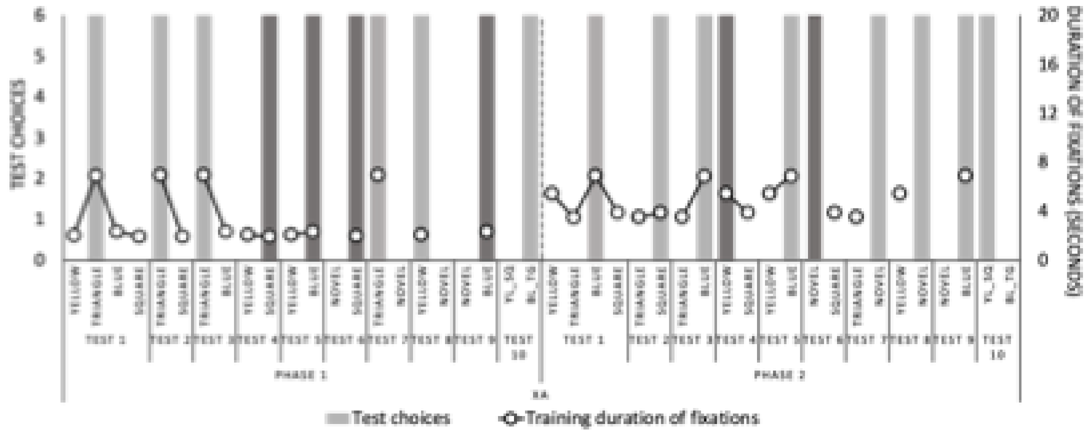
Comparison of Training Duration of Fixations and Test Choices



a.



b.



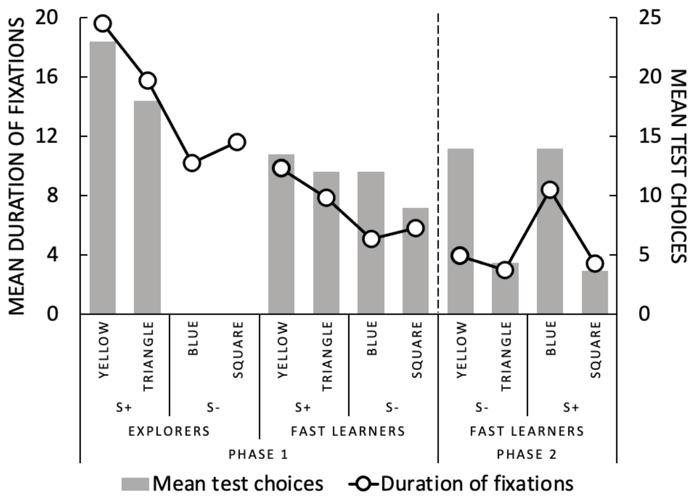
c.

Note. Parts a, b, and c, compare the test choices and the training duration of fixations, discriminated by participant. Bright columns represent choices to the S+ components, dark ones to the S-.

When totaling the responses per component, discriminated by learner type, the explorer—FD, phase 1—observed all components above 10 seconds and boasted perfect discrimination of both S+, whereas the fast learners observed every component below 10 seconds in phase 1 and distributed their responses randomly. Besides, fast learners observed more of the S+ color but chose equally both S+ and S- colors in phase 2 (Figure 15).

Figure 15

Comparison of the Duration of Fixations and the Mean Test Choices, by Learner Type

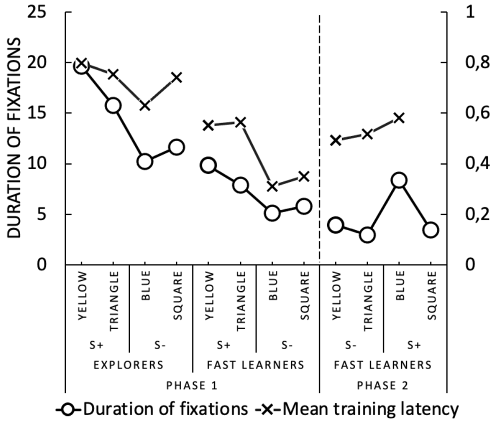


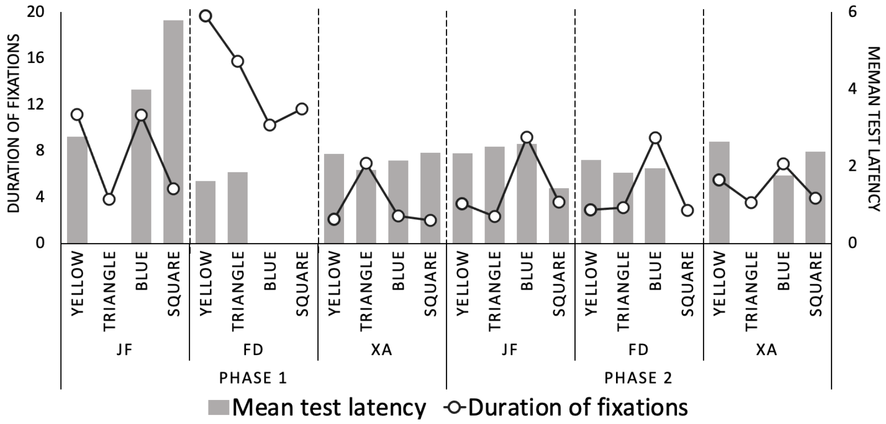
Note.

The explorer's latencies were longer than those of the fast learners for all components during acquisition (Figure 16a), but, unlike Experiment 2, were slightly shorter during testing (Figure 16b).

Figure 16

Comparison of the Duration of Fixations and Training Latencies, per Learner Type





b.

PI in Experiment 3 resembles that of experiments 1 and 2. Hence, yellow and blue do not seem to hinder or ease acquisition or reversion with respect to red and green. Second, as in Experiments 1 and 2, two learner type profiles emerged in which the degree of control by the components was determined by the observation patterns during training. Third, just like in Experiments 1 and 2, the 10-second threshold turned out useful in sorting out the participants who behaved differentially based on the discriminative function of stimuli, and those who did not. Finally, vertical randomization of the position of colors and shapes during training did not increase the duration of fixations to each component. Instead, fast learners continued to focus primarily on colors, suggesting that colors exert control other than topographical. Besides, this does not entirely meet results by Perez, Endeman, et al. (2015), whom participants chose color or shape idiosyncratically. In fact, colors attained straighter control than shapes in Experiment 4.

To clear out the possible effects of color-based control, Perez et al. mentioned the need to use components with similar luminance, color, and shape, not to allow any possible peripheral vision effects. Although the present study does not evaluate indirect observation, it focused on control established through direct visual contact. In doing so, Experiment 4 employed stimuli with these features to control the saliency variable while assessing the type of control—by selection or rejection—that derives from more neutral stimuli.

Experiment 4

Experiments 1, 2, and 3 evaluated the effect of observing shapes and colors like those used by Reynolds (1961) and Perez, Endeman, et al. (2015) on standard measures of stimulus control such as response rate and latency in extinction tests. These experiments found that the duration of fixation on each component does correlate to select control by both S+ components in non-contingent extinction tests. It was also determined that the lower the observing response, the lower the discrimination. Lower observing response also leads to color-based control—characterized as more salient (Terrace, 1966). Experiment 4 set out to evaluate these control relationships by more neutral stimuli, preventing their salience from influencing discrimination. A replication of Experiment 3 was performed, but this time employing patterns composed of one straight line each, circumscribed to circles like those used in the previous experiments, and whose only difference is the line's slope. All other conditions were identical to experiment 3. It is expected, on the one hand, that these patterns will hinder or prolong the acquisition and reversal of discrimination, but it is also expected that, being similar in luminance, shape, and color, those will favor discrimination based on contingency, rather than on formal aspects.

Method

Participants

Three adult participants, JC, AB, and NB, volunteered to participate in the experiment.

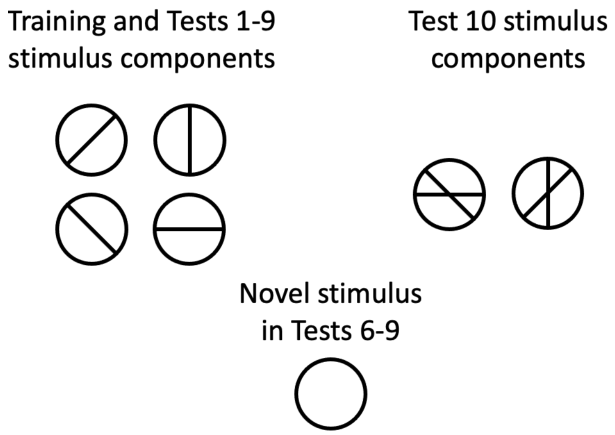
Stimuli

Four stimuli were employed during training and tests 1-5: (a) one straight-vertical line, circumscribed to an outlined circle—onwards referred to as 'vertical'; (b) one straight horizontal line within a circle—onwards referred to as 'horizontal'; (c) one straight line within a circle, placed diagonally from the upper-left corner to the lower-right one—onwards referred to as 'diagonal 2'; one straight line into a circle, placed diagonally from the upper-right corner to the lower-left one—onwards referred to as 'diagonal 1'. All components sized .52 cm*.52 cm. Tests 6-9, besides the described above, employed a blank outlined circle, equally sized. Stimuli during test 10 recombined the S+ diagonal with the S- axial component into a single circle, whereas the S+ axial component and the S- diagonal were enclosed into other circle, both sized 1.05 cm*1.05 cm—twice as the other components (Figure 17). All components and presentation-areas proportions were relative to the participant's computer screen dimensions. The proportions were as follows:

- Component size: .52 cm×.52 cm (1,05 cm×1,05 cm for test 10).
- Distance between components displayed in the same presentation-area: 7.95 cm.
- Distance center-to-center for the presentation-areas: 21,55 cm.
- Maximum size of each presentation-area: 9,92 cm×9,92 cm.

Figure 17

Components and Stimuli of Experiment 4



Procedure

Phase 1 started with a training session consisting of a Fixed-ratio-1 (FR1) simultaneous discrimination task that required the participants to produce as many beeps as they could. The beep was contingent on clicking either the vertical line or the diagonal 2—discriminative compound, S+—both enclosed into the presentation area. A dissonant ‘buzz’ sound was contingent on clicking either the horizontal line or the diagonal 1 in another presentation area—discriminative compound for punishment, S-.

The presentation-areas were randomly located in either of the two left-right upper corners of the screen on each trial, just as in Experiment 3, and the components within each presentation area were randomized vertically, so that neither the participant nor the experimenter could predict the location where each pattern would appear on the screen in each trial. Between trials meddled a 0.5-second intertrial interval, turning the screen blank before the next trial arrived. Every trial set the mouse-pointer back on the center of the screen to prevent clicking based on pointer-stimulus proximity. The dissonant buzz restarted the beep counter. The steady state criterium was set twelve (12) consecutive beeps, which signaled the discrimination accomplishment, ended the training session, and started the extinction tests. During testing, the stimuli were individually presented and occupied the center of each presentation area. Although responses during tests were not reinforced, the participants were asked to continue producing the beeps.

Each test consisted of 6 trials in which the responding rate and response latency to each separate stimulus tested in extinction were recorded to assess individual stimulus control. The stimuli were distributed across the tests as follows:

- Test 1 presented all four stimuli separately in a single presentation area, placed in every corner of the screen each. All locations were randomized for each trial, and up to three consecutive coincidences on the same corner for any stimulus.
- Tests 2-5 presented each S+ component against each S- component in a presentation area each, placed on the upper corners of the screen. All locations were randomized for each trial, and up to three consecutive coincidences on the same corner for any stimulus.

- Tests 6-9 presented each S+ and S- component against the novel stimulus, in a presentation area each, placed on the upper corners of the screen. Locations were randomized for each trial, and up to three consecutive coincidences on the same corner for any stimulus.
- Test 10 pitted against the two recombined compounds—diagonal 2 + horizontal vs diagonal 1 + vertical. Each recombined compound appeared on each upper corner of the screen. The locations were randomized for each trial, and up to three consecutive coincidences on the same corner for any component.

Once phase 1 ended, reversion in phase 2 began. The beep was already contingent on clicking either the diagonal 1 or the horizontal line, and the dissonant sound buzzed upon clicking either the diagonal 2 or the vertical line. All other conditions of phase 2 were identical to phase 1.

Table 6

Components and contingencies programmed in Experiment 4

	Phase	Training		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
Consequence		S+	S-	None	None	None	None	None	None	None	None	None	None
Stimuli	1	diagonal 2, vertical	diagonal 1, horizontal	diagonal 1, diagonal 2, vertical, horizontal	vertical, horizontal	vertical, diagonal 1	diagonal 2, horizontal	diagonal 2, diagonal 1	horizontal, novel	vertical, novel	diagonal 2, novel	diagonal 1, novel	dg_1+vd, dg_2+hd
Consequence		S+	S-	None	None	None	None	None	None	None	None	None	None
Stimuli	2	diagonal 1, horizontal	diagonal 2, vertical	diagonal 1, diagonal 2, vertical, horizontal	vertical, horizontal	vertical, diagonal 1	diagonal 2, horizontal	diagonal 2, diagonal 1	horizontal, novel	vertical, novel	diagonal 2, novel	diagonal 1, novel	dg_1+vd, dg_2+hd

Note. From left to right are presented the succeeding training and extinction tests with the respective components. The upper portion shows phase 1 and the lower portion shows phase 2.

Visual Contact Assessment

One gray layer covered each component during the training sessions. When the mouse-pointer hovered over the hidden areas, the layers withdrew to allow the participants to see the components placed behind them. The dark layer resumed covering the component behind as soon as the mouse pointer abandoned the stimulus area.

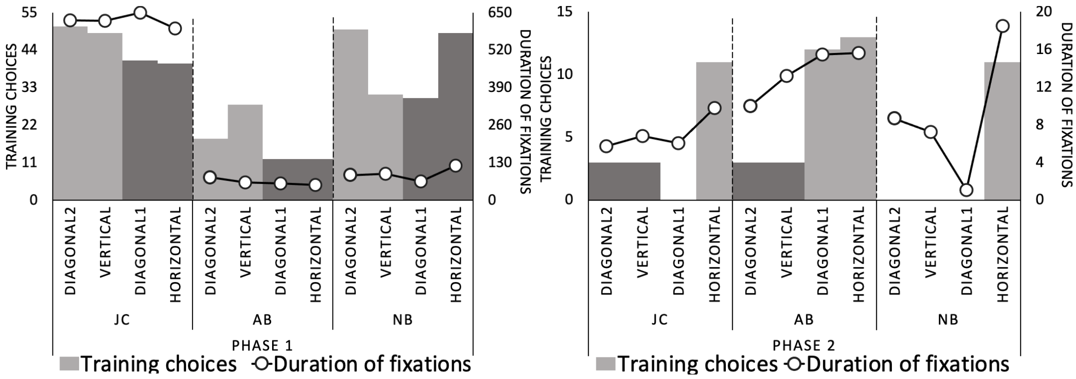
Results and discussion

All participants in Experiment 4 observed for longer—between 50 and 650 seconds—and clicked each component during training sessions twice or thrice than those in Experiments 1-3, especially in phase 1 (Figure 18a). Because all conditions from Experiment 3 were maintained except the formal properties of stimuli, the difficulty in reaching the stability criterion can be attributed to the new components being patterns rather than shapes and colors. Very long total duration of fixations in phase 1 implies that the 10-second cutoff between explorers and fast learners from previous experiments could be set, at least for that phase. And yet, exploratory patterns emerged. JC took much longer observing all components and clicking in phase 1 than AB and NB, and also AB lasted longer fixating on and made many more clicks on all components in phase 2. In accordance, JC will be treated as the explorer of phase 1, and AB will be treated as explorer in phase 2.

Figure 18b shows how, grouped by phase and by component, the explorers always recorded longer total duration of fixations to every component in both phases than fast learners, especially in phase 1.

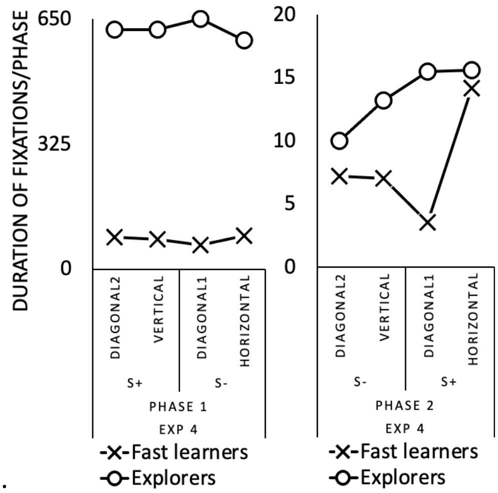
Figure 18

Duration of Fixations and Its Comparison to Training Choices



a.

b.

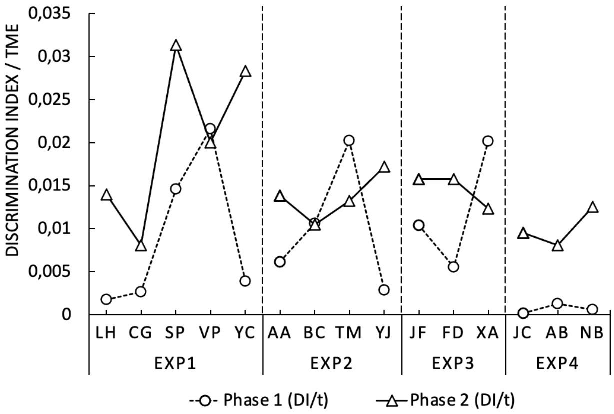


Note. Left and right panels of upper and lower portions depict Phase 1 duration of fixations upon 650 seconds and Phase 1 upon 20 seconds due to large differences from phase to phase.

PI was much lower for all participants in Experiment 4—especially in phase 1—than Experiments 1-3 (Figure 19a). Thus, colors and shapes promoted in the human participants a rapid acquisition of the discrimination, regardless of whether one or both S+ accounted for it. Perez, Endeman, et al. (2015) suggested that stimuli similar in luminance, shape and color may prevent a peripheral vision effect. The present study showed that, whereas enough direct visual contact of colors and shapes facilitates the establishment of stimulus control, direct visual contact with patterned stimuli does not ease discrimination at once but does not prevent it. Instead, only a very long observation of each component managed to correlate with almost-perfect discrimination in acquisition, while duration of fixations like those of shapes and colors managed to so in reversion. In other words, patterned stimuli hinder reaching a behavioral steady state, but once reached, it’s not that different from shapes and colors (Figure 19, PI in phase 2 of Experiment 4).

Figure 19

Performance of Experiments 1-4, Discriminated by Participant



JC chose both S+ components in phase 1 tests, but also chose horizontal against novel (Figure 20a). This means that both S+ components did control JC's responses via selection, but the horizontal pattern did not control via rejection. The preferred component in test 1 was diagonal 2, which is confirmed in test 10. In phase 2, JC observed every component below 10 seconds and only discriminated correctly the most fixated—horizontal. The remaining S+ component—diagonal 1—seems to have controlled too, but via rejection; test 9 confirms it. It's likely that rejection control by diagonal 1 prevailed from phase 1. Both S- components—vertical and diagonal 2—gained some control in the 1-on-1 tests, likely due to not having been observed enough during reversal training. Test 10 confirms the preference for horizontal in test 1.

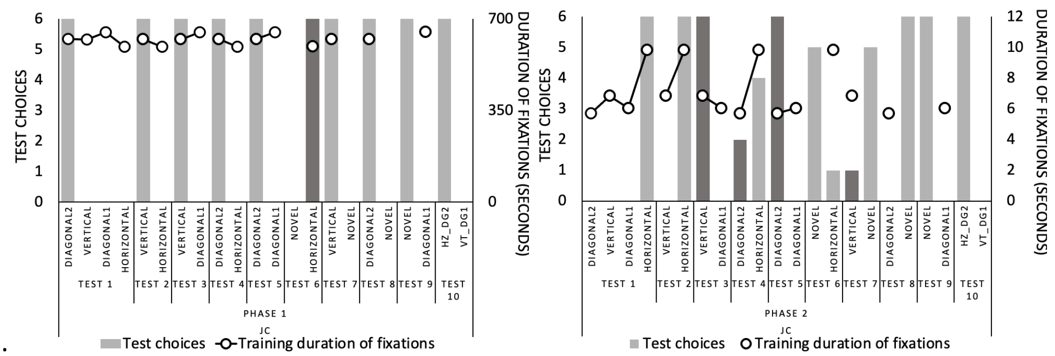
AB observed mostly diagonal 2 during acquisition but chose mainly S- components during testing (Figure 20b). His responses during phase 1 tests cannot be explained by observational patterns nor can they by the contingency. In tests 6-9, AB rejected all components except horizontal, but its control was not decisive during the other tests. In phase 2, AB observed all components above 10 seconds and correctly discriminated both S+ components, except for one response to diagonal 2 in test 1. Test 10 of phase 2 does not confirm the preference of test 1. Observational tendencies, primarily toward the S+ components, predicted all of AB's choices during testing in phase 2, where AB correctly discriminated all components and behaved as a standard explorer.

NB mostly observed the horizontal S- in phase 1 acquisition but chose vertical S+ in test 1 (Figure 20c). However, in all other tests of phase 1 she chose the components randomly, so it is not reasonable to attribute consistent control to any component. In phase 2, NB again mostly observed the horizontal S+, for 18 seconds, and chose it in all tests but against novel, which means that it did not gain consistent control. The remaining components were all observed for under 10 seconds. The S+ diagonal 1 was never chosen, neither was significantly observed during reversion. The two S- components were chosen in tests 3 and 5. All choices during tests 1-5 of phase 2 were reliably predicted by observational patterns during reversal, but not by the contingency, classic in fast learners. In no phase did NB discriminate correctly, just choosing one S+ component in tests 1, not in 1-on-1 tests.

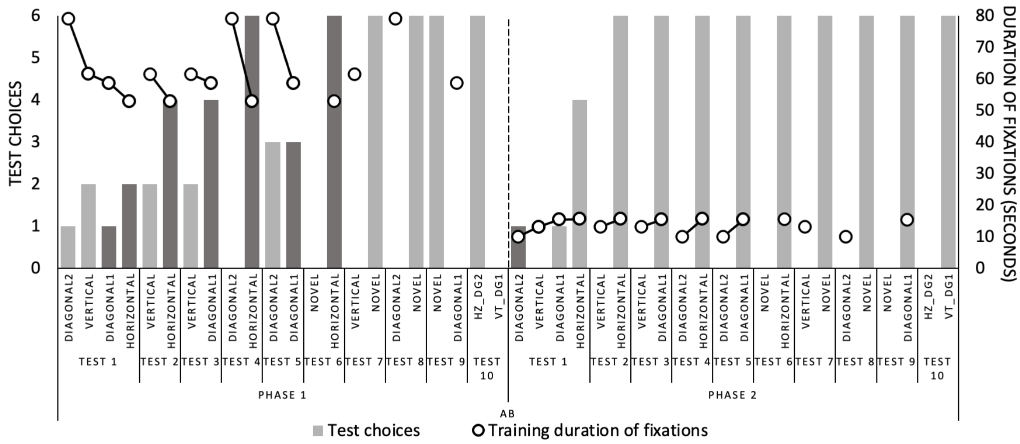
Figure 20d shows that in both phases, explorers—JC, phase 1; AB, phase 2—observed for longer all components than the average fast learner. Although long durations in phase 1, the observation periods in phase 2 stabilized in line with the observation times of experiments 1-3—above 10 seconds for the explorers, and below that threshold for the fast learners. Because of these differences in observation, explorers chose both S+ components and very rarely S- ones, in other words, they correctly discriminated stimuli that correlated with the consequence from those that did not. Fast learners, on the other hand, observed each component on average less than 10 seconds in phase 2—where duration of fixations stabilized as in Experiments 1-3—and did not correctly discriminate stimuli that correlated with the consequence from those that did not, especially in phase 1.

Figure 20

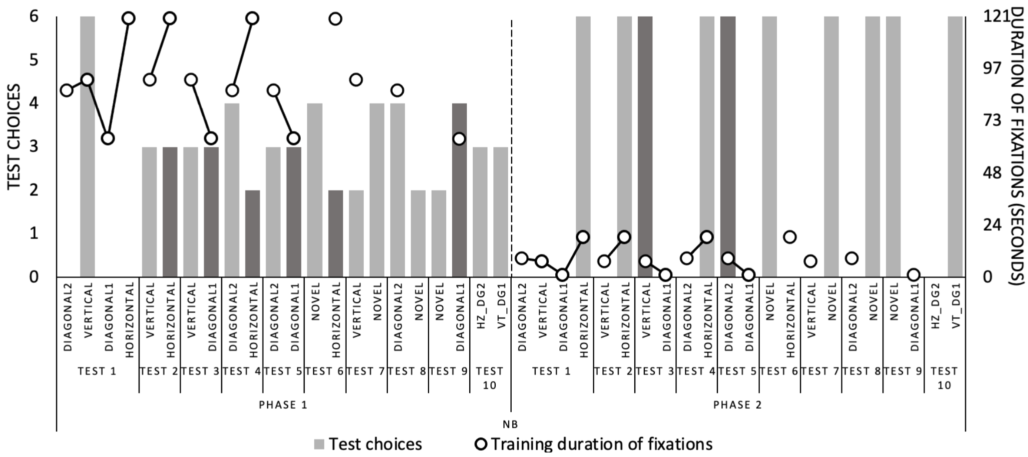
Duration of Fixations and Mean Test Choices by Participant, and Grouped by Learner Type



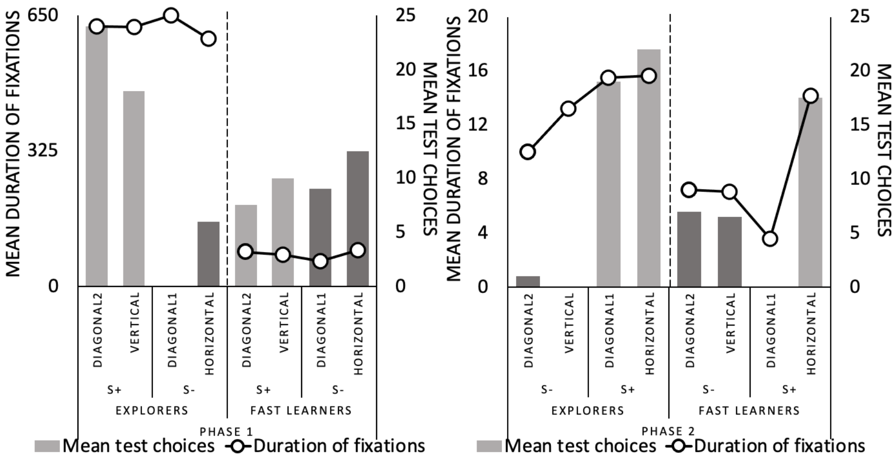
a.



b.



c.



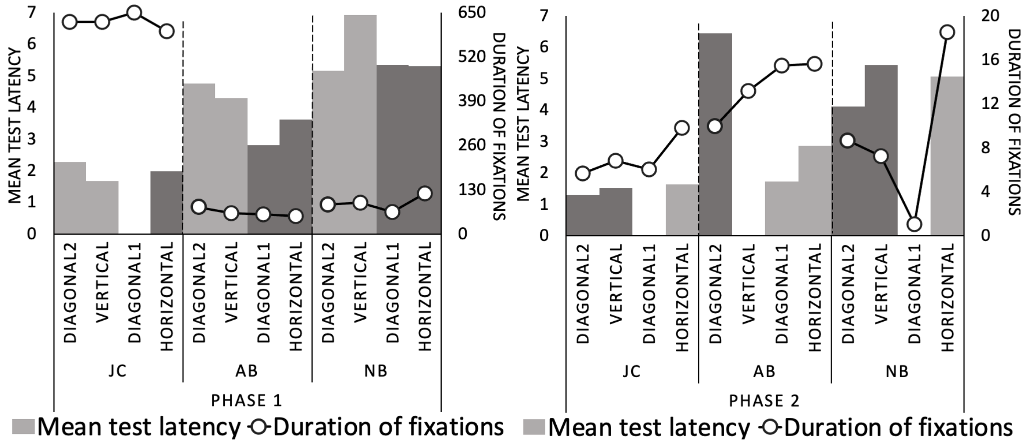
d.

Note. Each phase of JC is presented above different observation ranges due to large observation differences. Bright colors represent choices to the S+ component, dark ones to the S-.

In phase 1, JC registered shorter latencies to select components during testing than fast learners, but in phase 2 AB took longer than JC and less than NB, so nothing indicates an effect of fixation duration on latencies during testing. Neither there is evidence of longer latencies when selecting S+ components than S- ones during testing (Figure 21).

Figure 21

Comparison of the Duration of Fixations and the Mean Test Latency, per Participant



Note. Brighter columns represent latencies of S+ components, darker ones represent latencies of S-.

From Experiment 4 we conclude, first, that patterned stimuli are much harder to grab control than colors and shapes in acquisition, taking up to 650 seconds of direct observation and more than twice as many responses during training, for some components—for example, JC in phase 1. It is possible that the participants were under the control of an illusion of component rotation, since axial and diagonal lines are formed from 45° rotations. Such a factor could have made learning the task considerably more difficult. Two of the participants said so when debriefed. However, establishing stimulus control in reversion took about as much as reversion on experiments with shapes and colors.

Second, none of the patterns was particularly easy to discriminate relative to the others, unlike the dominance shown by colors over shapes in experiments 1-3. Only in phase 2 did the horizontal pattern show longer eye contact during reversal, but only the explorer—AB—chose it in test 6 against the novel stimulus. It is possible that the horizontal pattern has an inherent feature that facilitates its discrimination, since also in phase 1, when it played as S-, NB observed it more than the other components. Future studies should test this hypothesis. Third, unlike Experiment 1, Experiments 2-4 showed that explorers and fast learners can shift roles from phase to phase, but this is often the case when stimuli were carefully observed in one phase but rather dismissed in another.

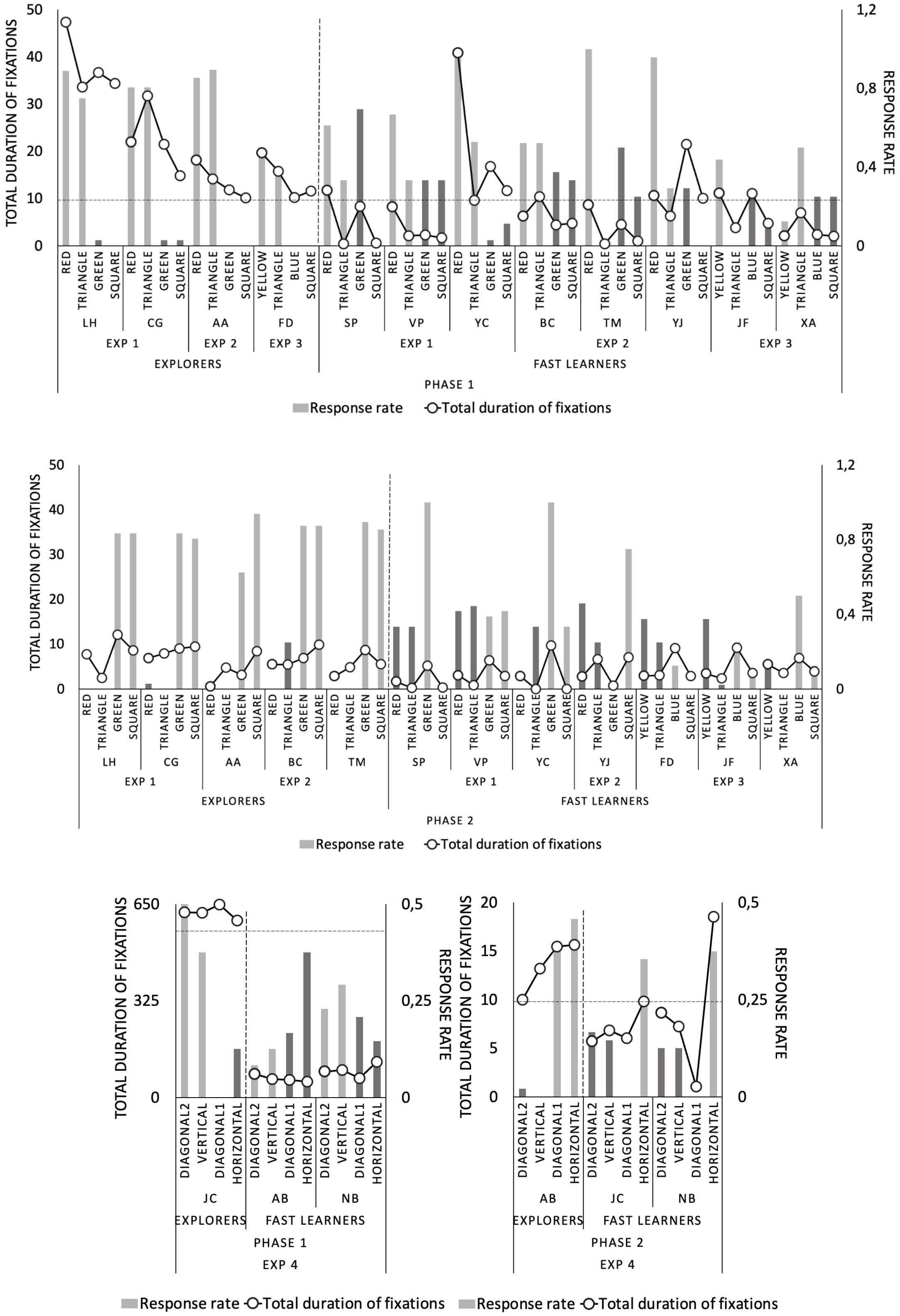
Another conclusion derived from tests 6-9 is that, like Experiments 2 and 3, explorers fell under control by the S+ components via selection and by the S- components via rejection, whereas the fast learners tended to reject all components, even horizontal, the one most observed during training. However, tests 6-9 of Experiments 2 and 3 show no evidence of prior control by selection or rejection, as all kinds of tendencies were seen: they chose a component against novel because it had been the most observed during training, or because it had gained control in the former phase, or they simply chose the components against novel.

General results

Some main findings stand out from the present study. First, I found an empirical observation threshold that distinguishes Explorers who fixate on components proportionately and for longer observation time, from fast learners, who do not fixate on components proportionately and for lower observation time. Although this threshold varies from experiment to experiment and from phase to phase, in most cases it is at least 10 seconds fixating on each component—phase 1 of Experiments 1-3, and phase 2 of Experiment 4 (Figure 22). In phase 2 of Experiments 1-3 explorers seemed to reach a behavioral stability that allows them perfect discriminations despite having displayed durations shorter than 10 seconds per component. The differences in phase 2 are too subtle to draw a clear threshold, but it is certain that explorers tend to distribute their gaze among all components, while fast learners tend to focus on colors. Explorers scored lower PI in training but choose antecedent stimuli according to its discriminative function in the contingency (Skinner, 1938). It was also found that explorers select both S+ components against novel, while choosing novel against both S- components—selection and rejection control, respectively. Fast learners, in turn, exhibit higher PI on training, but correctly discriminate only one S+, although selecting it inconsistently. Fast learners fail to consistently choose the S+ components against novel, nor do they always select novel against the S- components.

Figure 22

Comparison of the Duration of Fixations and Testing Response Rate



Note. The horizontal dotted line represents the hypothetical threshold distinguishing explorers from fast learners, where it could be traced. Brighter columns represent response rates to components featuring S+ during training; darker ones correspond to S- ones.

General discussion

Some measures of stimulus control that feature S+ and S- compounds have demonstrated control by more than one S+ component, and even by S- components (e.g., Farthing and Hearst, 1970). Not all components that feature control attain visual contact (e.g., Perez, Endeman, et al., 2015), a phenomenon to which one possible explanation is rejection control: responses to S+ are controlled by rejection of S- (Johnson & Sidman, 1993). A way to determine whether control is established via selection or rejection include measurement of eye contact (e.g., Magnusson, 2002). Follow-up studies have provided evidence that the establishment of reject control can be usually followed by long duration of fixations of the S- and by choices based on its exclusive observation, whereas the establishment of select control leads to long duration of fixations of the S+ and, correspondingly, choices based on its observation alone (e.g., Perez & Tomanari, 2020).

The aim of the present study was to examine the relation between the formal aspects of the compound's components and the direct observational response during discrimination training, and how those aspects did control behavior, via selection or rejection. For this purpose, the present study was based on Perez, Endeman, et al. (2015), one of the studies evaluating the effect of observation on stimulus control, and whose results are related to the type of control set, selection, or rejection. Perez et al. concluded, chiefly, that observing responses predicted reliably the choices in extinction, that participants' fixations allocated idiosyncratically on colors or shapes, and that, although both S+ components did control responses across testing, only the stronger S+—the longer fixated—controlled in test 1 which resembled Reynold's original all-at-once components presentation in extinction.

Most experiments reviewed, including that of Perez, Endeman, et al. (2015), employed eye tracking devices that allowed participants indirect or peripheral visual contact with other components without measuring that contact. The present study employed a different observing-response-assessment method, like that of Perez et al. (2015b; also, see Mcilvane, 2013), in which components were covered by a dark layer that was only removed when the mouse pointer hovered over, so that only one component could be seen at a time.

Four experiments reinforced responses to discriminative compounds and measured observational responding. Subsequent extinction tests measured response rates and latencies to each separate component. Except for the methodological variations including the change in visual response measurement, Experiment 1 was intended to replicate the results of Perez, Endeman, et al. (2015). Experiments 2-4 included tests that confronted each S+ and S- component with a novel stimulus, to determine whether control featured selection or rejection. Experiment 3 varied the colors to observe possible control by the components prior to the experiment and randomized the component's topographical arrangement to prevent topographical control. Experiment 4 employed patterned straight lines instead of colors and shapes, to rule out a possible control effect by the formal characteristics of the components.

The strongest—most observed—S+ component was color, for experiments 1-3. Color was found to gain control over most of observing and over most of non-contingent responses. For those who achieved the task on the basis of only color or shape, the remaining—weak—S+ component turned out irrelevant or just redundant (Carter & Werner, 1978). One hypothesis that explains it is that color is a more salient formal aspect of stimuli than shape (Terrace, 1966). The present study confirmed that either color or shape can can suffice to establish discriminations. Commonly, color will attain a great deal of attention, whereas shape might result redundant for resolving a discrimination task.

In the second place, all four experiments showed that the longer the observation of a single component during training sessions, the better its discrimination, although not so the remaining, less observed components. Customarily, long observation lapses of one component came along with similar observational responses to the other components, so that control by both S+ components was expected.

Experiment 2 went even beyond, showing that control by S+ components is settled via selection and control by S- components does so via rejection, so long as highly fixated during the former training sessions. The above implies that responses within a single 12-response extinction round could not only demonstrate control by the S+ components, but also rejection control by the S- components.

An around 10-second cutoff duration of fixations emerged as a threshold above which the exploratory learning type emerged, in which forceful selection and rejection control came out—such a threshold does not apply for patterns in acquisition of experiment 4, where it was much longer, due to the particularly laboriouS-to-discriminate patterns. Participants who fit this pattern were called 'explorers.' Below the 10-second cutoff, discrimination tends to decrease, leading to control by only one of the S+ components in test 1, weak or no control by both S+ components in subsequent tests, some control by one or both S- components, and stuttering or no control via selection or rejection in tests 6-9, as well response patterns in tests 10 not consistent with findings in test 1, to which it was directly compared. Participants belonging to this second pattern were called 'fast learners.' Both explorers and fast learners emerged in all four experiments, demonstrating that the explorer-fast learner dual classification is quite a useful construct to help understand the interaction between visual contact and stimulus control.

Although the threshold around 10 seconds is useful for distinguishing the type of learner, it is possible that there is a point of indifference above which, once discrimination is established, further observation of one component or the other does not affect discrimination. For example, the present study arbitrarily set 12 consecutive correct responses as the behavioral steady state, which, unintendedly, determines or at least restricts the duration of fixations recorded before the end of training. Future studies could vary the steady-state criterion and accurately assess the relationship between the discriminability of different components, the discrimination that occurs, and the amount of observation required for each degree of discrimination.

Experiment 3 showed that colors other than green and red seemingly don't ease or hinder the learning of the task, and, along with Experiment 4, showed that randomizing the components' location in every trial across training sessions just slightly fosters visual exploration. Nevertheless, what really appeared to increase the amount of visual contact is patterned components, which turned out much more demanding to discriminate than colors and shapes. On the pattern/color distinction, Dinsmoor (1985) noted that "[…] no matter where the pigeon looks, if it looks at any part of the key, it will see the color. This is not true of a visual pattern", a fact that can be attributed to the stimulus' salience (p. 372). And yet, neither did much longer observation take all participants straight to exploratory patterns, nor did it hinder the acquisition of the task so that no discrimination could be established. Indeed, participants of Experiment 4 played as explorers and fast learners just as much as Experiments 1-3. Although none of the patterns of Experiment 4 were particularly easy to discriminate relative to the others, the horizontal pattern featured, in general, longer eye contact, mainly during reversal, where it played as S+. Maybe culturally shaped control has been set upon horizontal patterns in our day-to-day life that yields such results.

Experiments 3 and 4 also tried to decrease a possible topographical control by randomizing the espacial distribution of components within the presentation areas. This methodological variation increased just slightly the duration of fixations, but not enough to prompt exploratory patterns beyond those registered in Experiment 2, which featured statically located shapes and colors that only shifted randomly from left to right, not vertically. Nor did the topographical randomization prompt more visual exploration in fast learners, who remained focused chiefly on colors. The above was enough to rule out a topographic control hypothesis. Experiments 2-4 showed that a single participant may shift from explorer to fast learner or vice versa, which is the case when stimuli are thoroughly observed in one phase, but not so or not clicked in the other.

Perez, Endeman, et al. (2015) suggested that 'by varying the stimulus arrangements, either of the two S+ components to some degree could control test responses.' The present study found the same results, adding that either direct or indirect eye contact, as well as some choices of both S+

components, are essential for those to gain control. Perez, Endeman, et al. (2015) also noted that one stimulus did control extinction responses despite not being directly observed in training. In cases where a component apparently not observed during training acquires control over responses, it is presumed that it was observed but indirectly, otherwise the one feasible explanation would be rejection of the comparison stimulus, or some shaping prior to the experiment. Thus, considering the present results, the participant in Perez et al. likely observed the component peripherally, as they themselves suggest.

Moreover, the present study rules out that reversal is possible without eye contact and without choices during training, since in the cases where a component continued to control in phase 2 as in phase 1, it is because it was not observed or was not selected during reversal. Thus, the ease with which extinction test arrays demonstrate control of multiple components depends on the degree of exposure and interaction with that component during training.

The present study showed that, after sufficient exposure and interaction with the components—the 10-second cutoff—those exhibit control even in tests presenting them all at once, as in Reynolds' (1961). In this regard, the current study showed that, unlike Perez, Endeman, et al. (2015), both strong S+ and weak S+ can control responses earlier, from test 1, which presents them all-at-once, if the participant plays explorer. When the participant plays as a fast learner, it is most likely the single control by the strong S+.

As for the analysis of preference for shape or color, Perez, Endeman, et al. (2015) reported participant-based idiosyncrasy. The present results showed the same variety, and some participants even switched preference from shape to color or vice versa, from one phase to the other, even explorers. However, the tendency was straightforward: colors gained slightly more eye contact than shapes, regardless of the colors used, especially by fast learners—see the difference between patterns of observation between experiments 1 and 2, versus 3. It is worth remarking, again, that the duration of fixations was restricted to arbitrarily established stability criteria, so that extending this criterion to 20 or 30 correct responses could reveal new preferences for shapes or colors in observation patterns.

Catania (2013, p. 140) argued that “salience is not a property of a stimulus; it is actually a property of the organism’s behavior with respect to that stimulus”, and one of those behavioral properties is the observing response. Thus, salience is not an inherent feature of a colored or shaped stimulus, nor should an inherent feature alone be thought of as the single nudge behind stimulus discriminability. It is the degree of exposure or contact with organisms that determines the control it will attain (e.g., Dinsmoor, 1985). Results from the present study endorse it. In the case of visual stimuli, salience is about the time spent by organisms staring at them, and by the interaction with such stimuli according to their discriminative function. For example, it may be easier to explain the control attained by a stimulus appealing to the learning history and previous exposure to it, than appealing to its formal properties alone (Hirai et al., 2011). Although certain colors would gain further control over responses than shapes in the present experimental arrangement, some response patterns seem to depend rather on foreign day-to-day contingencies that employ colors primarily. Take, for instance, SP’s response patterns in Experiment 1. In most cases she chose the same colors and shapes regardless of the contingency.

Because only the explorers recorded perfect control by selection and rejection in tests 6-9, whereas fast learners barely discriminated the most observed component, it seems fair to conclude that, in simultaneous discrimination tasks with compound stimuli like those employed in this study, selection and rejection come together, and both emerge together as a function of the way of visual exploration that characterized the establishing of the discrimination. That explains why looking for long at one component at the expense of the others simply leads to limited control by that component. In contrast, the proportional exploration of all components did produce more stable ways of control by all components, by both selection and rejection. As a matter of fact, the longer the eye contact and the higher the rate of responses during acquisition and reversal, the longer the experience with the consequence and the greater the discrimination of the components, which implies greater selection or rejection control.

To sum up, a final set of recommendations for future experiments is as follows:

- Future research should study how the visual availability of components inhibits or facilitates control by multiple components within a compound stimulus. The role of possible control established by components prior to the time of the experiment should also be evaluated.
- The time that each component is observed should be systematically varied and its effect on responses and latency in extinction should be measured, to try and manipulate the scanning patterns and ulterior stimulus control exhibited by participants.
- Because latency remains as a possible alternative measure of stimulus control, future studies should evaluate in greater detail whether explorers/fast learners' patterns or positive versus negative stimuli do correlate with longer or shorter latencies in testing.
- Upcoming studies should also vary the tilt of patterned components like those employed in Experiment 4, making them all play multiple roles within a contingency and evaluate whether, at some point, the tilt alone determines some sort of control. That is presumed about the horizontal pattern, which correlated with higher fixations than the other components, even in cases where it played as S-.
- Future studies should try new probe stability criterion, for example, up to 20 or 30 consecutive hits, and evaluate its effect on the visual contact established throughout training sessions, as well as over the discriminability of different components.

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Appendix

Consent form of Experiments 1-4

CONSENTIMIENTO INFORMADO

Yo ____, identificado con documento de identidad No. ______________ de__________, he sido invitado(a) a participar en el presente estudio.

El estudio busca explorar **la ejecución de los participantes en una tarea cognitiva que presenta cierto nivel de dificultad, NO** es una prueba de inteligencia ni de memoria ni de personalidad. La información que será recolectada con tu participación será usada para fines exclusivamente académicos, pertinentes a esta investigación. El estudio puede durar hasta 30 minutos. Por favor cerciórate de disponer de este tiempo, **apaga tu celular**, y procura concentrarte únicamente en la tarea que te será presentada a continuación.

Confidencialidad

El tratamiento, la comunicación y la sesión de los datos de carácter personal de todos los participantes se ajustará a lo dispuesto en la Ley 1090 de 2006. El investigador se compromete a la confidencialidad y utilizar los resultados sólo con fines científicos (los resultados pueden ser comunicados en congresos y también publicarse en revistas científicas siempre manteniendo **su anonimato**). **Ten en cuenta que por medio de este consentimiento te comprometes a NO divulgar los detalles de esta actividad hasta el momento en el cual te sea comunicado que lo puedes hacer.**

La participación en este estudio es voluntaria. Entiendo que tengo la libertad de retirar mi consentimiento de participación en cualquier momento y que en tal caso no tendrá ningún tipo de repercusión.

Para obtener información acerca de esta investigación puedo comunicarme con el psicólogo Pablo Andrés Ledesma Castro, miembro del grupo de investigación de Análisis Experimental y Aplicado del Comportamiento (AECUN) de la Universidad Nacional de Colombia, dirigido por el profesor Álvaro Arturo Clavijo Álvarez, al siguiente correo electrónico: paledesmac@unal.edu.co o aecun.info@gmail.com

IMPORTANTE: Si no eres mayor de edad no puedes participar en nuestro estudio.

CONSIENTO VOLUNTARIAMENTE PARTICIPAR EN ESTE ESTUDIO.

Consentimiento de participación firmado a los _____ dias del mes de _____________ del año ________.