The selective action of cfunc control

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Preregistration – Experiment 3

Author note

This work was funded by Ghent University grant BOF16/MET_V/002 awarded to Jan De Houwer.

Background

The conceptual background for this experiment can be found in the preregistration document for experiment 1 (https://osf.io/zv5r6/). Further context for this experiment by the preliminary report of the results from experiments 1 and 2. Briefly, two previous experiments employed a paradigm based on car races. Each trial had two components: i) a sample racecar screen which showed the performance of a sample racecar (i.e., moving either quickly or slowly and either forwards or backwards) and communicated via Crels and Cfuncs how the performance of each racecar compared with that of the sample racecar (i.e., either the same or different speed and same or different direction), and ii) a car race screen that would show the racecars race. Participants were told to pick as many winners as they could, a task that required effective action of Crels and Cfuncs. 22 participants completed Cfunc training and testing in experiments 1, and roughly 50% of participants had response accuracies ≥ 83% (50/60) at test. Experiment 2 was an attempt to increase the proportion of participants achieving high response accuracies, but produced highly similar results to experiment 1. Experiment 3 builds upon the previous experiments in another attempt at increasing the number of participants achieving high test accuracies.

Some specific features of the previous experiments provide good reason for making alterations to the procedure and conducting experiment 3. In experiment 2, when establishing Cfuncs for each stimulus dimension only one Crel and Cfunc pair was presented – the Crel and Cfunc pair specifying the target stimulus dimension. However, due to removing "irrelevant" Cfunc stimuli, participants in experiment 2 could complete phases establishing Cfuncs for each stimulus dimension without attending to the programmed Cfuncs for speed and direction. Participants need only identify the important dimension within the phase (i.e., speed or direction), observe the sample racecar, and select a race car based on the Crels for same and different. During mixed Cfunc training participants were required to attend to two pairs of programmed Crels and Cfuncs that specified speed and direction. A difficult task if to that point they have only attended to the Crel stimuli. The difficulty described here may have been encountered by the seven of the 23 participants in experiment 2 who achieved the training criterion (i.e., ≥ 85% accurate across the previous 20 trials) in the training phase for each Cfunc with before failing to meet the training criterion on mixed-trials and the Cfunc test.

When establishing Cfuncs for speed and direction in experiment 1, two Crel and Cfunc pairs were presented between the sample racecar and each racecar; one Crel and Cfunc pair that specified the target dimension (e.g., speed) and one Crel and Cfunc pair that specified the "irrelevant" stimulus dimension (e.g., direction). Each Cfunc training phase (i.e., Cfunc for speed, Cfunc for direction) was defined by the racecars having the same property along the irrelevant stimulus dimension. That is, when training the Cfunc for speed all racecars in a given trial would go the same direction. This meant that the Crel and Cfunc pair specifying how racecars compared to the sample racecar along the "irrelevant" dimension were identical, and could not be used to select the winning racecar. It did not mean that the sample racecar also had that same property along the irrelevant stimulus dimension. Therefore, within each training phase the sample racecar and racecar stimuli varied across both task relevant dimension (i.e., speed and direction), which made the task more difficult. A quick inspection of the data supports this interpretation. In 55% of exposures to these phases in experiment 1 the training criterion was met within 60 trials, whereas this figure was 83% for experiment 2.[1]

A Cfunc is partly a relation between variation in stimulus property and a second stimulus (e.g., the word speed bears a relation to the various speeds of various stimuli). We have argued that testing a Cfunc requires an environment in which multiple stimulus properties are task relevant (otherwise it cannot be determined if the Cfunc is selecting among stimulus properties). Producing a Cfunc will require providing a history in a similar environment. However, simply exposing participants to such a complex environment, as we did in experiment 1, produces highly variable behavior

[1] The mean number of trials to complete these phases is also informative, even if the maximum number of trials in each phase differed across experiments (150 in experiment 1 and 90 in experiment 2). The mean number of trials completed in these phases in experiment 1 was 81 trials, compared to 36 trials in experiment 2 (one tailed paired t-test of difference in means: mean difference = 44.8, $t(61.3) = 4.89$, $p < 0.001$, 90%CI [32.9, infinite], BF = 4667).

that is selected very slowly. When establishing a Cfunc, the relation between the Cfunc stimulus and the variation in a particular stimulus property should be more obvious when varying only the stimulus dimension with which we seek to establish a relation to a Cfunc.

It seems, therefore, that a more efficient way to proceed is to shape participants behavior to the more complex environment by exposing them to a series of situations in which the stimuli differ only along one task relevant dimension, and present both relevant and irrelevant Crel and Cfunc pairs in this situation. Across trials in these situations only the relevant Crel and Cfunc pair will change because this pair will covary with changes in the target stimulus property. This should make it easier to discriminate the relationship between the target Cfunc property and the relevant Crel and Cfunc pair. We suspect that the irrelevant Crel and Cfunc pair will be quickly ignored because they do not covary with changes in the stimulus property that are relevant to completing the task. If at a later stage the stimulus property that is relevant to completing the task changes, the previously relevant stimulus property becomes irrelevant so too will the previously relevant Crel and Cfunc pair. Similarly, the previously irrelevant Crel and Cfunc pair will become relevant as this Crel and Cfunc pair will covary with the stimulus dimension that is relevant to completing the task. If participants complete these tasks, they will have been exposed to a situations in which each Crel and Cfunc pair is relevant and irrelevant to completing the task, but each of these stimuli will always have been present, and thus combining the stimuli in a set of situations in which both stimulus dimensions are relevant may be quite likely.

The above is quite abstract. Imagine instead the role of Crels and Cfuncs in the more concrete car race example that has two major elements: i) a sample racecar which can go forward or backward either quickly or slowly, and ii) selection boxes presenting the sample racecar on the left, a racecar on the right, and four symbols appearing between the two racecars (i.e., the experimenter programmed Crels and Cfuncs). The experiment will begin with a set of trials in which all racecars including the sample go slowly, but can go either forward or backward. The direction of the sample racecar will vary across trials, as will the direction of each racecar. One pair of symbols will therefore covary with these inter-trial changes in direction (i.e., the relevant Crel and Cfunc pair specifying direction), and the other pair of symbols will not change throughout these trials (i.e., the irrelevant Crel and Cfunc pair specifying speed). A later stage of the experiment will present a set of trials in which all racecars including the sample go forward, but will do so either quickly or slowly. The speed of the sample racecar will vary across trials, as will the speed of each racecar. Similar to the previous phase, only one set of symbols will covary with these inter-trial changes speed, in this case the now relevant Crel and Cfunc pair specifying speed. In this stage, the Crel and Cfunc pair specifying direction will be irrelevant and will not change across trials. An important source of control here is likely to be discriminating the difference between situations in which one stimulus dimension varies and is task relevant (e.g., speed only) and the situations in which the other stimulus dimension varies and is task relevant (e.g., direction only). To facilitate this discrimination participants could be exposed multiple times to a brief series of each kind of trial (e.g., 30 trials from set 1, followed by 30 trials from set 2 before returning to set 1 etc.). The final stage will show racecars that vary across trials in both speed and direction.

How does this proposal differ from what was done in Experiment 1 and Experiment 2? It is different from experiment 1 because in each phase targeting one stimulus property-Cfunc stimulus relation the other stimulus property-Cfunc stimulus relation will be held constant (i.e., only slow cars in phase 1, only forward moving cars in phase 2). It is different from Experiment 2 in that both Crel and Cfunc pairs will be present at all stages, even when one of the Crel and Cfunc pairs is not relevant to the stimulus property-Cfunc stimulus relation that is the target of that phase. It is different from both experiments in that the blocks training each Cfunc will be intermixed, rather than first three blocks training one Cfunc followed by three blocks training the other Cfunc.

Changes relative to experiment 2

1. In experiments 1 and 2, all participants were exposed to Cfunc training regardless of their performance on Crel training and testing. Experiment 3 will terminate early if participants do not achieve accuracy ≥ 66% in Crel testing.

2. The second adjustment will be to the Cfunc training procedure. Stimuli in each Cfunc training phase will vary along one stimulus property dimension only (i.e., only slow cars in phase 1, only forward moving cars in phase 2).
3. Both Crel and Cfunc pairs will be present at all stages.
4. Training blocks for each Cfunc will be intermixed and will terminate either after 6 blocks of training or when the training criterion is met for both kinds of block.
5. Include a negative test of Cfunc control where only programmed Crels are presented.

Method

Sample

Data collection will be conducted online via Prolific Academic. Participants will be paid at a rate of £7.50 per hour.

Planned sample size & stopping rules

Data collection will stop when 20 participants who have passed Crel training within the experiment (i.e., accuracy ≥ 20/30) have been exposed to all Cfunc training and testing.

Inclusion criteria. English as a first language, between the ages of 18-65, 90% approval rating for previous studies on Prolific, no previous participation in similar studies from our research group, passing the Crel test in the experiment (i.e., accuracy < 20/30).

Exclusion criteria. Incomplete data, responding "yes, exclude my data" on the self-exclusion question, failing to provide correct responses after 3 blocks of the Crel training phase, or failing the Crel test (i.e., accuracy < 20/30).

IVs.

1. Crels: ■ = same, ▼ = different vs ▼ = same, ■ = different
2. Cfuncs: ✦ = speed, ◗ = direction vs ◗ = speed, ✦ = direction

DVs.

1. Response accuracy
2. Response time

Procedure

The procedure is designed to establish Crel and Cfunc properties for stimuli and assess their efficacy in specifying derived transformations of stimulus functions. The procedure can be decomposed into five phases: i) establishing Crels for the relations of same and different; ii) testing Crels for the relations of same and different; iii) establishing selective action of Cfuncs for speed and direction on transformations of functions via relations of same and different; iv) testing the selective action of Crels and Cfuncs established in the previous phase; v) testing for the generalization of the experimentally established Crels and Cfuncs.

Phases 1 and 2: establishing and testing Crels. A delayed MTS procedure used in a previous study (https://osf.io/w2n9g/) will be employed to establish the symbols ■ and ▼ as Crels for the relations of same and different. Participants will receive the instruction "Select the appropriately colored circle". At the beginning of each trail a Crel will be presented for 1000ms. After an SOI of 300ms, an arrangement of three circles of equal size, two of which will be the same color, that will serve as sample and comparison stimuli (e.g., a red circle at the top of the screen, a red circle at the bottom left, and a green circle at the bottom right). They will then select a comparison stimulus for each Crel (e.g., selecting the circle that is the same color as the circle at the top of the screen after seeing the Crel for same). The locations of the stimuli will be counterbalanced across trials. Selections for the left and right comparisons will be made with the 'E' and 'I' keys. Immediately after correct selections the message "Correct!" will appear in green text at the center of the screen for 500ms. The message "Wrong!" will appear in red text in the same location for 1000ms after incorrect responses. The MTS will present up to three thirty trial blocks, and will terminate early if participants achieve an accuracy score ≥ 17/20 across the previous 20 trials in a block. The established Crel properties will be tested in one 30 trial block presenting different colored circles and without response feedback. The experiment will terminate at this point for participants with accuracies < 20/30 on the Crel test.

Phases 3, 4 and 5: establishing and testing Cfuncs. Phases three, four and five present a series of trials in which both the speed and direction of racecar stimuli are relevant. There is a generic format common to these phases. Each trial consists of two parts, a sample racecar screen which is followed by the race screen. The layout of these components is shown in Figure 1. The sample racecar screen presents a sample racecar in the center of the screen, and allows participants to see how it performs (i.e., whether it moves to the left or right, and does so quickly or slowly). Selection boxes are presented beneath the sample racecar. Each selection box displays the sample racecar on the left, a racecar on the right, as well as two programmed Crels and two Cfuncs between the racecars. The selection boxes specify via the Crels and Cfuncs how each racecar will perform compared to the sample racecar. Within each selection box the Crels will always be located to the left of the Cfuncs, but the Cfuncs for speed and direction will be presented in the upper and lower positions within each selection box an approximately even number of times across trials. This sample racecar screen also presents a white start line, and a checkered finish line. The white start line remains in a fixed location at the center of the screen. The finish line is presented at the same location on both screens within a trial, but will appear at the left and right of the screen an approximately equal number of times across trials. This manipulation ensures that the direction of the racecars is relevant to selecting the winning racecar. This part of the study begins with a brief walkthrough that orients participants to these elements.

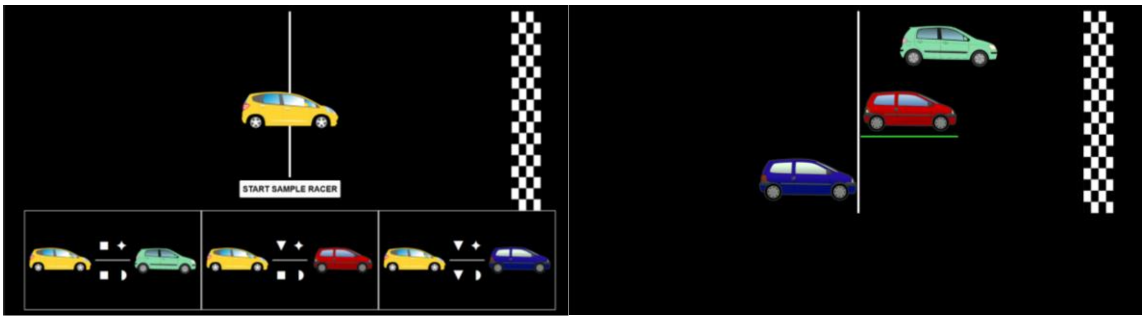

Figure 1. Screenshots of the sample racecar screen (left), and an screen shot of race from the race screen (right) from the Cfunc training task that employed in phases 3 and 4 of the experiment.

The Cfuncs for direction and speed will be established in different blocks using different kinds of trials. In this part of the experiment only two selection boxes appear beneath the sample racecar. In blocks establishing the Cfunc for direction all racecars will move slowly, and only the stimulus property of direction will vary across trials. In blocks establishing the Cfunc for speed all racecars will move forward, and only the stimulus property of speed will vary across trials. Participants will be exposed to one block targeting the Cfunc for direction, followed by the one block targeting the Cfunc for speed. This sequence of blocks will be repeated until a maximum of six blocks have been completed or the training criterion has been met in both kinds of block (i.e., ≥ 17/20 across the previous 20 trials in a block), whichever comes first. After completing each kind of block an instruction will inform them they are about to begin the next phase - “Phase complete! You are about to begin a new phase.” Participants will also receive additional training trials in which the racecar stimuli vary along both Cfunc dimensions. This will involve trials in which three selection boxes appear beneath the sample racecar and both the speed and direction of these three racecars vary within and across trials.

The selective action of the experimentally established Crels and Cfuncs will be tested in three ways. The first test will take the same format as the car race with three selection boxed described above, and will simply involve the removal of the programmed consequences for 60 trials. The second test will also employ the car race format, but will not present the programmed Cfunc stimuli for 30 trials. The third test is similar to the final test employed by Stewart, Barrett, McHugh, O’Hora, & Barnes-Holmes (2013) which assessed control selection responses. We will use a based test to assess whether the established Crels and Cfuncs generalize to relations between new stimuli, pictures of a bicycle, a truck, a helicopter and a plane oriented to the left or the right. Before completing the generalization test participants will rate each stimulus in terms of their speed via six item scale from “Very slow” to “Very fast”, and their direction as either “To the left” or “To the right”. On a given trial in the generalization test a pair of stimuli will be presented in four selection boxes similar to those described above for Cfunc training. The four selection boxes will differ in the precise constellation of Crels and Cfuncs that appear between the vehicle stimuli (see Figure 2). Participants will be required to select the appropriate box for each pair of stimuli and arrangement of Crels and Cfuncs. The generalization test will consist of 30 trials and feedback will not be provided.

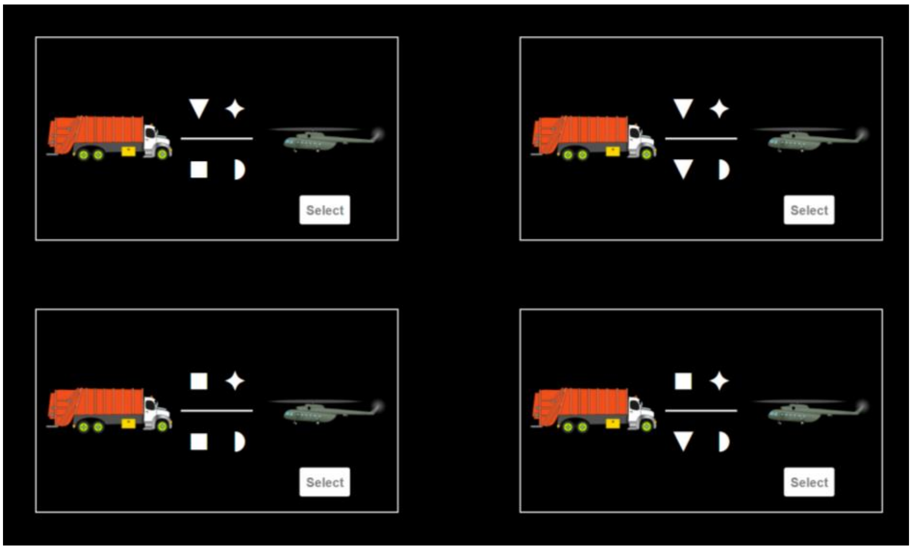

Figure 2. A screenshot of the generalization test in phase 5.

Measures

All measures implemented in lab.js (Henninger, Shevchenko, Mertens, Kieslich, & Hilbig, 2019).

Statistics of interest

1. Number of trials to complete Crel training
2. Number of correct selections in Crel test
3. Number of trials to complete Cfunc training
4. Number of correct selections in the 'racecar' Cfunc test
5. Number of correct selections in Cfunc generalization test
6. Number of participants achieving an accuracy score $\geq 83\%$ across both Cfunc tests

Hypotheses

H1. This procedure will produce accurate responding in the 'racecar' Cfunc test.

H2. More than 48% (i.e., 11/23) participants will achieve a test accuracy of 83% or greater in the Cfunc test employing the car race format.

Results

Analytic strategy

Data processing and exclusions.

Data will be processed and analysed in R.

Hypothesis tests.

H1. The primary hypotheses will be investigated with a one sample t-test with a 50% null and a one tailed alpha of 0.05. We predict that participants responding will be at more than 50% accuracy. Note that the 'racecar' Cfunc test provides three response options. 33% accuracy is chance level responding. However, this represents a low bar for demonstrating stimulus control via Cfuncs, and so we adopt a higher null.

H2. The secondary hypothesis will be investigated using a fishers exact test.

References

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