The selective action of cfunc control

Martin Finn & Jan De Houwer

Ghent University

Preregistration

Background

The concept of arbitrarily applicable relational responding was proposed to account for the behavioral impact of language and cognition from a behavior-analytic perspective (Hayes, Barnes-Holmes, & Roche, 2001). Since the earliest writings on arbitrarily applicable relational responding (Hayes & Hayes, 1989; Hayes, 1991) it has been an axiom that relational responding is contextually controlled by two types of stimuli; Crels and Cfuncs. The kind of relation that is brought to bear between stimuli is specified by a Crel, while the stimulus function that transforms in accordance with this relation is specified by a Cfunc. Hayes and Hayes provided a simple and compelling argument for the necessity of Cfunc control in a relational account of psychological functioning: "A given stimulus always has many functions. If all functions of one stimulus transferred to another and vice versa, there would no longer be two separate psychological stimuli, by definition. Thus, which functions transfer must be under contextual control." (Hayes & Hayes, 1989, p. 170).

Despite the critical role played by Cfuncs in behavioral accounts of relational responding, the vast majority of the research effort inspired by these accounts has focused on the relational activities controlled by Crels. This is understandable given that the powerful concept of stimulus relations greatly expanded the scope of behavioral accounts in the domains of language and cognition (Barnes-Holmes, Finn, Barnes-Holmes, & McEnteggart, 2018). The allure of the stimulus relations specified by Crels has meant that in general researchers have focused on demonstrating transformations of stimulus functions via stimulus relations of various kinds. In basic research this has typically involved establishing a behavioral function for a stimulus, establishing a relationship between this stimulus and another stimulus, and then testing this second stimulus for a transformed behavioral function derived from the first stimulus.

Critically, studies of relational responding often employed stimuli for which only one function is explicitly experimentally engineered – the function that would be transformed via a stimulus relation. In such a situation, where a stimulus has one function and it is transferred to another stimulus, observing the predicted transformation of function allows one to infer the impact of the stimulus relation

specified by a Crel. This situation does not explicitly establish Cfunc control and so does not allow one to infer directly the influence of a Cfunc. Strictly speaking of course, the stimuli employed in these studies often did possess multiple functions. Consider that a successful demonstration of transformation of function requires that a stimulus relation is established. The stimuli being related supported successful completion of a procedure for establishing stimulus relations, for which discriminative functions are required. Thus, in studies where the transformed function was not a discriminative function, the procedure must have involved the action of a Cfunc. Note the indirect nature of the inference involved here. The lack of direct evidence for Cfunc action appears to be a function of researcher goals (i.e., engineering derived transformations of stimulus function). This has dictated the functions for which researchers have tested (i.e., the transformed stimulus functions), and the functions over which they sought to exert experimental control (i.e., Crels and not Cfuncs).

We are aware of only one basic experimental study that clearly demonstrated the dual action of Crels and Cfuncs. This demonstration is provided by Stewart, Barrett, McHugh, O'Hora, & Barnes-Holmes (2013). The initial phases of the experiment established stimuli that functioned as Crels and Cfuncs. The final phase of the experiment involved matching to sample task. The sample and comparison stimuli were shape stimuli that contained dots. These stimuli differed in the type of shape, the number of shapes, as well as the number and size of the dots they contained. These stimuli could be related in terms of these four features, and the variance in these features across stimuli meant that each of the four features facilitated application of the relations same, more than and less than. In the matching to sample task participants were required to select the appropriate comparison(s) for each sample stimulus given the stimulus relation and stimulus feature specified by the Crel and Cfunc stimuli. Although this study provides an example of stimuli that specify the type of stimulus relation and stimulus feature along which two stimuli are related, it has its limitations. In this regard, it is worth noting that Stewart and colleagues (2013) did not present their work as an explicit demonstration of Cfunc control. Instead they describe their work as multiple contextual control over arbitrarily applicable

responding. Technically the authors' description is accurate. The contextual control in their study specifies the relevant stimulus relation and stimulus function for correct selection amongst comparison stimuli. It could be argued that this does not meet a technical standard of what constitutes a demonstration of Cfunc control of function transformation. That is, the alteration of the functions of one the stimuli being related via the dual action of Crels and Cfuncs. Nonetheless, the study by Stewart et al. provides what we regard as the best example of Cfunc control in the currently published literature.

As described above, a major reason for the relative lack of research on Cfunc control was the justified research interest in Crel control. A second reason for the lack of basic research on Cfunc control is that demonstrating Cfunc control is not straightforward. There are several necessary components to such a demonstration. First, the stimulus from which the transformed function derives must have at least two functions. Imagine a hypothetical scenario in which a source stimulus has only one function. If that function is transformed to another stimulus, this result provides no evidence of specification by a Cfunc. On the other hand, if that function is not transformed to another stimulus, the result could be explained by failure to establish a stimulus relation, in which case the result would be due to weak Crel control and not effective Cfunc control. Second, at least two of the source stimulus functions must be relevant to the situation in which the function transformation is assessed. Otherwise the absence of the influence of a given behavioral function at test may be attributed to the conditions of the testing context and not to the action of a Cfunc. Third, the Cfunc should be shown to specify the behavioral function in the context of at least two kinds of derived stimulus relations. This ensures that the Cfunc specifies the function that is transformed, and not, for example, that a single stimulus has functioned as both as a Crel and Cfunc. Finally, the precise function transformation specified by the Cfunc must occur when it is present and not when it is absent. This ensures that the stimulus identified as the Cfunc is indeed the effective Cfunc as claimed, and the function is not specified by some other element of the context.

We will examine the selective action of Cfunc control in a manner that satisfies these requirements. The procedure will involve source stimuli with two relevant stimulus functions, which can be transformed via two kinds of stimulus relation, presence and absence of Cfunc stimuli, and a test context in which both stimulus functions are task relevant. A generalization test of the engineered Cfunc stimuli will be conducted also. The basis of the procedure was partly inspired by a test procedure described by Belisle, Stanley, Schmick, Dixon, Alholail, Galliford, and Ellenberger (2020). In experiment 2 of their article, stimuli specifying "faster" and "slower" were tested in the context of two balls rolled at different speeds by the experimenter. In spite of many differences, the parallel between their procedure and our own will become obvious and the influence of this work should be acknowledged.

There are two motivations for conducting this work. The first of these is to provide a demonstration of a key component of arbitrarily applicable relational responding - the selective action of Cfunc control over derived transformations of functions. Relatedly, the study would contribute to the literature by providing an example of a procedure that produces Cfunc properties. This procedure could be adapted to study derived transformations of function. Investigating how Cfuncs may be efficiently established is likely to be informative for those engaged in basic and applied work on arbitrarily applicable relational responding.

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 have been exposed to 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.

Exclusion criteria. Incomplete data, responding "yes, exclude my data" on the self-exclusion question, failing to provide correct responses after 5 blocks of the Crel training phase, or failing the Crel test.

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 MTS procedure will be employed to establish Crels for the relations of same and different. Each trial will begin with a 300ms SOI. The sample stimulus, the word "SAME" or "DIFFERENT", will appear at the top center of the screen, and the comparison stimuli, the symbols ■ and ▼, will be presented at the bottom left and bottom right of the screen. The locations of the stimuli will be counterbalanced across trials. Selections for the left and right comparisons will be made with the 'D' and 'K' 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 five thirty trial blocks,

and will terminate early if participants achieve an accuracy score ≥ 17/20 across the previous 20 trials in a block.

Following the MTS the Crel properties of the symbols ■ and ▼ will be tested in a delayed MTS used in a previous study (https://osf.io/w2n9g/). First, 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). Participants will receive the instruction "Select the appropriately colored circle". 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). No response feedback will be provided. The established Crel properties will be tested in one 30 trial block.

Phases 3, 4 and 5: establishing and testing Cfuncs. Phases three and four present a series of trials in which both the speed and direction of racecar stimuli are relevant. 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 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.
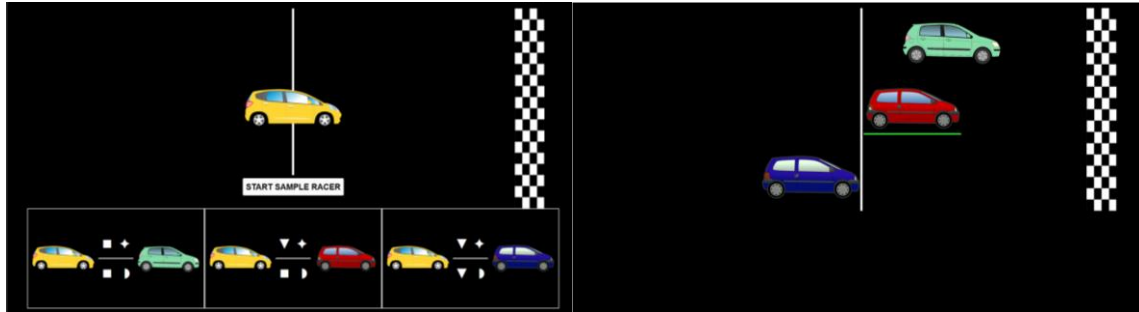

Figure 1. Screenshots of the sample racecar screen (left), and an screen shot of race from the race screen (right) from the Cfunc training task that employed in phases 3 and 4 of the experiment.

The car race task will present five different racecar stimuli are presented (four in each trial). The five racecar stimuli will appear equally often in each location throughout the study. Participants will also be instructed that "the performance of each racecar varies from one race to the next." Participants are required to select the racecar they think will win the next race. This will involve assessing the performance of the sample racecar, and how the performance of each racecar compares to the sample racecar, which is specified by the Crels and Cfuncs in each selection box. Consistent selections of the winning racecar would imply that the chosen racecars had acquired properties of speed and direction derived from the sample racecar. When participants have made their selection participants progress to the race screen where the racecar they selected is indicated by a green line. During the race screen, the racecars move across the screen. After a race is completed participants are informed whether they selected the appropriate racecar with the message "Your racecar won!" presented in green for 500ms or "Your racecar did not win!" presented in red for 1000ms. Blocks will consist of thirty races and will terminate early if participants achieve and accuracy score $\geq$ 17 across the previous 20 trials within a block.

The Cfunc for direction will be established before the Cfunc for speed. Initially only two selection boxes appear beneath the sample racecar. When establishing the

Cfunc for direction, the speed of the two racecars will bear the same relation to the sample racecar. Thus, only the Cfunc for direction will differ across racecars and across trials. When establishing the Cfunc for speed, the direction of the two racecars will be related to the sample racecar in the same way, and so only the Cfunc for speed will vary across racecars and trials. 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 two ways. The first test will take the same for as the car race with three selection boxed described above, and will simply involve the removal of the programmed consequences for 30 trials. The second 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.
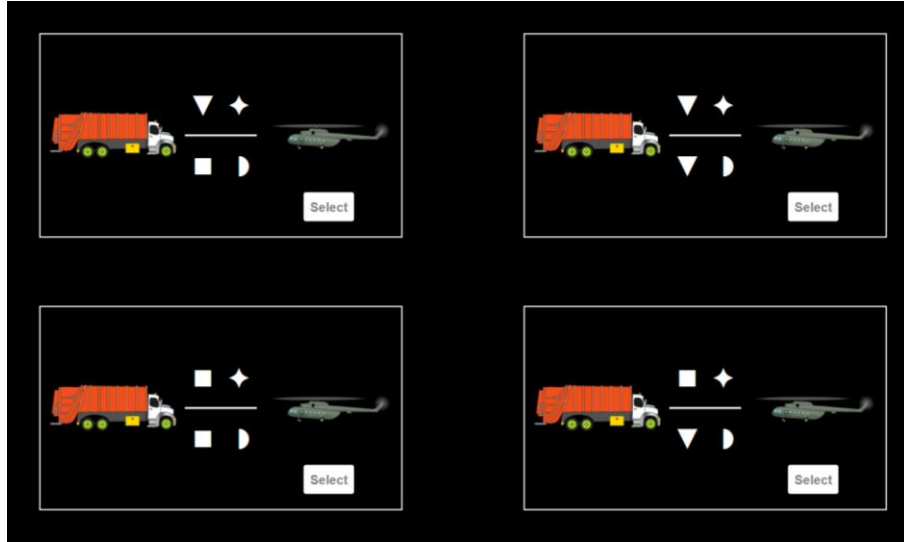
Figure 2. A screenshot of the generalization test in phase 5.

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 matching comparisons selected in Crel test

3. Number of trials to complete mixed 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 ≥ 51 out of 60 across both Cfunc tests

Hypotheses

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

Results

Analytic strategy

Data processing and exclusions. Data will be processed and analysed in R.

Hypothesis test.

H1. The primary hypotheses will be investigated with a one sample t-test with a 50% null and a one tailed alpha of 0.1. 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.

<div align="center">References</div>

Barnes-Holmes, D., Finn, M., McEnteggart, C., & Barnes-Holmes, Y. (2018). Derived stimulus relations and their role in a behavior-analytic account of human language and cognition. Perspectives on Behavior Science, 41(1), 155-173.

Belisle, Jordan, Caleb R. Stanley, Ayla Schmick, Mark R. Dixon, Amani Alholail, Megan E. Galliford, and Lindsey Ellenberger. "Establishing arbitrary comparative relations and referential transformations of stimulus function in individuals with autism." Journal of Applied Behavior Analysis 53, no. 2 (2020): 938-955.

Hayes, S. C. (1991). A relational control theory of stimulus equivalence. Dialogues on verbal behavior, 19-40.

Hayes, S. C., Barnes-Holmes, D., & Roche, B. (2001). Relational frame theory: A post-Skinnerian account of human language and cognition. New York: Kluwer Academic.

Hayes, S. C., & Hayes, L. J. (1989). The verbal action of the listener as a basis for rule-governance. In Rule-governed behavior (pp. 153-190). Springer, Boston, MA.

Henninger, F., Shevchenko, Y., Mertens, U., Kieslich, P. J., & Hilbig, B. E. (2019). Lab.js: A free, open, online study builder.

Lakens, D. ((2017). Equivalence tests: a practical primer for t tests, correlations, and meta-analyses. Social psychological and personality science, 8(4), 355-362.

Skinner, B. F. (1981). Selection by consequences. Science, 213(4507), 501-504.

Stewart, I., Barrett, K., McHugh, L., Barnes-Holmes, D., & O'Hora, D. (2013). Multiple contextual control over non-arbitrary relational responding and a preliminary model of pragmatic verbal analysis. Journal of the experimental analysis of behavior, 100(2), 174-186.