

**Function transformations of contingency components  
via stimulus-stimulus relations**

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**Experiment 2 preregistration**

**Author note**

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## Background

The purpose of the current experiments is to establish Crel and Cfunc functions for novel stimuli. The background for these experiments is provided in the preregistration document for Experiment 1 (<https://osf.io/na2jp/>). This experiment – Experiment 2 – is also informed by the results from Experiment 1. The method and results from Experiment 1 are summarized below to contextualize the method for Experiment 2 and the alterations made relative to Experiment 1.

In Experiment 1 20 participants completed training and testing of Crel and Cfunc functions in a novel bubble task. Participants were required to select between alternative bubble-clicking tasks that differed in the number of bubbles to be clicked within a time limit and the number of points each task returned for doing so. These between task differences in number of bubbles and points were indicated by four novel stimuli with the objective of establishing Crel and Cfunc properties for these stimuli such that they could indicate task differences involving more points, more bubbles, fewer points and fewer bubbles. Participants received points on any trial during which they successfully completed the bubble-clicking task. Importantly, when participant failed to successfully complete the bubble-clicking task they lost the number of points on offer during that task. For the purposes of monitoring performance, participant responses on a given trial were deemed accurate if they selected the pre-specified optimal task (e.g., more points, less bubbles, or more points and less bubbles than the alternatives) *and* successfully completed the subsequent bubble-clicking task. The training criterion (i.e., accuracy  $\geq 17/20$  across the previous 20 trials) was met by 11 of the 20 participants and one of the 20 met the testing criterion (i.e., accuracy  $\geq 50/60$ ). Statistical analysis of test accuracies versus a null of 50% accuracy indicated the procedure was unsuccessful in establishing Crel and Cfunc functions for novel stimuli  $M = 39$ ,  $SD = 22.2$ ,  $t(19) = -2.22$ ,  $p = 0.98$ , 90% CI = [32.4, 100], BF = 1.69.

Inspection of the data revealed that although the optimal task was evenly distributed across tasks involving more points and fewer bubbles, participants were more likely to select tasks involving fewer bubbles. This may have been because participants were very likely to successfully complete a task involving fewer bubbles

( $M = 97.8\%$ ,  $SD = 5.7\%$ ) and thus frequently earned points when selecting these tasks. In contrast, participants were on average less likely to successfully complete a task involving more points ( $M = 66.4\%$ ,  $SD = 26.7\%$ ). This is particularly important, because not only were participants less likely to be reinforced during these trials they were more likely to incur a loss of points, and one that was larger than those following other unsuccessful trials because of the increased points on offer. Another issue is that the differences in points offered by tasks may not have been readily discriminated by participants. During training tasks that differed in the number of bubbles offered 25, 30, or 35 points, tasks offering fewer points offered 15, 20, or 25 points, and tasks offering more points offered 35, 40, or 45 points. There is overlap between these sets of values which may have impeded discrimination of task differences, and played a role in the failure to establish Crel and Cfunc stimuli.

### **Alterations**

1. In an attempt to make reinforcement during tasks offering more points more likely, Experiment 2 will reduce the average number of bubbles to be clicked in each task by one. In Experiment 1, the number of bubbles presented to each participant was calibrated to their performance. The calibration procedure consisted of a number of bubble clicking tasks. Participants were provided up to 10 opportunities to complete the first trial. Each subsequent trial increased the number of bubbles to be clicked within this time window by two. The sequence terminated when the participant has failed to complete a trial. The number of bubbles a participant clicked in the final successful trial was the numeric set point for that participant. Experiment 2 will adapt this by subtracting one from the number of bubbles clicked in the final successful trial and taking that value as the numeric set point.
2. The differences in points offered by different tasks will be increased to facilitate discriminating these differences. Source tasks (see below) will offer 45, 50, or 55 points, tasks offering fewer points will offer 5, 10, or 15 points, and tasks offering more points will offer 95, 100, or 105 points.

## 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, or failing to complete any trial during the calibration.

### IVs.

1. Crel and Cfunc function:

► = more points, ■ = more bubbles, ♦ = less bubbles, and ▼ = less points

Vs

► = less bubbles, ■ = less points, ♦ = more points, and ▼ = more bubbles

### DVs.

1. Response accuracy
2. Response time

### Procedure

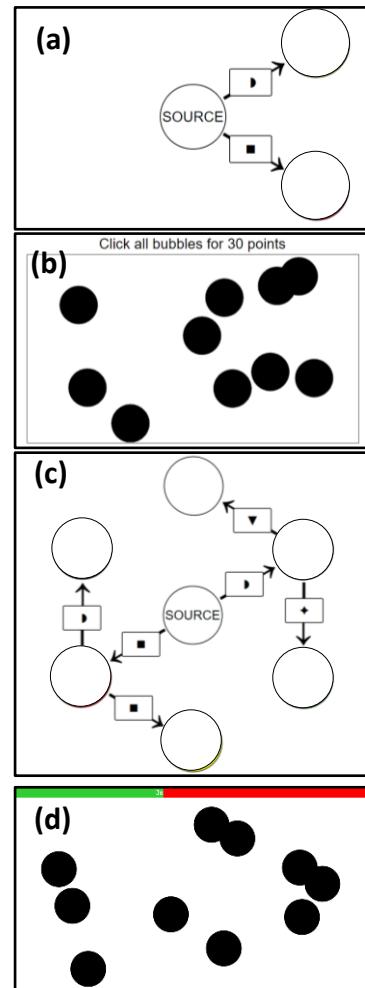
The procedure is designed to establish Crel and Cfunc functions for four stimuli, and assess the efficacy of these stimuli for specifying derived transformations of functions. The procedure centers on the bubbles task that is illustrated in Figure 1. The bubbles task involves a series of trials, across which participants earn points by choosing between bubble-clicking tasks on selection screens (Figure 1a and 1c) and then attempting to complete the bubble-clicking task they have selected (Figure 1d). Each of the bubble clicking tasks involves clicking a number of moving bubbles in a limited time window for a number of points. Time elapsed within this task is illustrated by a

timer bar that is initially green but becomes red in greater proportion with each passing second. The number of seconds remaining are indicated by a small white integer within the timer bar. Failure to click all of the bubbles within the time window results in no points being gained. Each trial ends with a feedback screen displaying the proportion of bubbles clicked, points earned in that trial, and the running points total. The goal is to earn as many points as possible. Critically, participants are provided with information about the task options. Participants are shown a miniature version of the source task (Figure 1b) as well as symbols that appear between the source and the task options (see Figure 1a and 1c). Each of the four symbols presented (i.e.,  $\blacktriangleright$ ,  $\blacksquare$ ,  $\blacklozenge$ , and  $\blacktriangledown$ ) covary with a particular difference between the miniature source task and the bubble-clicking task to which they lead. Specifically, each symbol indicates that the task option differs from the source task in one of four ways; the task involves more bubbles, or less bubbles, or offers more points, or less points for successful completion. Across trials the covariation of each symbol and a particular difference between the source task and the selected task ought to generate Crel and Cfinc functions for these symbols.

The procedure begins by presenting study guidelines, and collecting demographic data of age and gender. The bubbles task consists of three phases; phase 1) walkthrough and calibration of bubble-clicking tasks to the participant; phase 2) establishing Crels and Cfincs; phase 3) testing the established Crels and Cfincs.

**Phase 1: Walkthrough and calibration of bubble-clicking tasks.** The bubbles task begins with a walkthrough that describes the task to participants. Participants are informed they will complete a series of trials involving choices between tasks, and completion of the chosen tasks. They are shown an example selection screen

**Figure 1.** Two example choice screens and a task screen from the bubbles task.



the various elements of which are illustrated; the source, the miniature source task, the task options and the angles and positions they may occupy relative to the source, the presence of symbols that indicate how the task options compare to the SOURCE. The symbols for which Crel and Cfuc functions will be established are not presented in the walkthrough.

The calibration phase begins immediately after the walkthrough. The purpose of calibration is to ensure that changes in the number of bubbles within the task bear upon the likelihood of earning points. During calibration participants complete a series of seven trials in which the source task is the only available option. The first trial presents eight bubbles must be clicked within the five second time window. Participants are provided up to 10 opportunities to complete the first trial. Each subsequent trial increases the number of bubbles to be clicked within this time window by two. The sequence terminates when the participant fails to complete a trial. The numeric set point for a participant will be one less than the number of bubbles a participant clicks in the final successful trial. This set point can be 7, 9, 11, 13, 15, 17, or 19.

**Phase 2: Establishing Crels and Cfuns.** In this part of the task participants are provided with choices between two tasks that differ along task relevant dimensions (i.e., number of bubbles, number of points; Figure 1a). On each trial participants first view the miniature source task that displays a number of moving bubbles (i.e., the calibrated set point  $\pm 1$ ) and a message indicating the number of points on offer (i.e., 50 points  $\pm 5$  points). Participants cannot select the source task option, but must select one of the two other task options that displayed on each selection screen. The task options are presented at an equal distance from the source task, and can appear at  $30^\circ$ ,  $90^\circ$ ,  $150^\circ$ ,  $210^\circ$ ,  $270^\circ$ , and  $330^\circ$  angles relative to the source task. The precise location of each option, and its angle relative to the source task is counterbalanced across trials. The manner in which the properties of each task differ from the source task are specified by Crels and Cfuns. On each trial there is an optimal choice. To ensure this is the case participants are offered choices between the following pairs; more points or less points, more points or more bubbles, less bubbles or less points, and less bubbles or more bubbles. Note that the first option in each pair is

deemed the optimal choice. Upon selecting a task option participants are exposed to a bubbles task with the specified properties. Specifically, relative to the source, less bubbles means a 50% decrease in bubbles, more bubbles means a 50% increase the number of bubbles, more points increases the number of points by 50, and less points decreases the number of points by 40. These differences are relative to the values illustrated in the miniature source task in that trial. Responses in each trial are deemed correct when participants select the optimal choice and successfully complete the selected bubble task. A trial is deemed incorrect if a participant fails to fulfill either of these criteria. This phase comprises five 30 trial blocks, and terminates either upon completion of these five blocks, or upon reaching the training criterion of 17 or more correct trials across the previous 20 trials within a block.

**Phase 3: Testing the established Crels and Cfuncs.** In this part of the task participants complete trials involving task options multiple steps from the source. The format of the selection screen in these trials is illustrated in Figure 1c. The source is always presented in the center of the screen. The task options one step removed from the source appear at opposite sides of the source at 90° and 270°, 30° and 210°, and 150° and 330° angles relative to the source respectively. The task options two steps removed from the source appear at angles relative to these task options such that all task options appear equidistant from the source. The exact locations, and symbols appearing between the task options are counterbalanced across trials. As in phase 2, there is an optimal choice on each trial in phase 3. The optimal choice is always two-steps removed from the source and involves either 100 more points, 25% fewer bubbles, or 50 more points and 50% fewer bubbles. Responses are deemed correct when the optimal choice has been selected and the related task is successfully completed. Phase 3 involves two 30 trial blocks, and terminates upon completion of these trials. After phase 3 participants are asked to indicate what they think each of the Crel and Cfunk symbols mean. The experiment concludes with debriefing and payment.

## Measures

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

### Statistics of interest

1. Number of optimal choices selected in training
2. Number of bubbles tasks successfully completed in training
3. Number of trials to complete Cfunc training
4. Number of participants successfully completing training
5. Number of optimal choices selected during testing
6. Number of bubbles tasks successfully completed during testing
7. Number of participants successfully completing the test phase (i.e., selecting the optimal choice in  $\geq 50/60$  (i.e., 83%) of test trials)

### Hypotheses

**H1.** This procedure will produce accurate responding in the test of established Crels and Cfuncs.

### Results

#### Analytic strategy

**Data processing and exclusions.** Data will be processed and analyzed 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 0.05. We predict that participants responding will be at more than 50% accuracy. Note that the Crel and Cfunc test provides six response options. Thus, 16.7% accuracy is chance level responding. However, this represents a low bar for demonstrating stimulus control via Cfuncs, and so we adopt a higher null.

**References**

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