

**Instructing via relations: Function transformations of response and  
outcome functions of upcoming contingencies**

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*Pilot study report*

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The purpose of these studies was to develop the bubble task - a procedure for producing Crel and Cfunc stimuli (Hayes et al., 2001). A brief description of the task is provided here (see Method for a full description). Participants are instructed that their goal is to earn as many points as possible. Points can be earned by successfully clicking all the moving bubbles in a bubble-clicking task in a fixed time window. Points are lost when participants fail to successfully complete a bubble-clicking task (i.e., click all bubbles within the fixed time window). Each trial of the bubble task begins by presenting an animation of a source task that shows a number of moving bubbles and indicates a number of points. This screen also indicates how a number of alternative task options differ from this source task option with respect to the number of bubbles to be clicked and points these tasks offer. These between task differences are indicated by symbols that act as Crels and Cfuncs that specify transformations of number and points properties via the relations of more than and less than. On this screen participants must choose between the alternative task options (i.e., more or less bubbles or points). Upon a selection the chosen bubble-clicking task is initiated. The proportion of bubbles clicked and points earned in that trial are provided as post-trial feedback as is the running points total. The effort to accumulate points entails responding appropriately to the experimenter programmed Crels and Cfuncs which facilitates the generation of Crels and Cfuncs (Finn & De Houwer, 2021).

The bubble task allows for the specification of components of contingencies. The bubble-clicking component that is central to the bubble task engenders a fixed ratio reinforcement contingency – participants must click all bubbles within the time window to earn points. Before beginning a bubble-clicking task participants can choose between alternative task options. These task options differ in the precise formulation of the fixed ratio reinforcement contingency. Some task options result in more bubbles having to be clicked, and some result in fewer bubbles. These are differences in the response component of the contingency. Further, some task options offer more points for successful completion, and some offer fewer points for successful completion. These are differences in the consequence component of the contingency. Across trials of the bubble task each of these differences in contingencies relative to the source task are specified

by Crels and Cfuncs. The bubble task thus specifies transformations of functions where the functions undergoing transformation are components of contingencies. The functions that are transformed are the functions of the components of the target task, more specifically a response component (how many bubbles need to be pressed) and an outcome component (how many points can be earned). These functions are transformed by relating the upcoming task to a source task, more specifically, to the response and outcome components of the standard task. The way in which the source and target task are related is specified by Crel (that specify a relation of more or less) and Cfunc (that specify whether this relation applies to the response component or the outcome component). It should be noted that the target task does not employ cues to specify the contingency itself (i.e., it does not specify if-then relationships between behaviors and consequences). Instead, the reinforcement contingency within the task is directly experienced.

Reported here are two experiments investigating some variables influencing the establishment of novel Crels and Cfuncs in the bubble task. These two experiments constitute the initial attempts at using the bubbles task to establish Crels and Cfuncs that specify transformations of functions of the response and consequence components of reinforcement contingencies. Although conducted sequentially, these experiments differ in two details and will be presented together for the readers benefit. Ethical approval for these experiments was granted by the Ethics committee of the Faculty of Psychology and Educational Sciences at Ghent University. All experiments were preregistered and details of the preregistration as well as experimental scripts, data, and analysis scripts can be found on the osf (<https://osf.io/py9cz/>). Code for running the bubble task is freely available from the same repository.

## Experiments 1 and 2

Experiments 1 and 2 were the first deployments of the bubbles task to establish Crels and Cfuncs. These experiments informed the development of the task. The purpose of Experiment 1 was to collect data that would allow an initial assessment of its efficacy in establishing Crels and Cfuncs. These data could then inform alterations to that task in Experiment 2 that aimed to improve its efficacy. Following analysis of

the data from Experiment 1 two changes were made. The set point for the number of bubbles a participant could click (see below) was calculated differently (i.e., 1 less than the number of bubbles clicked in the final successfully completed trial of the calibration phase) and the size of difference in points offered by various tasks (i.e., less points meant 40 points less while more points meant 50 points more).

## Method

Data were collected online via Prolific Academic where participants were paid £7.50 for completing the procedure. The preregistered stopping rule for recruitment was 20 participants completing all phases of the procedure and indicating that their data could be included in the study. All participants were prescreened by Prolific Academic and indicated that they spoke English as a first language, and were aged between 18 and 65. No participant had previously participated in an experiment conducted by our research group.

### ***Participants***

20 participants (12 female, mean age = 41,  $SD = 13$ ) completed Experiment 1. 20 participants (12 female, mean age = 36,  $SD = 11$ ) completed Experiment 2.

### ***Procedure***

The procedure began by presenting study guidelines, obtaining informed consent, then collecting demographic data of age and gender. The bubbles task was then initiated. The bubbles task consists of three phases; phase 1) walkthrough and calibration of bubble-clicking tasks to the participant; phase 2) establishing Crels and Cfuns; phase 3) testing the established Crels and Cfuns.

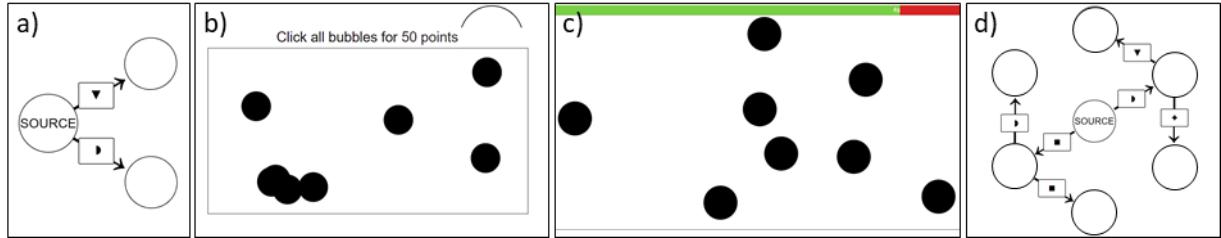
**Phase 1: Walkthrough and calibration of bubble-clicking tasks.** The bubbles task began with a walkthrough that described the task to participants. Participants were informed they would complete a series of trials involving choices between tasks, and completion of the chosen tasks. They were shown an example selection screen the various elements of which are illustrated; the source, the miniature source task, the task options and positions they may occupy relative to the source, the presence of symbols indicating how the task options compare to the source task. The

symbols for which Crel and Cfunc functions were to be established were not presented in the walkthrough. The calibration phase began immediately after the walkthrough. The purpose of calibration was to ensure that changes in the number of bubbles within the task bore upon the likelihood of earning points. During calibration participants completed a series of seven trials in which the source task was the only available option. The first trial presented eight bubbles to be clicked within the five second time window. 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 failed to complete a trial. The number of bubbles clicked in the final successful trial was the set point for that participant. This set point could be 8, 10, 12, 14, 16, 18, or 20. For Experiment 2 the possible set points were 1 less than each of these values to increase the likelihood of fulfilling the reinforcement contingency.

**Phase 2: Establishing Crels and Cfuncs.** In this part of the task participants were provided with choices between two tasks that differed along task relevant dimensions (i.e., number of bubbles, number of points; Figure 1a). On each trial participants first viewed the miniature source task that displayed a number of moving bubbles (i.e., the calibrated set point  $\pm 1$ ; Figure 1b) and a message indicating the number of points on offer (i.e., 30 points  $\pm 5$  points in Experiment 1, and 50 points  $\pm 5$  points in Experiment 2). The source task could not be selected, but the two other task options displayed on each selection screen could. The task options were presented at an equal distance from the source task, and can appear at 30°, 90°, 150°, 210°, 270°, and 330° angles relative to the source task. The precise location of each option, and its angle relative to the source task was counterbalanced across trials. The manner in which the properties of each task differed from the source task was specified by Crels and Cfuncs. On each trial there was an optimal choice. To ensure this is the case participants were 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 was deemed the optimal choice. Upon selecting a task option participants were exposed to a bubbles task with the specified properties (e.g., Figure 1c).

Specifically, relative to the source, less bubbles meant a 50% decrease in bubbles, more bubbles meant a 50% increase the number of bubbles. In Experiment 1 more points increased the number of points by 10, and less points decreased the number of points by 10. In Experiment 2 more points increased the number of points by 50, and less points decreased the number of points by 40. This was done to facilitate discriminations between outcomes associated with each cue. Responses in each trial were deemed correct when participants selected the optimal choice and successfully completed the selected bubble task. A trial was deemed incorrect if a participant failed to fulfill either of these criteria. This phase comprised five 30 trial blocks, and terminated 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.

Figure 1.



**Phase 3: Testing the established Crels and Cfuns.** In this part of the task participants completed trials involving task options multiple steps from the source. The format of the selection screen in these trials is illustrated in Figure 1d. The source was always presented in the center of the screen. The task options one step removed from the source appeared at opposite sides of the source at 90° and 270°, 30° and 210°, and 150° and 330° angles relative to the source respectively. This ensured that all task options appeared equidistant from the source. The exact locations, and symbols appearing between the task options were counterbalanced across trials. As in Phase 2, there was an optimal choice on each trial. The optimal choice was always two-steps removed from the source and involved either 25% fewer bubbles, 20 more points or 10 more points and 50% fewer bubbles. In Experiment 2 these final two options involved

100 more points, or 50 more points and 50% fewer bubbles. Responses were deemed correct when the optimal choice had been selected and the related task was successfully completed. Phase 3 involved two 30 trial blocks, and terminated upon completion of these trials. After Phase 3 participants are asked to indicate what they thought each of the Crel and Cfunc symbols mean. The experiment concluded with debriefing and payment.

## Results and discussion

Table 1.

	Training				Test				
	Acc.	Clicking task success	N trials	N of 20 meeting criterion	Acc.	Clicking task success	N of 20 acc. $\geq 50/60$	Opt. path choices	N of 20 Opt. path choices $\geq 50/60$
Exp 1	58%	72%	110	11	39%	83%	1	65%	3
Exp 2	68%	84%	66	16	56%	90%	3	78%	12

Note. Details of the seven preregistered outcome metrics for the four experiments. *Acc.* is accuracy calculated across all trials within a phase and requires successful completion of the subsequent bubble-clicking task. *N of 20 acc.  $\geq 50/60$*  is the number of participants achieving an accuracy score of greater than 50/60 by the *Acc.* metric. *Opt. path choices* is the number of selections of task-options along paths from the source that include only cues for “more points” and “less bubbles”.

Details of the nine outcome metrics can be found in Table 1. In Experiment 1, 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  $\geq 50/60$ ).<sup>1</sup> In Experiment 2, 16 of the 20 participants met the training criterion, while only three of the 20 participants met the testing criterion. Non-statistical comparison of Table 1 suggests that reducing the set-point by one succeeded in increasing the number of tasks completed in Experiment 2. Critically however, statistical analysis of test accuracies versus a null of 50% accuracy indicated the procedure was unsuccessful

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<sup>1</sup> Note that in the test phase selections of one of the six response options is deemed correct, and by this metric the probability a test accuracy score of more than 83% is  $p < 1 \times 10^{-29}$ .

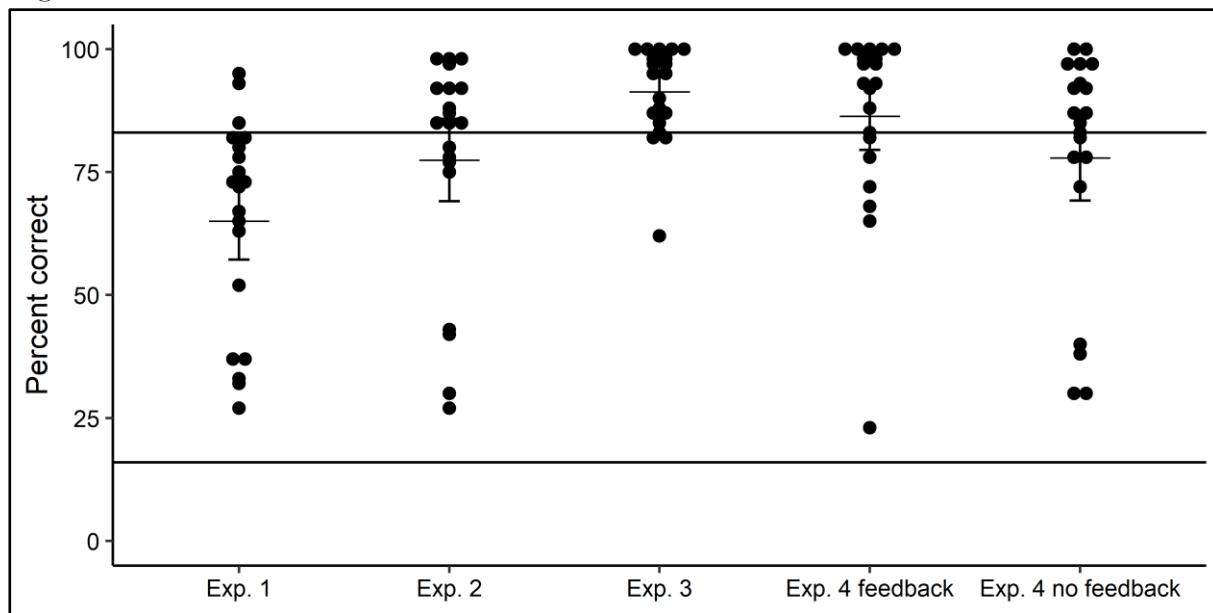
in establishing Crel and Cfunc functions for novel stimuli in Experiment 1 ( $M = 39$ ,  $SD = 22.2$ ,  $t(19) = -2.22$ ,  $p = 0.98$ , 90% CI = [32.4, 100], BF = 1.69) and Experiment 2 ( $M = 56$ ,  $SD = 26.2$ ,  $t(19) = 0.99$ ,  $p = 0.17$ , 90% CI = [48, 100], BF = 0.36).

Table 1 also presents an alternative metric of test accuracy that was not mentioned in the preregistration documents for Experiment 1 or Experiment 2 and the number of participants achieving accuracy  $\geq 50/60$  according to it. By the alternative metric accurate responses are selections of task-options along paths from the source that include only cues for “more points” and “less bubbles” (i.e., “more points”, “less bubbles”, “twice increased points”, “twice decreased bubbles”, “increased points and decreased bubbles”).<sup>2</sup> This metric is a better index of Crel and Cfunc control as it is not influenced by success in subsequent bubble-clicking tasks, and allows for participants selecting task-options one step removed from the source as in training. Statistical analyses of scores calculated by this metric were not pre-registered for Experiments 1 and 2, but are presented here for consistency with the subsequent studies. By this metric Experiment 1 were statistically greater than chance ( $M = 65$ ,  $SD = 21.3$ ,  $t(19) = 3.16$ ,  $p < 0.01$ , 90% CI = [58.7, 100], BF = 8.9, not preregistered), but not reliably at the individual participant level with only three participants achieving test accuracy scores  $\geq 50/60$ . In Experiment 2 accuracies were statistically significant ( $M = 78$ ,  $SD = 22.8$ ,  $t(19) = 5.38$ ,  $p < 0.00001$ , 90% CI = [70.7, 100], BF = 718, not preregistered) and 12 participants scored  $\geq 50/60$  at test. These data are presented in Figure 2. Finally, the functions of the four symbols were correctly identified by X participants in Experiment 1, and X participants in Experiment 2 (see Appendix A below).

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<sup>2</sup> By this metric selections of two of the six possible response options are deemed correct, and the probability a test accuracy score of more than 83% is  $p < 1 \times 10^{-15}$ .

Figure 2.



Note. Individual participant percentages for selections of task-options along paths from the source that include only cues for “more points” and “less bubbles”. Group means for each condition and associated 90% confidence intervals are presented also.

On trials where the optimal choice was not selected, comparisons were made between the option that was selected and the available task options. This was done to assess whether task options deemed by the experimenter to be appetitive and aversive were actually so. When doing this the selected sub-optimal task could have involved more bubbles or offered fewer points than the alternatives.<sup>3</sup> In Experiment 1 an average of 50% of chosen tasks offered fewer points than alternatives, and 31% of chosen tasks involved more bubbles than alternatives. A Welch two sample t-test ( $t(32.27) = 2.84$ ,  $p < 0.01$ , 90% CI = [7.8, 30.4], BF = 581, not preregistered) indicated that tasks involving more points were more aversive than task involving fewer bubbles. In Experiment 2 an average of 33% of chosen tasks offered fewer points than alternatives, and 24% of chosen tasks involved more bubbles than alternatives. However, a Welch

<sup>3</sup> In making such comparisons the relative difference between choices offering more bubbles and choices fewer points is interpretable, because on average across trials the optimal task (i.e., one of the alternatives) was equally likely to involve fewer bubbles or more points. Absolute scores are not interpretable because some trials presented options that were optimal in one respect but sub-optimal in another (e.g., more points and more bubbles, or less bubbles and less points) and not choosing these may have been appropriate.

two sample t-test ( $t(37.88) = 1.26$ ,  $p = 0.22$ , 90% CI = [-3.2, 21.8], BF = 7.5, not preregistered) indicated these alternatives were not differentially aversive. Across these experiments the tendency in trials where participants did not select the optimal task, was for participants to choose tasks that offered fewer points than they were to choose tasks that involved more bubbles than the alternatives. That is, participants were more likely to avoid trials involving more points, than they were to avoid trials involving fewer bubbles. Participants choices may have reflected that trials involving more points also involved a risk of losing a larger number of points. Inconsistency in the point-loss contingency across task-options appears to have introduced an unwanted source of behavioral control.

### General Discussion

The aim of the current studies was to establish Crels and Cfuncs that specify transformations of functions of the response and consequence components of reinforcement contingencies. Experiments 1 and 2 were initial and unsuccessful efforts at achieving this aim. These experiments were informative however. Results from Experiment 1 indicated that the calibrated set point for bubble-clicking task was too demanding, and results from both experiments suggested that inconsistency in the point loss contingency rendered task-options involving more points more aversive than desired.

### References

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## Appendix A

Participant	◐ meaning	█ meaning	♦ meaning	▼ meaning
1	most bubbles	second least bubbles	second most bubbles	the least bubbles
2	Increase bubbles	Decrease bubbles	Same amount	Decrease by half
3	More bubbles	more amount needed	Less amount needed	Less bubbles
4	square	inverted triangle	half circle	star
5	Lots of bubbles	Ok amount of bubbles	Ok amount of bubbles	Lowest amount of bub
6	most bubbles	little bit less	half	least amount
7	more bubbles	covered bubbles	overlapping bubbles	fewer bubbles
8	Total amount	Total amount/3	Total amount/2	Total amount/5
9	Most difficult	More difficult	Less difficult	Least difficult
10	square	triangle	half moon	STAR
11	more bubbles to pop	more bubbles to pop	less bubbles to pop	similar to source
12	Moderate difficulty	Crazy difficult	Dead easy	Moderate difficulty
13	fairly hard	hard	easy	very hard
14	Not too many bubbles	Fewer bubbles	Medium amount of bub	
15	triangle	half circle	star	
16	most	medium plus	smallest	medium
17	harder boxes	more boxes	less boxes	fewer boxes
18	less bubbles	downward	No idea	more bubbles
19	It was the second ea	It was the hardest	it was the easiest	it was third easiest
20	fast moving sequence	slowed down	very slow	fast moving

Meaning of the four novel stimuli that were programmed as Crels and Cfuncs in Experiment 1.

Participant	◐ meaning	█ meaning	♦ meaning	▼ meaning
1	MORE BUBBLES	DIFFICULT TASK	LESS BUBBLES	LESS DIFFICULT
2	increase amount	decrease value	increase value	decrease amount
3	theyre going down	a few dots	many dots	
4	Diffcult	Fast?	Lesser/Easier	Slow?
5	lot of bubbles	some bubbles	could go either way	fewest bubbles
6	more dots	faster	?	less dots
7	square	triangle	crescent	star
8	Reduces points	Increases speed	Doubles the points	Halves the bubbles
9	Doubles Bubbles	Halves Points	Doubles Points	Halves Bubbles
10	has less points	has more balls	sometimes has 0	most difficult
11	box	arrow	half moon	star
12	don't remember, bad	hard 100 points?	easy 50 points	medium 95 points?
13	add to amount	little slower	half of the amount	slower
14	more	more	slow	slow
15	No idea	I don't know	I have no idea	Sorry, don't know!
16	Increases bubbles	Speeds up.	Reduces bubbles.	Slows bubbles.
17	low points	lots of bubbles	Half bubbles	lots of points
18	less points	more bubbles	less bubbles	more points
19	pays you lss	x3 number of balls	1/2 number of balls	random
20	Less Amount Subtract	Not Sure	Half bubbles	Not Sure

Meaning of the four novel stimuli that were programmed as Crels and Cfuncs in Experiment 2. Rows with four verbal reports deemed correct are shaded.