**Documentation for data from McCormack Simms McGourty Beckers QJEP**

This data file gives the data reported in McCormack, T., Simms, V., McGourty, J., & Beckers, T. (2013). Encouraging children to think counterfactually enhances blocking in a causal learning task. Quarterly Journal of Experimental Psychology, 66, 1910-1926.

Data is provided in an excel file with the variables labelled.

**Experiment.** According to a higher-order reasoning account, inferential reasoning processes underpin the widely-observed cue competition effect of blocking in causal learning. The inference required for blocking has been described by as modus tollens (if p then q, not q therefore not p). Young children are known to have difficulties with this type of inference, but research with adults suggests that this inference is easier if participants think counterfactually. In this study, 100 children aged 4-5 and 6-7 years were assigned to two types of pretraining groups. The counterfactual group observed demonstrations of cues paired with outcomes and answered questions about what the outcome would have been if the causal status of cues had been different, whereas the factual group answered factual questions about the same demonstrations. Children then completed a causal learning task. Counterfactual pretraining enhanced levels of blocking as well as modus tollens reasoning but only for the younger children. These findings provide new evidence for an important role for inferential reasoning in causal learning.

**Participants.** One hundred children took part in the study: fifty-one 4-5-year-olds (mean age = 65 months, range = 59 to 71 months) and forty-nine 6-7-year-olds (mean age = 78 months, range = 72 to 83 months). These children were recruited and tested individually in their schools. Testing took place over two separate testing sessions, each lasting around 25 minutes. Children from both age groups were randomly assigned to either a control (*N* = 49) or counterfactual (*N* = 51) pretraining group.

**Materials.** The causal learning task involved a purpose-built toy robot. The “tummy” of the robot had a transparent Perspex center and along both the right and left sides of the center were two semi-opaque light boxes that contained battery-powered LED lights. The bottom half of each light box was pink and the top half was red. There was a hidden speaker inside the robot. There was a movable platform in the robot’s mouth that toy foodstuffs could be placed on. When the robot’s nose was pressed, the platform moved downwards into the robot’s tummy and tilted, dropping any foodstuffs on it into the robot’s tummy. After this one of three responses occurred: weak, strong, or no response. A weak response consisted of the bottom part of the robot’s tummy lighting up along with a quiet, low noise. A strong response consisted of all of the robot’s tummy lighting up, along with a loud, high noise. These responses lasted for 3 s, following which the experimenter removed the food-stuff(s) from the robot’s tummy through a hole at the back of the robot. The platform returned to the start position (the robot’s mouth) automatically. The robot’s responses were controlled by an input file selected by the experimenter from a computerized program on a laptop. There were 7 sets of 5 foods, one of which was a training set.

Procedure. **Initial pretraining phase.** Participants were introduced to the robot and were shown that pressing the robot’s nose caused any foodstuffs placed on the platform to drop into his tummy. The additivity of outcomes was demonstrated using the series of trials shown in Table 1a (see below). Each demonstration was repeated, and which foodstuff was used for each cue (F-I) was varied between participants. When a weak outcome occurred, the experimenter described the robot’s responses as “a bit of his tummy lighting up” and when a strong outcome occurred, the experimenter described this as “all of his tummy lighting up”. In this part of pretraining, children were asked a series of comprehension questions in order to ensure that they understood the additivity of outcomes.

**Factual and Counterfactual pretraining.** All children experienced four additional pretraining scenarios. These are displayed in Table 1b. Children were given two tasks where the outcome to the compound was weak and two tasks where the outcome to the compound was strong. The order of presentation of these scenarios was counterbalanced between children.

***Counterfactual pretraining group.***

*Weak outcome.* After the child observed the two element and the compound trials the experimenter stated “We know that food J makes part of the robot’s tummy light up and food K doesn’t make the robot’s tummy light up. So when we put food J and K into the robot’s tummy together only part of the robot’s tummy lit up.” The experimenter then introduced the counterfactual component of the pretraining: “Now I want you to imagine something different. I want you to imagine that food K *was* a food that makes part of the robot’s tummy light up as well. Ok, so imagine that both food J and food K were foods that make part of the robot’s tummy light up by themselves. Ok, so are you imagining that both J and food K were foods that make part of the robot’s tummy light up by themselves?” The child was then asked a counterfactual question: “What would have happened when we put both food J and food K in the robot’s tummy together?” If the child answered that all the robot’s tummy would have lit up, the experimenter confirmed that they were correct. In a small minority of cases the child answered incorrectly that part of the robot’s tummy would have lit up. When this occurred, the experimenter reminded children about the additivity of outcomes and then repeated the question a single time. Children were given two of these pretraining tasks.

*Strong outcome.* After the child observed the two elements and the compound trials the experimenter stated “We know that both foods L and M make part of the robot’s tummy light up on their own. So when we put both food L and M into the robot’s tummy together they made all of the robot’s tummy light up.” Once again, the experimenter introduced the counterfactual component of the pretraining: “Now I want you to imagine something different. I want you to imagine that food L *wasn’t* a food that makes part of the robot’s tummy light up. Ok, so imagine that food L wasn’t a food that makes part of the robot’s tummy light up by itself and food M was a food that makes part of the robot’s tummy light up by itself . Ok, so are you imagining that L wasn’t a food that makes part of the robot’s tummy light up by itself and food M was a food that makes part of the robot’s tummy light up by itself?” The experimenter then asked the counterfactual question “What would have happened when we put both food L and food M in together?” If the child answered that part of the robot’s tummy would have lit up, the experimenter confirmed that they were correct. In a small minority of cases, the child answered incorrectly that all of the robot’s tummy would have lit up. If this occurred, the experimenter reminded children about the additivity of outcomes and repeated the question once. Children were given two of these pretraining tasks.

***Factual pretraining group.***Children in the factual group observed identical pretraining trials to children in the counterfactual group, shown in Table 1b. However, these children were not asked the counterfactual questions. Instead, the following factual questions were asked to this group.

*Weak outcome.* After the child had observed the element and compound cues the experimenter stated “We knowthat food J makes part of the robot’s tummy light up and food K doesn’t make the robot’s tummy light up.” The experimenter then asked the factual question “What happens when we put both food J and K into the robot’s tummy together?” Children never answered these questions incorrectly.

*Strong outcome.*After the child had observed the element and the compound cues the experimenter stated “We know that both foods L and M make part of the robot’s tummy light up on their own.” The experimenter then asked “What happens when we put both food L and M into the robot’s tummy together?” Children never answered these questions incorrectly.

**Training phase.** Training trials immediately followed the pretraining phases and followed the protocol in Table 1c. Note that for each task, the compound phase includes a pair of control cues, C and D. Unlike the experimental cue B, neither of these cues was paired with the outcome on its own. Each participant completed 6 tasks: 3 blocking and 3 unovershadowing tasks. In each task, each trial shown in Table 1c was given 3 times, with the order of presentation of trials within each phase varied. Thus, for each task participants observed 12 trials in total before being asked test questions, with the presentation order of blocking and unovershadowing tasks counterbalanced.

Each task used a new set of foodstuffs, and, within each set, foodstuffs were counterbalanced in terms of which element they represented (A-D). Element E was a filler item that was included to ensure that there was at least one cue per blocking trial that was not paired with an outcome.

**Test phase.** Testing followed immediately after the training phase. Once children had observed all of the trials for any given task, the following questions were asked “Is (food name B, e.g., cheese) a food that makes the robot’s tummy light up?” and “Is (food name C, e.g., bread) a food that makes the robot’s tummy light up?” The order of the questions (B or C) was counterbalanced, and children were required to give a yes or no response. Children were also asked a forced-choice question: “If you had to choose one of these foods to make the robot’s tummy light up, which one would you choose (experimenter holds out B and C)?” Children could either name or point to one of the foods (control or experimental). No feedback was given to participants.

In the first testing session, children completed 3 cue competition tasks and 2 reasoning questions (see below). In the second testing session, they were given a brief reminder of the additivity pretraining, and then factual or counterfactual pretraining was refreshed by giving children two tasks identical to those used in pretraining in the first session (one with a weak outcome and one with a strong outcome). After this, children completed the remaining 3 cue competition tasks and answered the final 2 reasoning questions.

**Reasoning questions.** All children also answered two disjunctive and two modus tollens reasoning questions related to the operation of the robot, with new foods used for each question.

***Modus tollens questions*.** Children initially observed that a compound of two novel foods made part of the robot’s tummy light up a single time. The experimenter then stated:“Look, when we put food N and O in the robot’s tummy together part of the robot’s tummy lights up.” The experimenter then asked “Do both of the foods (hold up N and O) or only one of the foods make the robot’s tummy light up?”Answering this question requires children to reason that if both foods are causal, the whole of the robot’s tummy would light; it did not, so both cannot be causal (a modus tollens inference).

***Disjunctive questions.*** Children initially observed that a compound of two novel foods made part of the robot’s tummy light up a single time. The experimenter stated “Look when we put food P and Q in the robot’s tummy together part of the robot’s tummy lights up.” The experimenter then asked “One of these foods (hold up P and Q) doesn’t make the robot’s tummy light up. Does the other food make the robot’s tummy light up?” Answering this question involves reasoning that because either P or Q must be causal, and one of them is not causal, the other food must be causal (a disjunctive inference).

**Table 1**

*(a) Initial Pretraining, (b) Factual/****C****ounterfactual Pretraining, and (c) Experimental Design.*

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| 1. Initial Pretraining | | |
|  | F+/G-/H+/I-/FG+/FH++ | |
| 1. Factual/Counterfactual Pretraining |  | |
| Weak outcome | J+/K-/JK+ | |
| Strong outcome | L+/M+/LM++ | |
| 1. Experimental Design | | |
| Task | Phase 1 | Phase 2 |
| Blocking | A+, E- | AB+/CD+ |
| Unovershadowing | A-, E+ | AB+/CD+ |

*Note*. - indicates no outcome, + indicates a weak outcome, ++ indicates a strong outcome. C items were controls; E items were fillers and ensured that there was at least one demonstration in which the outcome did not occur per trial. Trials in both pretraining phases were shown twice. Trials in each of the tasks at test were shown three times.

**Results**

The data file gives the variables as follow:

* Age in months
* Condition ( 1= control, 2 = experimental)
* Modus Tollens reasoning scores (0-2)
* Disjunctive reasoning scores (0-2)
* Blocking difference scores (measure of whether children showed blocking on the causal learning task)
* Unovershadowing difference scores (measure of whether children showed unovershadowing on the causal learning task)