

# Observations vs. Interventions in Causal Induction: Heuristics in the Discrete and Continuous Paradigm Experiments

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## Abstract

A descriptive model for covariation detection, the dual factor heuristic (DFH), has been proposed. While observation based covariation detection is an important initial stage of causal induction, intervention is indispensable to identify genuine causal links. An experiment examined DFH's descriptive power in an environment where people manipulate causal events. DFH fit the data of the intervention task as well as the observation task.

Acquiring causal knowledge is crucial for living adaptively in continuously changing environments because it brings the advantage of predicting the future. Discovering candidates for cause from a vast number of irrelevant events is an important initial stage of causal induction. Assessing covariation information based on a contingency table, as shown in Table 1, can be useful to screen out irrelevant events.

Hattori (2003) proposed *dual factor heuristic* (DFH), a descriptive model of covariation detection. Hattori and Oaksford (2006) evaluated 40 models including the DFH against past data in the literature and showed that DFH best fit the data. DFH is based on an index defined as follows:

$$H \triangleq \lim_{d \rightarrow \infty} \phi = \sqrt{P(e|c)P(c|e)}. \quad (1)$$

Correlation, however, does not generally imply causation. To identify genuine causes, we have to *intervene* in correlated events (Pearl, 2000). For example, we must prevent the rooster from crowing (i.e., intervene on a causal candidate) to prove that its crow does not cause the sun to rise. Recently, some researchers have suggested that the cognitive processes involved in intervention differ from those of observation (e.g., Sloman & Lagnado, 2005). This distinction is directly related to the two different paradigms in causal judgment experiments: the *discrete* and the *continuous paradigms* (Anderson & Sheu, 1995).

DFH may be concerned with an observation based process because it approximates  $\phi$ , a well-known normative statistic of correlation. On the other hand,  $\Delta P$ , defined as follows, may describe an intervention activity, although it was once proven to be a poor predictor of covariation assessment (Hattori, 2003):

$$\Delta P \triangleq P(e|c) - P(e|\neg c). \quad (2)$$

Thus the experiment detailed below was conducted to examine this idea.

**Table 1**

A  $2 \times 2$  Contingency Table Containing Covariation Information

		Effect Event	
		Present ( $e$ )	Absent ( $\neg e$ )
Cause Event	Present ( $c$ )	$a$	$b$
	Absent ( $\neg c$ )	$c$	$d$

## Method

### Tasks

Participants were asked to assess the strength of the causal relationship between using a particular type of fertilizer and subsequent plant blooming. In the *Observation Task*, participants only observed a sequence of scenes (a total of 12–15) in which fertilizer (cause) and plant blooming (effect) are either present or absent. The cell frequencies of  $2 \times 2$  contingency tables used in this task are shown in Table 2 (left). Each participant was presented with 12 stimuli in a randomized order, each corresponding to a line in the table.

In the *Intervention Task*, two probabilities were assigned per stimulus, as shown in Table 2 (right): a probability that the plant blooms ( $e$ ) when fertilizer was used ( $c$ ),  $P(e|c)$ , and a probability that the plant blooms ( $e$ ) when fertilizer was not used ( $\neg c$ ),  $P(e|\neg c)$ . Each participant inspected 30 cases for each stimulus. In each case, he or she chose to either use or not use fertilizer and observed plants bloom or not bloom. Given participant's choices, the plant bloomed according to the probabilities in Table 2 (right).

### Procedure

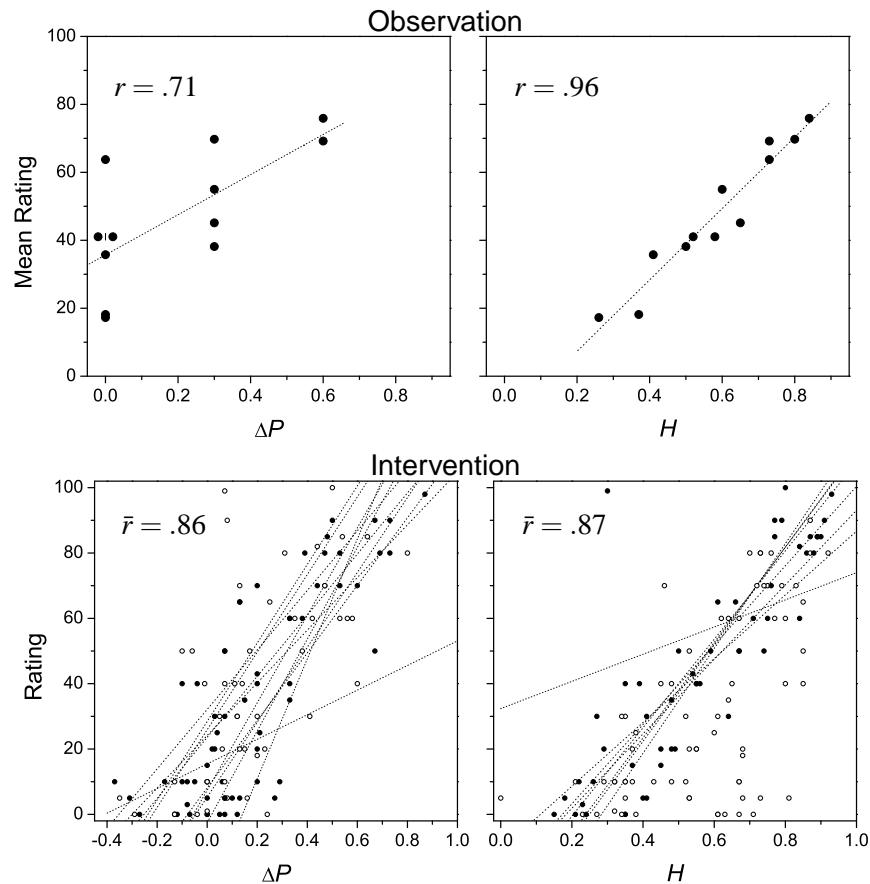
The experiment was conducted on personal computers. Every time a participant clicked the mouse, a new picture was displayed in a randomized order. After observing a series of situations (i.e., pictures), participants rated the subjective strength of the causal relationship with a value between 0 (completely unrelated) and 100 (completely related). This cycle was repeated for all stimuli shown in Table 2.

### Participants and Design

A total of 39 undergraduate students from Ritsumeikan University participated in the experiment as unpaid volunteers. They were randomly assigned either to the Intervention Task ( $n = 20$ ) or to the Observation Task ( $n = 19$ ).

**Table 2**  
Stimuli in Observation (Left) and Intervention (Right) Tasks

No	$a$	$b$	$c$	$d$	$\Delta P$	$H$	No	$P(e c)$	$P(e \neg c)$	$\Delta P$
1	2	8	1	4	.00	.37	1	.20	.20	.00
2	1	4	2	8	.00	.26	2	.50	.20	.30
3	5	5	1	4	.30	.65	3	.50	.50	.00
4	2	2	2	8	.30	.50	4	.80	.20	.60
5	4	4	2	2	.00	.58	5	.80	.50	.30
6	2	2	4	4	.00	.41	6	.80	.80	.00
7	8	2	1	4	.60	.84				
8	4	1	2	8	.60	.73				
9	8	2	2	2	.30	.80				
10	4	1	5	5	.30	.60				
11	8	2	4	1	.00	.73				
12	4	1	8	2	.00	.52				



**Figure 1.** Participant ratings of causal strength in Observation (upper panels) and Intervention (lower panels) Tasks. Regression lines drawn in the lower panels are for participants whose ratings significantly correlated with the index ( $p < .05$ ).

## Results

Figure 1 shows the relation between index values and participant ratings. Regarding the Observation Task where all participants received exactly identical stimulus sets, stimulus-by-stimulus mean ratings were calculated and shown as a plot. The correlation of mean ratings was much stronger with  $H$  ( $r = .96$ ) than with  $\Delta P$  ( $r = .71$ ).

In the Intervention Task, each participant experienced different stimuli (i.e., cell configurations) according to her own intervention frequencies and the randomness of the computer's responses to her actions. Consequently, every rating is plotted as a single point in the lower panels of Figure 1. Correlation coefficients were calculated by participants and averaged based on the Fisher transformation. The results indicate that participant ratings have as much correlation with  $\Delta P$  ( $\bar{r} = .86$ ) as with  $H$  ( $\bar{r} = .87$ ).

## Discussion

The results suggest differences in causal cognition between situations where we only observe the occurrences of events and situations where we ourselves intervene in the system. Nevertheless, DFH well described the data on the Intervention Task, as in the case with  $\Delta P$ .  $\Delta P$  is a normative model of the effect of intervention, as the first term of Equation 2 is the probability of the effect being present when a person *do*

the possible cause, while the second term is the probability when she does not *do* this action. In contrast, DFH is a sophisticated *shortcut* to detect covariation between events via observation (Hattori & Oaksford, 2006). The results might be caused by an individual difference in *strategy shifting*. Even if a heuristic is useful in many situations, it may not be useful in other situations. The degree of adherence to the heuristic can be optimized at a different (meta)cognitive level.

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## References

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