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Base-rate neglect based on base-rates in experience-based contingency learning

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Abstract

Predicting criterion events based on probabilistic predictor events, humans often lend excessive weight to predictor event information and insufficient weight to criterion event base-rates. Using the matching-to-sample paradigm established in studies on experience-based contingency learning in animals, Goodie and Fantino (1996) showed that human judges exhibit base-rate neglect when sample cues are associated with response options through similarity relations. In conceptual replications of these studies, we demonstrated similar effects when sample cues resemble the response options in terms of base-rates skewed in the same direction rather than physical similarity. In line with the pseudocontingency illusion (Fiedler & Freytag, 2004), predictions were biased toward the more (less) frequently rewarded response option following the more (less) frequently presented sample cue. Thus, what is a demonstration of base-rate neglect from one perspective turns out to reflect the judges' sensitivity to the alignment of skewed base-rate distributions.

Base-rate neglect based on base-rates in experience-based contingency learning

When adult humans make probabilistic predictions from predictor events, they tend to under-weigh the base-rates of the criterion events (Tversky & Kahneman, 1982). Instead they make predictions that tend to follow the case-specific information conveyed by the predictor. For example, when the predictor is an eye witness's testimony that a suspect car was blue, they tend to belief that it actually was blue, even in the face of evidence that in the particular town the base-rate of blue cars is low. Thereby they under-weigh the base-rate of the criterion event, the modal color of cars in that town, and act as if merely the contingency between predictor and criterion provided relevant information.

Recently, Goodie and Fantino (1996, 1999) translated this *base-rate neglect* into an operant learning paradigm, in which information conveyed by predictor events (samples) and criterion base-rates is to be learned and utilized across multiple trials. In several studies these authors showed that physical similarity between samples and response options facilitates the neglect of criterion base-rates. For example, they used the words 'blue' and 'green' as predictor samples and squares with blue and green hues as response options. This similarity manipulation resulted in a tendency to match the color of the predicted option to the color of the sample, thereby counter-acting the tendency to predict the option with the higher base-rate.

Notably, what such prediction behavior implies is that a contingency is assumed between samples and response options. According to Allan (1993), a cognitively represented contingency manifests itself in different conditional response probabilities for different predictors. This was the case in Goodie and Fantino's (1996) studies, as judges chose the similar response options at a higher rate than the dissimilar option.

Thus, Goodie and Fantino found evidence for contingency-based predictions even when criterion events were merely similar to, but not statistically contingent on predictor samples. Extending this idea, we introduce another source of inferred contingencies that is independent of genuine statistical contingencies. We propose that when the base-rates of both event types (the occurrence of the samples and the response options being the correct prediction) are skewed, human judges tend to relate the frequent events (i.e., the prevalent sample with the prevalently correct response option) and the infrequent events (i.e., the infrequent sample with the infrequently correct response option). Thus, we propose the alignment of skewed base-rates as a source of inferred contingencies in addition to actual contingencies that may hold across the stimulus series and in addition to potential similarities between samples and response options within individual trials.

Our reasoning is based on the so-called *pseudocontingency* (PC) illusion (Fiedler, Freytag, Forgas, Williams & von Hippel, 2003; Fiedler & Freytag, 2004; Fiedler, Freytag & Unkelbach, 2007). Several studies on PC effects confirm that, in the absence of a genuine contingency, two variables appear to be related when the distributions of their values are skewed in the same direction. For example, imagine a teacher who, at the beginning of the school year, meets the parents of a new class. Without knowing which student belongs to which parent, he realizes that in this class the proportion of families with a weak socioeconomic background is particularly high. Later, in the course of teaching he realizes that the average grades in this class are particularly low. Based on these two base-rates he infers that the proportion of students with poor performance is higher among the students of low socioeconomic status. This inference about a contingency is called pseudocontingency as it is solely based on two aligned base-rates.

Like Goodie and Fantino (1996), we use a matching-to-sample (MTS) paradigm to study this influence of skewed base-rates on experience-based contingency inferences. In a MTS task, participants are repeatedly presented with one of two samples to which they have to respond by choosing one of two response options. Every trial entails feedback as to whether the choice was correct or false. In the present experiments, this feedback was accompanied by monetary rewards and punishments of equal size. So every trial involves a prediction about which of the two response options is correct and will be reinforced.

We adapted a version of this MTS paradigm in which the actual contingency between the predictor samples and the correct response options is zero. Under these conditions, we expect prediction behavior to be a function of two tendencies working together, a tendency to predict the response option with the higher base-rate of reinforcement, and a tendency to predict the response option with a base-rate (i.e. of reinforcement) similar to the base-rate (i.e. of occurrence) of the predictor sample, in accordance with the PC illusion. From various MTS studies, there is evidence for probability matching, that is, the rates with which judges choose the two response options roughly equals the reinforcement-rates (Humphreys, 1939; Shanks, 1990). With monetary incentives, a tendency toward ‘optimizing’ (i.e. exclusively choosing the more frequently rewarded response) has also been reported (Shanks, Tunney & McCarthy, 2002). We hypothesize that, pooling across trials with frequent as well as infrequent samples, participants will choose the frequently rewarded response option at a rate between its reinforcement-rate and 1 (see Footnote 1). However, crucially, when taking the samples into account, we expect that the rate of choosing the frequently rewarded option is higher for trials involving the frequent sample as compared to trials involving the infrequent sample.

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[1] We only consider one response option because the rates for the frequently and infrequently rewarded response options sum up to one.

Experiment 1

We used two instrumental tones as samples (a high pitch piano sound and low pitch saxophone sound) and the two keys (‘A’ and ‘Ä’ on the left and on the right side of a German computer keyboard) as response options. Thus a pre-existing association, e.g. in terms of physical similarity, between samples and response options was extremely unlikely.

Method

Participants and Design. Forty eight undergraduate students (41 female, 7 male) from the University of Heidelberg participated in an experiment on information processing. Participants were randomly assigned to one of two stimulus distribution conditions and every participant was exposed to the two different sample types, resulting in a 2 (stimulus distribution: both base-rates skewed vs. no skew) x 2 (sample type: frequent vs. infrequent) mixed design with repeated measures on the last factor. The experiment was run in groups up to six participants. Personal computers controlled the stimulus presentation and recorded participants’ responses.

Procedure. Participants were instructed to figure out as quickly as possible which response key was the correct prediction following one of two instrumental tones. The tones were delivered via earphones and participants could adjust the volume to their liking. Each trial started with the presentation of a tone and the keyboard was locked for 500 ms. Subsequently, participants could stop the tone and prompt the feedback indicating whether the prediction had been correct, by pressing one of the response keys. After an intertrial interval of 1500 ms the next tone was presented. Sessions lasted until participants had responded to a total of 160 tones. On average, sessions lasted for about 13 minutes. Participants started with an account of 3€ (approximately 4$) of prospective compensation. For each correct response 0,05€ were added to this account, for each false response 0,05€ were subtracted. At the end of each trial, participants were informed about the success on the current trial (either plus or minus 0,05€), their choice (either left or right) and their updated account-value.

Stimulus Distributions. For every participant, the computer generated a random sequence of tones and corresponding correct responses by drawing without replacement from one of two predetermined distributions. In the ‘skewed’ distribution (top panel in Figure 1) the high-pitch tone was three times as frequent as was the low-pitch tone, and the key on the left was rewarded three times as frequently as was the key on the right (sounds and orientations were counterbalanced across participants). In the ‘no skew’ distribution (mid panel in Figure 1) samples and reinforcements were evenly distributed. As can be seen, there was no actual contingency in either condition.

Results and Discussion

The conditional rates of choosing the frequently rewarded response option given the frequent and given the infrequent sample were estimated. We analyzed the second half of the trials only to exclude variability during early trials. A two factorial repeated measures analysis of variance with skew as between-participants factor (skewed vs. no skew) and sample-type as within-participants factor (frequent vs. infrequent) reveals a large skew main effect, $F(1, 46) = 83.30$, $p < .01$, a sample-type main effect, $F(1, 46) = 5.01$, $p < .05$, and a sample-type-by-skew interaction, $F(1, 46) = 9.09$, $p < .05$. Figure 2 shows the average response rates for the frequently (gray portion of bars) and the infrequently rewarded response (black portion of bars), conditional on the type of the preceding sample.

The skew main effect shows that participants are sensitive to the base-rates of reinforcement for the two response options. When averaged across sample types, participants in the skew condition chose the more frequently rewarded response at a slightly higher rate than its 75% reinforcement-rate (M = 0.80, sd = 0.13), and in the no skew condition they chose the responses without preference (M=.50, sd=.10). However, crucially, the degree to which choice was governed by the reinforcement base-rate depended on the sample presented before the choice. The response rate for choosing the frequently rewarded response option was higher after the frequently presented sample (M=.85, sd=.13) than after the infrequently presented one (M=.74, sd=.17). This result is in line with the PC illusion, because a contingency manifested itself that reflects the alignment of predictor and criterion base-rates. Additionally, neither a statistical contingency nor any physical similarity between samples and response options can account for the contingency driving the predictions.

However, because we jointly manipulated predictor and criterion base-rates, it was not possible to disentangle the tendency to optimize from the tendency to form a PC. Therefore, in Experiment 2 we included a condition in which the criterion but not the predictor base-rate was skewed.

Experiment 2

Experiment 2 was an extended replication of Experiment 1 with an additional stimulus distribution and a slightly modified cover story. This time the task was framed as gambling with a ‘flawed gambling machine’. Participants were instructed to maximize their returns. In addition to the stimulus distributions of Experiment 1 we included a distribution (bottom panel of Figure 1) in which the reinforcement base-rate but not the sample base-rate was skewed at the ratio of three to one. In this ‘criterion skewed’ condition we hypothesized that participants would choose the more frequently rewarded response option at the same rate following either of the samples. By contrast, when the sample base-rate was also skewed (skewed condition), we expected a higher rate of choosing the more frequently rewarded response for trials involving the frequently presented sample than for trials involving the infrequently presented one.

Method

Participants and Design. Sixty three students (20 female, 43 male) from the university of Mannheim participated in the study. The experiment was run in groups up to 15 participants. Personal computers controlled the stimulus presentation and recorded the participants' responses. Conditions resulted in a 2 x 3 design with sample-type as within-participants factor (frequent vs. infrequent) and skew as between-participants factor (skewed, criterion skewed, no skew).

Results and Discussion

Again, response rates for choosing the frequently rewarded response conditional on the type of preceding sample were calculated for the second half of the trials. Figure 3 shows the average response rates for the frequently (gray portion of bars) and the infrequently rewarded response option (black portion of bars). The mixed ANOVA revealed a large skew main effect, $F(2, 60) = 99.92$, $p < .001$, and a sample-type-by-skew interaction, $F(2, 60) = 5.10$, $p < .05$.

The skew main effect reflects participants' sensitivity to the base-rate of reinforcement. When the reinforcement base-rate was skewed, subjects chose the frequently rewarded response option at a rate of 0.84 (sd=.10) as compared with a rate of 0.50 (sd=.07) when reinforcements were evenly distributed. There was no significant difference ($t(41)=1.22$, $p>.20$) between the skewed condition (M=.84, sd =.12) and the criterion skewed condition (M=.83, sd =.09). However, crucially, the interaction is due to the fact that in the skewed condition the response rate for the frequently rewarded response was higher ($t(20)=2.67$, $p=.015$) after the frequent sample (M=.90, sd=.08) than after the infrequent sample (M=.79, sd=.20). No such difference was found in the criterion skewed condition ($t(20)= -1.10$, $p>.20$; M=.81/.84, sd =.12/.09) or in the no skew condition ($t(20)= -1.24$, $p>.20$; M =.46/.53, sd=.13/.15).

These results replicate and extend those of the previous experiment. Again, a contingency between predictors and criterion events became manifest that followed the alignment of the base-rates, a pattern consistent with a PC. They show how the tendency to optimize and to form a PC jointly explain participants' choice behavior.

General Discussion

In an operant analysis of what has been conceived as base-rate neglect, Goodie and Fantino (1996) found physical similarity between (statistically unrelated) predictor samples and response options to cause contingency-based predictions, thereby reducing the weight given to criterion base-rates. Complementing these findings, we demonstrate how base-rates themselves can prompt contingency-based predictions from predictors statistically unrelated to criterion events.

In the critical condition of a MTS task, where the base-rate of the criterion events *and* the base-rate for the occurrence of the predictor samples were skewed, the alignment of the base-rates prompted contingency-based predictions. Specifically, when presented with a frequent predictor sample, participants predicted a frequently rewarded response option to a larger extent than when presented with an infrequent predictor sample.

The results can be interpreted as reflecting the joint operation, and a compromise, of two behavioral tendencies. One is to base predictions on a *pseudocontingency* illusion (Fiedler & Freytag, 2004; Fiedler et al., 2007) that assumes a relation between predictor and criterion based on the alignment of their base-rates. The other is to *optimize* predictions by predicting the frequent criterion event (Shanks et al., 2002).

Our results show both base-rate neglect and sensitivity to base-rates. They show base-rate neglect, in that participants do not exclusively rely on the criterion base-rate but take statistically irrelevant predictors into account. However, they also show that base-rates are utilized, in that participants tend to ‘match’ their predictions to the predictors on the basis of predictor and criterion base-rates. They show base-rate neglect based on base-rates.

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Figure Captions

Figure 1. Incidence tables indicating the predetermined stimulus distributions used in the experiments. In Experiment 1, the base-rates of both sample cues and reinforcement-rates were either skewed at a ratio of 3:1 (top panel) or evenly distributed at a ratio of 1:1 (mid panel). Experiment 2 included an additional condition in which the reinforcement base-rate was skewed at a ratio of 3:1, whereas the sample cue base-rate was evenly distributed at a ratio of 1:1 (bottom panel).

Figure 2. Rate for choosing either the frequently (gray portion of bars) or infrequently (black portion of bars) rewarded response conditional on the type of sample (frequent or infrequent) preceding the choice.

Figure 3. Rate for choosing either the frequently (gray portion of bars) or infrequently (black portion of bars) rewarded response conditional on the type of sample (frequent or infrequent) preceding the choice.

Figure 1

Skewed condition

		Correct: Left Key	Correct: Right Key	
Sample	Piano	90	30	120
	Saxophone	30	10	40
		120	40	160

No skew condition

		Correct: Left Key	Correct: Right Key	
Sample	Piano	40	40	80
	Saxophone	40	40	80
		80	80	160

Criterion skewed condition

		Correct: Left Key	Correct: Right Key	
Sample	Piano	60	20	80
	Saxophone	60	20	80
		120	40	160

Figure 2

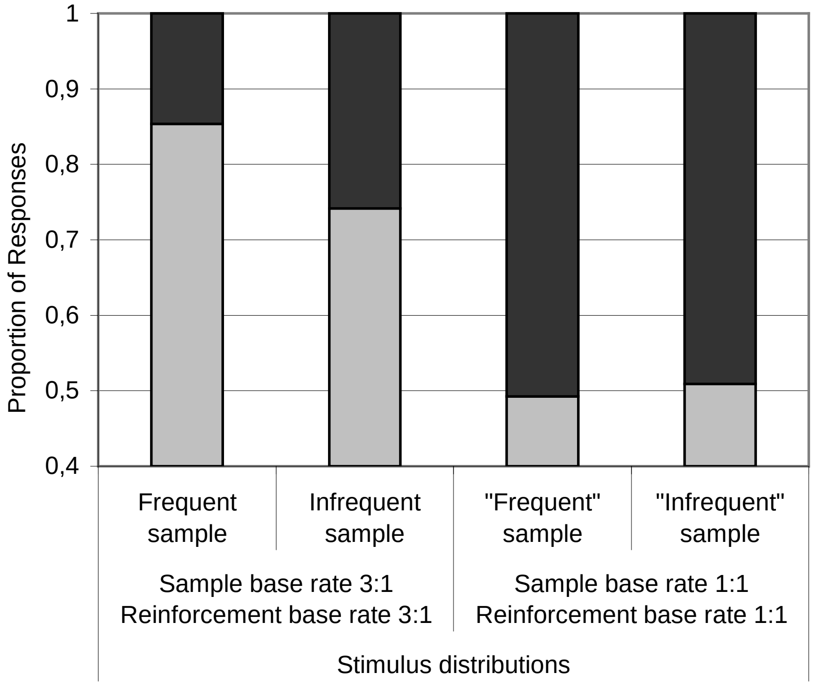
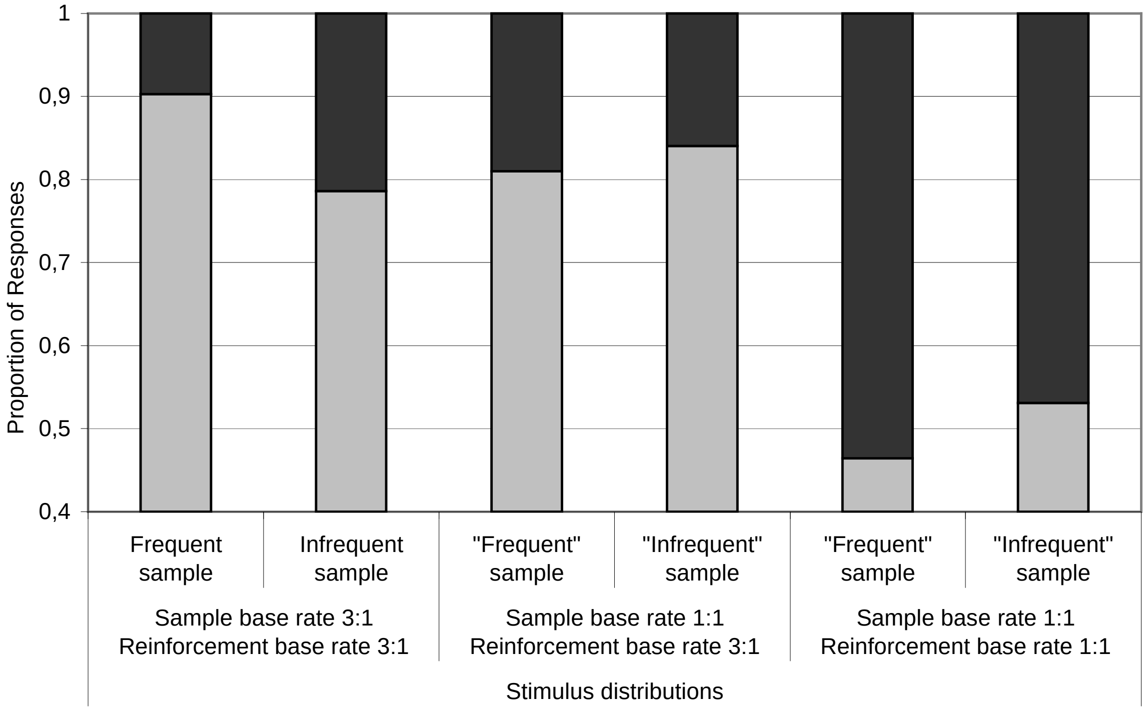

1
0,9
0,8
0,7
0,6
0,5
0,4
Proportion of Responses
Frequent sample
Infrequent sample
"Frequent" sample
"Infrequent" sample
Sample base rate 3:1
Reinforcement base rate 3:1
Sample base rate 1:1
Reinforcement base rate 1:1
Stimulus distributions

Figure 3


1
0,9
0,8
0,7
0,6
0,5
0,4
Proportion of Responses
Frequent sample
Infrequent sample
"Frequent" sample
"Infrequent" sample
"Frequent" sample
"Infrequent" sample
Sample base rate 3:1
Reinforcement base rate 3:1
Sample base rate 1:1
Reinforcement base rate 3:1
Sample base rate 1:1
Reinforcement base rate 1:1
Stimulus distributions

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