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AN EXPLANATION OF CONSERVATISM IN THE BOOKBAG-AND-POKERCHIPS SITUATION *

D. F. MARKS
University of Otago, Dunedin, New Zealand

and

J. K. CLARKSON
University of Sheffield, U.K.

ABSTRACT

An experiment is described in which subjective probability revisions were obtained in a standard probability estimation task, the 'bookbag-and-pokerchips' situation. Three aspects of probability revision were examined: conservatism, sequential effects, and coherence. Under two experimental conditions, the conservatism effect obtained was closely related to subjects' use of a simple strategy. A recency effect was also obtained. Coherence of the probability estimates was excellent. Conditions under which the observed strategy leads to conservatism are explored and previously published results are reconsidered in the light of this strategy. Conservatism in the bookbag-and-pokerchips situation is explained as an artefact of subjects' strategies.

1. INTRODUCTION

Many experiments have shown that, in certain probability estimation tasks, the numbers people give, when revising their opinions in the light of new information, are less extreme than the numbers obtained by the application of Bayes' theorem. This difference between subjective probabilities (SPs) and the experimenter's calculated or 'objective' probabilities (OPs) has been termed 'conservatism' (EDWARDS and PHILLIPS, 1964). A review of the evidence on conservatism, and other aspects of intuitive statistics, has been published by PETERSON and BEACH (1967) and more recently by MANZ (1970).

Much of the experimental work on conservatism has involved what EDWARDS (1968) calls the 'bookbag-and-pokerchips' situation. In the simplest variant of this task subjects are shown (or asked to imagine) two bookbags (or urns), R and B, each of which contains a large number,

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say 1000, of pokerchips (or balls). Bag R contains a proportion p_r of red chips and a proportion p_b, or $(1 - p_r)$, of blue chips; bag B contains p_r of blue and p_b of red chips. The experimenter chooses a bag at random and samples, randomly and with replacement, a number (n) of chips. The subjects are told the number (r) of reds and the number (b) of blues and are required to give a figure between 0.00 and 1.00 as an estimate of the probability that the sample has been taken from a given bag. As defined above, an estimate is conservative if it is closer to 0.50 than the experimenter's mathematically derived probability. Typically, this is obtained by the use of Bayes' theorem. The likelihood ratio, L, in favour of hypothesis, H_R, that bag R has been sampled over the hypothesis, H_B, that bag B has been sampled is given by

$$L = (p_r / p_b)^{r-b}. \tag{1}$$

Bayes' theorem may be written briefly as

$$\Omega_1 = L\, \Omega_0, \tag{2}$$

where Ω_1 are the posterior odds of H_R relative to H_B, and Ω_0 are the prior odds. Substitution for L from eq. (1) gives

$$\Omega_1 = (p_r / p_b)^{r-b}\, \Omega_0. \tag{3}$$

If Ω_1' is the subjective posterior odds, then, for $r > b$, conservatism occurs when

$$\Omega_1 > \Omega_1' \tag{4}$$

or, alternatively, when

$$(p_r / p_b)^{r-b}\, \Omega_0 > \Omega_1'. \tag{5}$$

The three main hypotheses to account for conservatism in the bag-and-chips situation are discussed by Edwards (1968, p. 18). These are the misaggregation hypothesis, the misperception hypothesis, and the hypothesis that conservatism is an artefact. Clearly the first two of these hypotheses are not mutually exclusive since both misaggregation and misperception could occur in subjective probability revision. Edwards (1968) reports results which appear to support both these hypotheses and concludes with a probability judgement of his own (1968, p. 51): 'I do believe, though, that misaggregation contributes considerably more to conservatism than does misperception.' Although Edwards

(1968, p. 46) rejects the third hypothesis, that conservatism is an artefact, he states that he can offer no evidence against it.

It is the main purpose of the present paper to describe experimental results which support the idea that conservatism in the bookbag-and-pokerchips situation is indeed an artefact and to provide part of the answer to the question: artefact of what? Two further aspects of subjective probability revision were explored in the experiment to be reported –sequential effects, and coherence.

1.1. *Sequential effects*

An implication of Bayes' theorem is that the amount of revision to be made to a probability should not be affected by the order in which information is encountered. Hence Ω_1 should be invariant for two samples presented in the orders S_i, S_j or S_j, S_i. One variable of interest in this context is the extent to which different pieces of information may be concordant, i.e. favour the same hypothesis, or, discordant, i.e. favour different hypotheses.

1.2. *Coherence*

In order to be coherent, the sum of the subjective probabilities of an exhaustive set of mutually exclusive statements must equal 1.0. The possibility of incoherence can arise when a person gives a subjective probability judgement for statement X, SP(X), on one occasion and for not - X, SP($\sim X$), on a separate occasion, assuming no change in the information which is available on the two occasions. Incoherence occurs when

$$\mathrm{SP}(X) \neq 1 - \mathrm{SP}(\sim X). \tag{6}$$

If a reliable departure from coherence is observed, then some bias or asymmetry must be present in the probability-judgemental process. Indeed, in the light of what is known about judgement (e.g. Guilford, 1954; Johnson, 1955; Helson, 1964), incoherence seems rather likely.

2. Experiment

2.1. *Procedure*

The value for p_r was 0.60. Two samples were presented on each of 52 trials and subjects gave estimates after each first-sample (S_1) and after each second-sample (S_2). Genuine sampling was carried out on four practice trials only, and for the 48 experimental trials samples were read to the subjects from a list. The subjects were told that the samples had been drawn before the experimental session in order to 'save time'. Estimates were written as a number between 0.00 and 1.00 on response sheets. The experimental trials occurred at the rate of about 2 per minute.

The experimental trials were divided into four blocks of 12 trials each. In two of these blocks of trials, subjects gave SP estimates for H_R and in the other two, estimates for H_B. Half the subjects gave estimates in blocks ordered H_R, H_B, H_R, H_B and half had the reverse order. Two groups of subjects received different experimental conditions:

Group 1. The sample size was held constant at 20. In terms of their $(r - b)$ values, the frequency distribution of sample-types was bi-modal, rather than approximately normal, the statistically expected distribution for this situation. Samples with $(r - b) = 0$ were of little interest and therefore fewer were used than would be expected from true sampling. The range of $(r - b)$ was -14 to $+14$. To investigate sequential effects, 32 of the 48 experimental trials were divided into 16 matched pairs, with samples in paired trials occurring in the two orders S_i, S_j and S_j, S_i. These matched trials all contained concordant samples (i.e. both favouring the same hypothesis).

Group 2. The sample size was held constant at 10. The distribution of $(r - b)$ was rectangular for values in the ranges -8 to -2 and $+2$ to $+8$. No samples were presented with $(r - b)$ equal to zero. To investigate sequential effects for this group, 40 of the 48 experimental trials were divided into 20 matched pairs, with samples in paired trials occurring in the two orders S_i, S_j and S_j, S_i. These matched trials all contained discordant samples.

Each subject was interviewed individually after the experiment and questioned on comprehension of the required task and on strategies which may have been employed.

2.2. *Instructions*

Following a pre-amble on the concept of subjective probability, subjects were given the following instructions: 'The present experiment consists of 4 practice trials and 48 experimental trials. At the beginning of each trial one of the two urns (urn R and urn B) is chosen at random (by flipping a coin). Each urn contains 500 pokerchips. Urn R contains 300 red chips and 200 blue; urn B contains 300 blue chips and 200 red. On each trial two samples of 20 (10) chips each are taken from the chosen urn. Since there is an even chance on each trial that urn R or urn B has been chosen your subjective probability at the beginning of a trial should be 0.50. Your task is to give a probability estimate that the experimenter has chosen urn R or urn B after each sample has been drawn, remembering that *both samples on a given trial come from the same urn* and that *a different urn will be chosen randomly at the start of each new trial.* On some trials you are asked to give the probability that urn R has been chosen, and on others the probability that urn B has been chosen. Please give each estimate to two places of decimals e.g. 0.73, 0.12, or 0.40. Which urn you are to be estimating for is noted on the response sheet, but please note that this will change every 12 trials.'

2.3. *Subjects*

Thirty-four undergraduates at the University of Sheffield served as subjects in group 1, and 32, in group 2.

3. Results

The data were analysed for four subgroups of subjects. Fourteen subjects in group 1 and 12 in group 2 used a simple strategy to generate all, or the majority, of their judgements. These two subgroups are referred to as 1S and 2S respectively. The strategy used by these subjects is described below. The two other subgroups, 1N and 2N, include 20 subjects of group 1, and 16 of group 2, respectively, who (i) understood the required task; (ii) did not admit to having given estimates on the basis of the strategy mentioned above; and (iii) had not, from examination of their results, used the strategy for more than 39 of the experimental trials. The post-experimental interviews revealed that 4 subjects in group 2 had not understood the task and their data were discarded.

3.1. *Sequential effects*

The two samples, S_1 and S_2, on each trial were rated as 'weak' (W) or 'strong' (S), according to the relative strength of the evidence in favour of the hypothesis being judged. For example, for an estimate of $P(H_R/S_i)$, where S_1 and S_2 had $(r - b)$ values of $+6$ and -2 respectively, S_1 was rated S, and S_2 was rated W. As stated above, samples on the same trial were concordant for group 1, and discordant for group 2, in the evidence afforded with regard to which bag had been chosen. For each subject, means were calculated of the final estimates given after samples presented in the orders *W*, *S* and *S*, *W*. The results are presented in table 1.

TABLE 1
Mean SP estimates for second-revisions after samples in orders *W*, *S* and *S*, *W* and values of *t*.

Group	*W*, *S*	*W*, *S*	Difference	t	p
1N ($n = 20$)	0.511	0.489	0.022	2.36	< 0.05
1S ($n = 14$)	0.539	0.491	0.048	2.86	< 0.02
2N ($n = 16$)	0.620	0.396	0.224	5.70	< 0.001
2S ($n = 12$)	0.587	0.429	0.158	3.35	< 0.01

For group 1N mean SP after 16 pairs of samples in the order *W*, *S* was larger by 0.022 than the mean SP after the same samples in the order *S*, *W* ($t = 2.36$; $df = 19$; $p < 0.05$). Hence, there was a slight recency effect. The magnitude of the 'weak-strong' difference between samples in a pair, as indexed by the difference in $(r - b)$ values, was positively correlated (Spearman rank correlation) with the magnitude of the recency effect ($\varrho = + 0.66$; $n = 16$; $p < 0.01$). A similar result was obtained for group 1S ($\varrho = + 0.70$; $n = 16$; $p < 0.01$).

Using the same analysis as that used for groups 1N and 1S, it was found that all sixteen subjects in group 2N gave a higher SP after order *W*, *S* than after *S*, *W*. In group 2S, eleven out of twelve subjects showed a recency effect. As shown in table 1, the mean difference between *W*, *S* and *S*, *W* was much higher for groups 2N and 2S, who received pairs of discordant samples, than for groups 1N and 1S, who received concordant samples. Group 2N gave a significant positive correlation between the size of the recency effect and the difference in sample diagnosticity ($\varrho = + 0.73$; $n = 20$; $p < 0.001$) but for group 2S the correlation was not significant ($\varrho = + 0.12$).

3.2. *Coherence*

Samples with $(r - b)$ equal to $+ d$ and $- d$ have complementary objective probabilities (OPs), as defined by Bayes' theorem (eq. 2). Coherence can be assessed by summing the mean SPs for such pairs of samples and thereby obtaining an estimate of the 'total SP' (TSP). On each trial subjects revised their SPs after each of two samples, and the mean TSP was separately determined for first- and second-revisions.

The significance of the difference of these mean TSP values from 1.0 was evaluated. The results are summarised in table 2.

TABLE 2
Mean TSP for first- and second-revisions and values of t.

Group	Revision	Mean TSP	t	p
1N	First	1.016	2.734	< 0.02
	Second	1.032	6.218	< 0.001
1S	First	1.005	0.798	n.s.
	Second	1.028	3.391	< 0.01
2N	First	1.018	3.448	< 0.01
	Second	1.044	2.355	< 0.05
2S	First	1.032	4.364	< 0.005
	Second	1.030	1.934	< 0.10

There was a slight, although significant, tendency for TSP to exceed unity. Fourty-nine of the total of 62 subjects gave a mean TSP greater than 1.0. The small mean difference of 0.017 between first-revision and second-revision TSP was significant ($t = 2.812$; $df = 61$; $p < 0.01$).

3.3. *Conservatism*

The mean SP estimates for first- and second-revisions are plotted against the OPs given by Bayes' theorem in fig. 1. These results are for subgroups 1N and 2N. Substantial conservatism occurred at both ends of the scale and, as implied by the result described above that TSP exceeded unity, SPs below 0.50 were slightly more conservative than those above 0.50. Comparison of figs. 1a and 1b indicates that conservatism was greater for group 1N than for group 2N.

As mentioned above, twenty-six subjects (about two-fifths of the total sample) had used a simple rule to generate all or many of their probability estimates (groups 1S and 2S). This strategy, which will be referred to as the 'division rule', is defined by the equations

$$\mathrm{SP}(H_{\mathrm{R}}/S_j)=r/n, \tag{6}$$

and

$$\mathrm{SP}(H_{\mathrm{B}}/S_j)=b/n=1-r/n, \tag{6a}$$

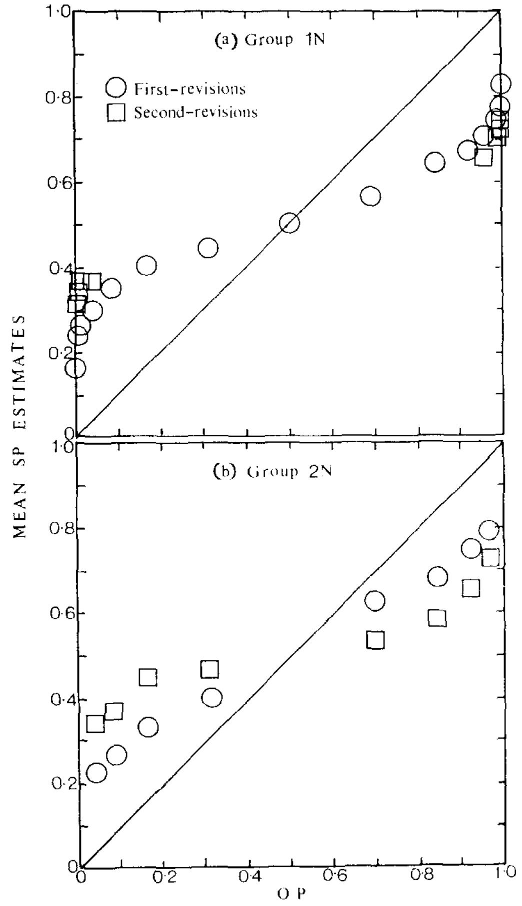

Fig. 1. Mean SP estimates plotted against probabilities generated by Bayes' theorem (OPs).

where S_j is a sample of size n containing r red chips and b blue chips. The general case may be written

$$SP(H_i/S_j)=C_i/n, \tag{7}$$

where H_i is the hypothesis that S_j has been drawn from a bag containing predominantly chips of colour i, and C_i is the number of chips of colour i in the sample.

Equation 7 describes the data obtained from the 26 overt users of the division rule almost perfectly. To investigate how the mean SP estimates of the remaining 36 subjects related to this rule, mean estimates were plotted against C_i/n for each sample which occurred as S_1. Figs. 2a and 2b give the results for groups 1N and 2N respectively.

For group 1N there was a marked correspondence between mean SP estimates and rule-generated values. There is strong evidence, even for those subjects who did not admit to having used the rule, that mean estimates are linearly related to C_i/n. Group 2N's results provide similar evidence, although in their case, the slope is less than 1.0.

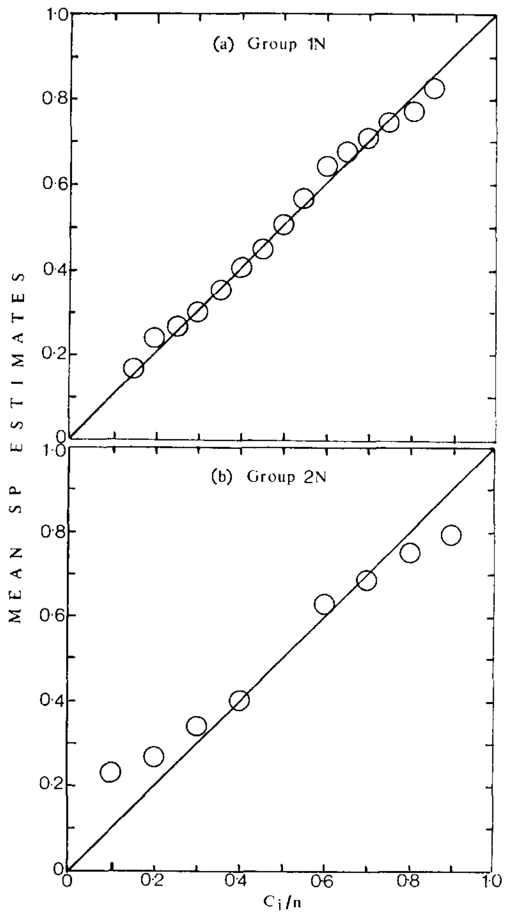

Fig. 2. Mean SP estimates plotted against probabilities generated from the division rule (C_i/n).

The closeness of individual subjects' estimates to the division rule was calculated by taking, for each subject, the absolute deviation of each judgement from its corresponding rule-generated estimate and calculating the mean deviation for all judgements. Similarly, each subject's mean absolute deviation from OPs was calculated. Table 3 presents the results.

TABLE 3

Mean absolute deviations from OPs and from C_i/n.

		From OPs		From C_i/n	
Group	n	Mean	*SD*	Mean	*SD*
1N	20	0.22	0.05	0.07	0.03
2N	16	0.17	0.04	0.10	0.03
Both	36	0.20	0.05	0.09	0.03

Every subject in groups 1N and 2N gave estimates which were closer on average to the division rule than to Bayesian probabilities. As indicated by table 3, the mean absolute deviation from the division rule was less than half the mean absolute deviation from the OPs.

4. DISCUSSION

The results on sequential effects were quite unambiguous – a recency effect occurred. Recency was stronger for discordant than for concordant samples, and for both groups, the amount of recency was positively correlated with the amount of discordance in the sequence. This result is the opposite of the primacy effect obtained by DALE (reported by EDWARDS, 1966). There are, however, at least three differences between the present experimental situation and that of Dale. In Dale's experiment (i) there were four mutually exclusive hypotheses instead of two; (ii) probability revisions were required after each single datum rather than after samples of size 10 or 20; and (iii) the mean processing rate was about 1 datum per minute (subjects being allowed as much time as they wished to revise their SPs) while for groups 1 and 2 the processing rates were about 40 and 20 data per minute respectively. Clearly, further experiments are needed to determine what variables are relevant in determining recency or primacy.

The present experiment differs also from that of another study in which a 'primacy' effect is reported. In two experiments, PETERSON and

DuCharme (1967) presented a sequence of 100 data of which the first 30 (or 33) favoured one hypothesis, and the remainder, an alternative hypothesis. SP estimates were found to change from favouring the first hypothesis to favouring the second later in the sequence than did the Bayesian probabilities. It is unclear to the present authors how the lag in SP revision obtained by Peterson and DuCharme differs operationally from the usual finding that SP revisions are less extreme than the OPs, i.e. that SPs are conservative. The recency effect obtained in the experiment reported here is defined independently of Bayes' theorem, as is the primacy effect obtained by Dale.

The present data have provided further evidence of conservatism in the binomial bookbag-and-pokerchips task. Of the three explanations of conservatism suggested by Edwards (1968), i.e. that conservatism is due to misaggregation, misperception, or to an artefact, the third appears to be the right one. Estimates were generated, at least in part, from a simple deductive rule (eqs. 6, 6a, and 7) which involves solely the sample information, a finding which is supported by the results of Beach et al. (1970). Complete adherence to this rule would have led to perfect coherence but this did not occur. Although coherence was good, there was a systematic tendency for low SPs to be slightly less conservative than high SPs. To elucidate this response bias, further data are needed.

One important implication of subjects' use of the division rule is that, providing certain conditions hold, probability estimates generated from this rule will show conservatism. *This is because, for certain combinations of p_r and $(r - b)$, in relation to optimal posterior odds calculated with Bayes' theorem, the division rule is itself conservative.* For the binomial bookbag-and-pokerchips task, the division rule states

$$\Omega_1' = r/b. \tag{8}$$

Substituting for Ω_0 and Ω_1' in (5), we have

$$(p_r/p_b)^{r-b} > r/b. \tag{9}$$

Putting $k = r - b$, and $n = r + b$, the sample size, this becomes,

$$(p_r/p_b)^k > \frac{n+k}{n-k}. \tag{10}$$

This inequality defines the range of conditions for which the division rule produces conservative probability estimates. This range of conditions will now be explored in some detail.

When $k = 0$, both sides of (10) are equal to unity, and Bayes' theorem and the division rule therefore agree upon the value of Ω_1. When $k = n$, the division rule yields infinite Ω_1, which obviously cannot give conservatism. When the sample contains both red and blue chips and in unequal numbers, the maximum value of k is $(n-2)$ (i.e. $(n-1)$ red and 1 blue). Setting $k = n-2$, (10) becomes

$$(p_r/p_b)^{n-2} > n-1,$$

or

$$(p_r/p_b) > (n-1)^{1/(n-2)}. \tag{11}$$

It remains to be shown that if p_r/p_b is set at a minimal value to satisfy inequality (11) for a given value of n then (10) will hold for all values of k where $0 < k \leqslant n-2$. From (10) we have

$$(p_r/p_b) > \left(\frac{n+k}{n-k}\right)^{1/k}$$

and it will suffice to prove that

$$(n-1)^{1/n-2} \geqslant \left(\frac{n+k}{n-k}\right)^{1/k},$$

or, that

$$(n-1)^{(k/n-2)} \geqslant \frac{n+k}{n-k}. \tag{12}$$

Putting $x = k/n$, where $0 < x \leqslant (n-2)/n$, (12) becomes

$$(n-1)^{nx/(n-2)} \geqslant \frac{1+x}{1-x}.$$

Hence

$$\left(\frac{nx}{n-2}\right) \log (n-1) \geqslant \log \left(\frac{1+x}{1-x}\right).$$

Expanding the right-hand side and dividing by x, we have

$$\left(\frac{n}{n-2}\right) \log (n-1) \geqslant 2\left(1 + \frac{x^2}{3} + \frac{x^4}{5} + \dots\right). \tag{13}$$

Given that (13) is true for x at the maximum value of $(n-2)/n$, it must also hold for lower values of x. Hence inequality (10) is true for all k where $0 < k \leqslant n-2$. *Consequently, when* (p_r/p_b) *is greater than*

$(n - 1)^{1/(n-2)}$, *and* $n > 2$, *conservatism is a necessary consequence of the division rule.* Table 4 gives minimum values of p_r/p_b and p_r required to obtain conservatism for various values of n assuming subjects' use of this rule.

TABLE 4

Minimum values of p_r/p_b and p_r yielding conservatism.

n	3	4	5	6	7	8	9	10	11
p_r/p_b	2.000	1.732	1.588	1.496	1.431	1.383	1.346	1.316	1.291
p_r	0.667	0.634	0.613	0.599	0.589	0.580	0.574	0.568	0.564
n	12	13	14	15	16	17	18	19	20
p_r/p_b	1.271	1.253	1.238	1.226	1.213	1.203	1.193	1.185	1.178
p_r	0.560	0.556	0.553	0.551	0.548	0.546	0.544	0.542	0.541

The corollary of the above analysis is that, for a given value of n, if p_r is lower than the minimum value given in table 4, use of the division rule will give 'super-optimal' estimates. PHILLIPS and EDWARDS (1966, expt. III) obtained estimates for p_r values of 0.55, 0.70, and 0.85 with samples up to size 20. These estimates were averaged across different values of n (PHILLIPS and EDWARDS, 1966, figs. 5, 6) however, and so it is not possible to compare rule-governed values with mean subjective estimates for each value of n separately. However, for $p_r = 0.55$, Phillips and Edwards observed 'super-optimality' for all values of k, which is what we would expect for a mean sample size of 10 if their subjects used the division rule.

This simple strategy could also explain the finding of VLEK (1965), VLEK and BEINTEMA (1967), VLEK and VAN DER HEIJDEN (1967), and PITZ et al. (1967) that varying p_r had no significant effect on mean SPs obtained for a particular sample. This is because subjects' use of the division rule makes p_r irrelevant. Further evidence on the invariance of mean SPs across different values of p_r is present in the data of PHILLIPS and EDWARDS (1966, fig. 5). These results, presented in terms of deviations from Bayes' theorem, suggest a difference in mean SPs for p_r values of 0.85 and 0.70. However, if they are re-analysed simply in terms of absolute mean SPs, little or no difference is evident. Mean SPs resulting from this re-analysis are shown for even values of k in table 5. (SPs for odd values of k are similarly indifferent to values of p_r.)

TABLE 5
Mean SPs obtained by PHILLIPS and EDWARDS (1966, expt. III).

k	$p_r = 0.85$	$p_r = 0.70$
2	0.60	0.60
4	0.72	0.69
6	0.82	0.77
8	0.84	0.84
10	0.90	0.88
12	0.93	0.93

A further implication of the division rule is that, when k is constant, a change in mean SP occurs as a function of increasing sample size, producing an increase in 'conservatism'. This effect was observed by MANZ (1968), PETERSON et al. (1965), PITZ (1967), VLEK (1965), VLEK and VAN DER HEIJDEN (1967), and in the experiment reported here. Despite the departure of mean SPs of group 2N from the division rule in the direction of conservatism, group 1N, which had the larger sample size, showed the greater conservatism effect. The reasons for the departure of group 2N's mean SPs from the division rule are unclear and further experiments must be conducted to determine the factors leading to sub-varieties of the simple division strategy. It is significant, however, that mean SPs for group 2N, like those of group 1N, were linearly related to rule-generated probabilities. Perhaps subjects in this group used the division rule to generate estimates and systematically modified these to produce what seemed to be more intuitively reasonable probabilities. It is likely that response biases will play some role in determining the 'conservatism' effect, e.g. the avoidance of extreme values of the response-scale. This would account for the observation in some studies (e.g. VLEK, 1965) that posterior probabilities follow a negatively accelerated function of $(r - b)$, while the division rule involves a linear function.

Conservatism in the situation investigated appears to be largely determined by a very simple strategy. That people use such a strategy is not surprising in the light of studies of human cognition. BRUNER et al. (1962, p. 112) make the following relevant point: 'When the nature of a task imposes a high degree of strain on memory and inference, the strategy used for coping with the task will tend to be less conducive to cognitive strain.' GUILFORD (1954, p. 322) makes the same point, more bluntly: 'Faced with what seems to be an impossible judgment task, O will grasp at anything that seems to be an aid.' Further study of such 'aids' will doubtless throw light on the minor anomalies yet to be resolved, and may prove to have relevance to many judgemental tasks in psychology. The value of questioning subjects after an experimental session, often dismissed as useless by experimental psychologists, is hardly to be doubted.

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References

Beach, L.R., J. A. Wise and S. Barclay, 1970. Sample proportions and subjective probability revisions. *Organizational Behavior and Human Performance* **5**, 183–190.

Bruner, J. S., J. J. Goodnow and G. A. Austin, 1962. *A study of thinking*. New York: Science Editions.

Edwards, W., 1966. *Non-conservative probabilistic information processing systems.* ESD-TR-66-404, Report 05893-22-F, University of Michigan, Institute of Science and Technology, Electronics Systems Division.

Edwards, W., 1968. Conservatism in human information processing. In: B. Kleinmuntz (ed.), *Formal representation of human judgment*. New York: Wiley.

Edwards, W. and L. D. Phillips, 1964. Man as transducer for probabilities in Bayesian command and control systems. In: G. L. Bryan and M. W. Shelly (eds.), *Human judgments and optimality*. New York: Wiley.

Guilford, J. P., 1954. *Psychometric methods*. New York: McGraw-Hill.

Helson, H., 1964. *Adaptation-level theory: an experimental and systematic approach to behaviour*. New York: Harper & Row.

Johnson, D. M., 1955. *The psychology of thought and judgment*. New York: Harper.

Manz, W., 1968. Schätzungen nach der Bayesschen Regel. In: *Abschlussbericht zum Forschungsprojekt Subjektive Wahrscheinlichkeit*. Unpublished Diplomarbeit, University of Köln, 90–125.

Manz, W., 1970. Experiments on probabilistic information processing. *Acta Psychologica* **34**, 184–200.

Peterson, C. R. and L. R. Beach, 1967. Man as an intuitive statistician. *Psychological Bulletin* **68**, 29–46.

Peterson, C. R. and W. M. DuCharme, 1967. A primacy effect in subjective probability revision. *Journal of Experimental Psychology* **73**, 61–65.

Peterson, C. R., R. J. Schneider and A. J. Miller, 1965. Sample size in the revision of subjective probabilities. *Journal of Experimental Psychology* **69**, 522–527.

Pitz, G. F., 1967. Sample size, likelihood, and confidence in a decision. *Psychonomic Science* **8**, 257–258.

Pitz, G. F., L. Downing and H. Reinhold, 1967. Sequential effects in the revision of subjective probabilities. *Canadian Journal of Psychology* **21**, 381–393.

Phillips, L. D. and W. Edwards, 1966. Conservatism in a simple probability inference task. *Journal of Experimental Psychology* **72**, 346–354.

VLEK, C., 1965. *The use of probabilistic information in decision making.* Report No. 009-65, Psychological Institute, University of Leiden.

VLEK, C. and K. A. BEINTEMA, 1967. *Subjective likelihoods in posterior probability estimation.* Report No. E 014–67. Psychological Institute, University of Leiden.

VLEK, C. and L. H. C. VAN DER HEIJDEN, 1967. *Subjective likelihood functions and variations in the accuracy of probabilistic information processing.* Report No. E 017–67, Psychological Institute, University of Leiden.