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Foundations of a Theory of Prominence in the Decimal System Part IV: Task-Dependence of Smallest Perceived Money Unit, Nonexistence of General Utility Functions, and Related Paradoxa

by

Wulf Albers

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University of Bielefeld

33501 Bielefeld, Germany

Abstract

In Part III we related the theory of prominence to the WEBER+FECHNER law of psychophysics, which describes the reaction of men to physical stimuli as brightness, loudness, weight, etc. by three rules. The identical three rules can be used to characterize the perception of the size of numbers. However there is a fundamental difference between the approaches: While for physical stimuli the smallest perceived value only depends on variable and person, but is indipendent from the task, the numerical stimuli are perceived such that the smallest perceived value depends on the task. While WEBER+FECHNER did not even consider the smallest perceived absolute amount as an essential part of the theory, the smallest absolute amount becomes very important for the perception of numerical stimuli, especially, when payoffs are compared, with $a \neq b$ and $a \leq 0 \leq b$. A central consequence of this observation is, that perception cannot be modelled by a universal function. Insufficiencies of the π-function of KAHNEMAN+TVERSKY seem to be based on this fact. – The power of the new theory to explain experimental results could be shown in Part III, where the modification of three traditional fairness criteria concerning different bargaining problems according to the perception function of the theory of prominence are given. The transformation simplifies the structure of the criteria, and gives the respective 'best' presently available models to explain the experimental data. – In this paper we describe additional experiments which support the theory of prominence, namely an experiment on group decisions on a joint numerical response, and experiments concerning the evaluation of 50%-50%-prospects. Main point of the latter experiments is that they leed to paradoxa which contradict traditional concepts, as for instance the prospect theory of KAHNEMAN+TVERSKY. The theory of prominence permits to explain the phenomena. Moreover it could be used to predict a new type of preference reversal for prospects with 50%-50% probabilities, which thereafter could be verified in experiments. The basically same kind of phenomenon causes the paradox of iterated halving. – The fundamental kee to understand the paradoxa is the insight that the smallest perceived money unit is task dependent, and is influenced by the set of prospects that are icluded in a (single) task. The effect is that the same prospect can be evaluated with different smallest perceived money units (and thereby with different evaluation functions), if it is evaluated as a singular prospect, or if it is compared with another prospect.

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0 Notations

The prominent numbers are $\{a * 10^i : a \in \{1, 2, 5\}, i\,\text{integer}\}$. The spontaneous numbers are $\{a * 10^i : a \in \{1, 1.5, 2, 3, 5, 7\}, i$ integer$\}$. A presentation of a number is its presentation as a sum of prominent numbers, where each number occurs at most once, and all coefficients are either +1, -1, or 0. The exactness of a presentation is the smallest prominent number with coefficient unequal zero. The exactness of a number x is the crudest exactness among all presentations of x. The relative exactness of $x \neq 0$ is its exactness devided by $|x|$. The exactness of 0 is ∞, its relative exactness is 1. A number has a level of [relative] exactness p, if its [relative] exactness is $\geq p$. A set of data has [relative] exactness p, if p is the crudest prominent number such that at least 75% of the data have [relative] exactness p. – A scale $S(r, a)$ is the set of $\{0\}$ and all numbers numbers with (1) relative exactness $\geq r$, and (2) exactness $\geq a$; numbers x, y of $S(r, a)$ are identified, when their relative difference $(|y - x|)/max(|x|, |y|)$ is smaller than r.

1 Fair Agreements for a 1-Dimensional Joint Decision Problem

The experiment: "What is the probability of another armed intervention of the US in the Iraque during the next year (starting from today), give the response in percentages." – This and similar questions were posed to 32 subjects. According to their first answers the subjects were assigned to 4 groups of 5, and 4 groups of 3 persons in a way that diversity of opinions was maximal. The questions were selected such that the subjects were really engaged in representing their opinion. In every group the subjects were asked to find "a joint answer to the problem, the joint decision is reached when everybody sends the same number to all others". Communication was free, via terminals, and anonymously. – The first information about the individual opinions was questioned one day before the experiment. (According to these answers the groups were composed.) Before the negotiations started, everybody was again asked for her opinion. Thereafter there was a first phase of discussion, during which it was not permitted to mention any numbers. In advance we said, that this discussion time would be 5 minutes, but we did not inform when this time was over, so after some time the subjects asked the experimenter in their room, if they were permitted to use numbers, and we allowed that. – We made no other restrictions to the communications and did not make any proposals, how the groups might come to an agreement.

Predictions: The Theory of Prominence predicts that the subjects perceive probabilities (below 50%) according to some scale $S(r,0)$. The most common traditional solution concepts to find a joint compromise is the mean $(x_1 + \ldots + x_n)/n$. According to the mapping induced by the Golden Rule this transforms to $(per(x_1) + \ldots + per(x_n))/n$. Assuming that all numbers x_i are greater than the smallest perceived probability unit, the prediction transverts to $(\log(x_1) + \ldots + log(x_n))/n$, which is the value of the prediction in the perception space. The image under the inverse perception function $per^{-1} = \log^{-1}$ gives the geometric mean $(x_1 * \ldots * x_n)^{1/n}$ as prediction. – Specificly can be predicted: 1. The agreement should be such that the sum of concessions - measured on the scale $S(r,a)$ - is zero, i. e. they should compromise on the geometric mean of the initial positions (since this result is below the arithmetic mean, traditional social psychologists denote this deviation as 'risky shift'). 2. Assuming that the subjects are far apart from each other in their initial positions, it can be expected that the first concessions are on a rather high level of exactness, may be the spontaneous numbers. 3. It is not clear, whether the subjects stay on this crude level of exactness throughout the whole process, or if they refine their analysis when they approach the final decision.[1]

Results: The main results of the experiment were as follows:

1. Verbal arguments seem to have been completely irrelant (except for one case, where a group reacted to an argument by a shift of the individual opinions, interestingly enough this argument was wrong, but nevertheless worked).
2. The opinions right before the negotiations had an exactness of half steps.
3. The subjects spontaneously subdivided the negotiations into rounds.
4. In each round they observed the concessions made, and cared that the sum of concessions over all members were 'balanced', the data are as if thay controlled that

[1] We remark that the presented situation is not the typical condition for the risky shift phenomenon, since this phenomenon is basically meant for situations where the decision alternatives are binary judgements, as 'guilty' or 'not guilty'. It might be interesting - also from the Theory of Prominence point of view, to observe in detail, how subjects behave under this condition.

the sum of concessions, measured in steps, aggregated to zero.

5. Numbers during the negotiations were on half steps, only in later phases some groups turned to quarter steps in order to find an agreement point.

6. In some groups remained a last step of concessions (as for instance when one person is at 10% and 4 persons are at 15%), to break the tie some groups then decided with simple majority (here to select 15% as a compromise), others finally agreed to select the arithmetic mean of these last positions.

7. The geometric mean of the initial positions was clearly the best predictor for the obtained results.

Comment: Main point is that the subjects behaved as if they measured the half steps (although they of course did not have our theory). – There was only one subject who did not make concessions for a long time. This caused worst abuses by the others. He thereafter conceded for a long step egalizing all concessions the others had made meanwhile.

The result strongly supports the hypothesis that subjects evaluate differences in steps of the Scale S(.26,0), and not on a linear scale. This is one of the crucial experiments supporting the Theory of Prominence, since it clearly shows that subjects use the steps according to the theory as reference points, and that they evaluate concessions in numbers of steps.

2 Evaluation of 50%-50%-Prospects

Prospects of type $[x, y] := [x(50\%), y(50\%)]$ are denoted as 50%-50%-prospects. At the time when we performed the experiments with 50%-50%-prospects, we did not have a theory for the evaluation of arbitrary prospects. 50%-50%-prospects were a first attempt to understand the evaluation of prospects. Assuming that 50%-50%-prospects are evaluated by the mean of the values of the alternatives, these prospects are also a good instrument to investigate the shape of the perception function.

Experiment: 16 subjects (advanced students of Economics, Business Administration, and Mathematical Economics) were asked to give money equivalents for 19 prospects. More precisely, we asked them as follows: "Imagine, in front of you on a table are the given prospect, and an amount of money. Give the highest [smallest] money amount, at which you prefer to get the prospect [the money]". We decided to put the question in this way, in order to avoid the 'endowment-effect', i. e. that the subjects considered one or the other alternative as their endowment, and asked for compensation before they gave it away. The money equivalent was by the mean of the two responses. The prospects are listed in Table 3.1 below.

Predictions: 1. Perception should follow the perception function for money (see Part III, Sections 6, and 7).

2. The evaluation of negative payoffs, and the smallest perceived absolute money unit are predicted according to Part III, Section 8:

> **Evaluation of Negative Steps:** Steps within the range of negative numbers are evaluated double.
>
> **Absolute Exactness Selection Rule:** When two numbers are involved in a judgement then the median smallest absolute amount (in full steps) considered by the subjects is 20% of the amount of the larger absolute number.

3. To evaluate 50%-50%-prospects, it is not necessary to have a general perception function for probabilities. The special case can be handled by the

> **50%-50%-Prospects Evaluation Rule:** The money equivalent of a 50%-50%-prospect $[x, y]$ is the midpoint of x and y on the step scale.

(This prediction accords to the Golden Rule, Part III, Section 9, and to the evaluation principle of the preceding section.) – Before we present the results, we give two Examples that may illustrate the procedure. –
Example 1: The prospect $[+5000(50\%), -1000(50\%)]$ is perceived with a smallest absolute amount of 1000 (by the 20%-rule). This gives the (full) steps -1000, 0, +1000, +2000, +5000. Since steps in the negative range count double, the weighted midpoint of the two amounts of the prospects is the midpoint of the full steps 0 and 1000, i. e. the half step 500. – If rule (*) is applied, the prospect is evaluated with an absolute exactness of 20% of 1000, i. e. 200. Then the full steps are -1000, -500, -200, 0, +200, +500, +1000, +2000, +5000. Again taking into accaunt that negative steps count double gives that 5 steps from the right are egalized by 2.5 steps from the left. Remains the interval between the zero-point and 1.5 steps from the zero-point to the left. The midpoint is at -3/4, i. e. at -150. – Example 2: The prospect $[+1000(50\%), 0(50\%)]$ is perceived with a smallest absolute amount of 20%*1000=200. The steps are 0, +200, +500, +1000. The midpoint is at the half step 300.

Results: The predictions could be confirmed, however subjects' behavior is explained more accurately by assuming an additional rule concerning the selection of absolute exactness, which is sometimes applied when a positive and a negative payoff are involved in one prospect, and the absolute value of the negative number is smaller than the positive number. (In our experiments, the subjects applied this rule in about half of the cases, where it could be applied.)

> **Rule (*) (Supplement to the Absolute Exactness Selection Rule):** For a 50%-50%-prospect $[x, y]$ with $x < 0 < y$, $|x| < |y|$, $|x| \geq 500$ DM the absolute exactness can be selected as $|x|/5$.

To check whether the smallest perceived money unit really followed the 20% criterion of the Absolute Exactness Selection Rule, we assumed in our analysis that the smallest absolute value of the scale is given by a certain percentage p% of the the larger of the two absolute values of the payoffs of the prospect (i. e. we replaced the 20% rule by a p% rule). We distinguished the values $p = 1, 2, 5, 10, 20, 50$, and determined for every prospect of the experiment that p-value that explained the median of the subjects' responses best. The frequencies were as follows:

	%-rule that fits best to the median response										
	50%		20%		10%		5%		2%		1%
cases without rule (*)		1	8	7	2	1					
cases with rule (*)						2	2	2	1		

The result shows that the 20%-rule is a good predictor for the median behavior of the subjects, if rule (*) is not applied. In the other cases the obtained result must be compared with the result predicted by rule (*). We therefore counted the frequencies of cases which are at p^* (i. e. according to the prediction of rule (*)), nearer to a full step above p^* (denoted as $2p^*$), or nearer to a full step below $p*$ (denoted as $p^*/2$). The result is

	distance from the prediction of rule (*)				
	$2p^*$		p^*		$p^*/2$
cases with rule (*)	1	1	5	-	-

There were no values finer than predicted by rule (*). In two cases there are results between the prediction of rule (*) and the original prediction. This is explained by assuming that only part of the subjects applied rule (*), so that the median of the observed responses was between the predictions with and without rule (*).

3 Selection of 50%-50%-Prospects and Preference Reversal

In the selection situation, a subject has to decide which of two given prospects she prefers:

$$A = [a(50\%), b(50\%)]$$
$$A' = [a'(50\%), b'(50\%)]$$

(In the following we assume without loss of generality that $a > a' > b' > b$, since otherwise the two prospects can be exchanged, or the the decision between the prospects is obvious.)

Experiment: The experiment was performed with the same 16 subjects and 14 pairs of prospects. All pairs were selected such that we suggested that a preference reversal might happen. The pairs are listed in Table 3.1.[2]

Prediction: The decision criterion we expected was

> **50%-50%-Prospect Selection Rule):** Prospect A is preferred to A' if $per(a) - per(a') > per(b) - per(b')$, where the absolute exactness as the minimum of the exactnesses of the two prospects.[3]

[2] Two of the pairs do not even theoretically fulfill the condition of preference reversal.

[3] Another criterion is obtained by assuming that the exactnesses of the two pairs a, a', b, b' are obtained separately. By our data we cannot decide which of the two criteria is the better predictor.

The important difference between a comparison via money equivalents, and the pairwise comparison is, that in the absolute exactness. Accordingly, it is possible that the two conditions select different prospects ('preference reversal').

Example: Consider $A = [+1000(50\%), 0(50\%)]$, $B = [+5000(50\%), -1000(50\%)]$. The comparison happens on the scale

$$\begin{array}{ccccccccc} -1000, & -500, & -200, & 0, & +200, & +500, & +1000, & +2000, & +5000 \\ & & & \longleftarrow & & A & \longrightarrow & & \\ \longleftarrow & & & & & B & & & \longrightarrow \end{array}$$

The difference of the lower steps is -3, that of the higher steps is +2. It is not even necessary to count negative steps double, to obtain the result that A is preferred. The result of the selection process is that A is preferred. In the examples of the preceding section we calculated the corresponding money equivalents. Since the money equivalent of B is higher than that of A, we state a preference reversal in the predictions. – The reason of the preference reversal is, that the prospect B was in the individual condition evaluated with absolute exactnes 1000, in the selection condition with absolute exactness 200. This gives completely different evaluations. Here we see, how important it is that the absolute exactness is selected task dependent.

Results: The results are presented in Table 3.1. The aggregated data over all cases show an essential shift of the preference, which is for the aggregated data of all questions: 189 : 34 for the decisions via selections, and 110 : 102 for the preference concluded from the money equivalents. (The difference is siginificant on the .0001 level.) Remarkable is that the theoretical prediction is to a high proportion fulfilled for the pairwise comparison condition, while the theoretical prediction of the individual judgement conditions is only fulfilled by 50% of the answers. This suggests the conclusion thet the theoretical prediction of pairwise comparison are more reliable. Howewer, it should be remarked that the evaluation of the individual prospects was preformed after the selection among pairs, and that the individual prospects were again presented as pairs, in the same way as before, so that some subjects may have remembered their preceding decision and adjusted their evaluations accordingly to create consistant data. From this part of view the setup did certainly not support to obtain preference reversals.

It should be remarked that the type of preference reversal presented here has not yet been mentioned in the literature. Up to now, the general idea seems to be that preference reversals are introduced by specific constellations of percentage and money values, which are such that under certain conditions the money is more important ('dollar auction'), and under other conditions, probabilities are more important ('probability auction'). Other examples seem to be costructed in a way that under different situations different kinds of rounding are applied. The example here shows, that the effect works with quite clear alternatives, and even when the probabilies are always 50%.

The effect very clearly supports the general approach of this paper, namely that the perception depends on the absolute exactness, and that the absolute exactness can in fact be task-dependent.

Table 3.1: Results of the Preference Reversal Experiment 3)

pair of prospects	preferences by 1) choice	money.eq.	pair of prospects	preferences by 1) choice	money.eq.
[100, −10]	14	6	[100, −100]	16	11
[500, −100]	2	10	[500, −1000] *)	0	3 (3)
[100, −100]	15	5	[100, 0]	15	8
[1000, −500] *)	1	8 (3)	[500, −1009]	1	8 (1)
[200, 0]	15	9	[100, 50]	11	8
[1000, −200]	1	7	[500, −50]	5	7
[100, −20]	6	7	[100, 100]	13	9
[1000, −100]	10	9	[500, −50]	3	7
[100, −10]	13	7	[500, −10]	11	8
[1000, −100]	3	9	[2500, −100]	5	8
[100, −10]	16	6	[10, 10]	14	8
[200, −50]	0	6 (4)	[100, −50]	2	7 (1)
[2000, −100]	15	11	[1000, −1009]	15	7
[10000, −1000]	0 (1)	5	[5000, −1000]	0 *)	8 (1)
total, all pairs				189	110
				34 (1)	102 (12) 2)
total, only pairs where preference reversal				144	86
is predicted by theory				31 (1)	84 (6) 2)

*) cases where preference reversal is not predicted by theory

1) cases of indifference in brackets

2) results are significant on $\alpha < .0001$ (chi-square)

3) 16 subjects, 14 pairs of proposals

4 The Paradox of Iterated Halving

In the last section of the paper we present an effect which is insofar related to 50%-50% prospects that again the midpoints of stimuli are selected. Besides the ability to judge whether the intensity of a stimulus is in the middle of two others (see section 3), another type of judgement is whether one stimulus is half as intense as another.

This judgement is only possible, when the distance of zero-point and a given stimulus can be measured. I. e. if there is some smallest perceived level of intensity which has a distance of finitely many steps to the stimulus. The selected response with half intensity should divide the numbers of steps between the stimulus and the zero point by two.

We presented two tasks related to the two judgements mentioned above:

> Task 1: By iterated questions we asked subjects for a sequence of payoff-values, such that they perceived every value as double as intense as the preceding one. (The question was "by some surprising event you get a certain amount of a

DM. At what amount x do you feel double as happy as getting a?")
Task 2: We asked the subjects to give a sequence of numbers, for which they perceived the stimulus of every element as being in the middle of the stimuli of the two neighbours, starting with the alternatives 1000 and 3000.
Result: The typical responses of Task 1 are sequences as ..., 300, 1000, 3000, 10000, 30000, 100000,.... The chains of Task 2 look similar with slightly lower differences as ...,100, 300, 1000, 3000, 9000, 25000,....

The following types of sequences would be expected:

	task 1	task 2
under logarithmic perception	$c\, c^2\, c^4\, c^8 \ldots$	$c\, c^2\, c^3\, c^4 \ldots$
under linear perception	$c\, c^2\, c^3\, c^4 \ldots$	$X\, X + c\, X + 2c\, X + 3c \ldots$

The experimental results of both tasks are rather similar. In both cases one obtains sequences, where the distances of neighboured elements (in steps) are constant. This conforms with the prediction of linear perception for Task 1, and with the predictions of logarithmic perception for Task 2. This seems paradox.

The result of Task 2 can be explained, if one assumes that an amount $10 * 10^i$ induces an absolute exactness of $2 * 10^i$ (according to the 20%-rule) and thereby in the steps $0, 2 * 10^i, 5 * 10^i, 10 * 10^i$, so that the mean between 0 and $10 * 10^i$ is reached at 1.5 of the 3 steps, i. e. at $3 * 10^i$.

We presume that the same experiment can be made with physical stimuli (as brightnes, etc.) as well. This would mean that also in psychophysical perception the smallest perceived intensity depends on the task. Moreover, it would suggest that the effects described by the WEBER-FECHNER law are not physiological phenomena, but – as in the perception of numerical stimuli – happens between perceived stimulus and the response. This would mean that the WEBER-FECHNER law is not a phenomenon of perception, but a phenomenon of judgement support the idea that also the WEBER-FECHNER describes phenomena of 'psychomathematics' rather than of 'psychophysics'.

5 Other Paradoxa Concerning Decisions on Prospects

There are several paradoxa concerning prospect decisions. And several attempts have been made to explain these paradoxa. HEY (1994) gives an overview over these concepts. The reader may ask, how the theory of prominence works compared to these theories. The point is that the concepts that have been developed meanwhile can explain the 'older' paradoxes, which should – from that point of view – no longer be denoted as paradoxes, because they are 'solved'.

However, the Paradoxa described above are not solved. They describe Phenomena which can (only?) be easily explained by the assumption that the finest perceived money unit depends on the task. This dependence is not addressed by the other theories, and – from our point of view – does not seem natural for them. Accordingly, the 'disadvantage' of using an additional parameter (namely the smallest perceived money unit) turns out to be the natural kee to understand certain phenomena.

We close with an overview over paradoxa concerning prospects that can be explained by prospect theory (as an example), and the theory of prominence:

Table 4.1: Explanation of Paradoxes by Prospect Theory, and Theory of Prominence

	Prospect Theory	Theory of Prominence
1. Allais Paradox	++	++
2. Common Ratio Effect	++	++
3. Ambiguity	++	++
4. Classical Preference Reversal	??	++
5. New Preference Reversal	--	++
6. Iterated Halving	--	++

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