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The Point and Interval Perceptions of Automobile Risks in the Top-down and Bottom-up Procedures

Abstract

Based on the belief that our risk perceptions are basically distributional rather than pointwise, the triple-value approach was used in the present work on the public evaluation of automotive risks by college students in the top-down (Group T) and bottom-up (Group B) procedures. 8 individual parts and the whole system were judged in the single-event risks, while 6 pairs of engine and another part were presented in the compound (conjunctive and disjunctive) events. Despite the prominent high risk levels about the *engine* and the *other* categories of Group B in the single event judgment, there was no procedural difference about the *whole*. The results were attributed to the use of availability heuristics in Group B and anchoring in Group T, on one hand, and the unique evaluation scheme for the whole system independent of the direction of evaluation, on the other. Other group differences were noted, too. The fairly constant interval lengths across items, types of events and procedures suggest the underlying qualitative processing of uncertainties. Though not descriptively tenable, the centrality model may serve well as the basis of an anchor for the point evaluation given an interval. The alternative wave model was not compatible with our data. Presentation of own previous responses was proposed as a judgmental aid in hope of reducing cognitive loads in compound judgments that were incompatible with the probabilistic laws. Finally, the prerequistes of the Birnbaum's model received only partial supports.

The Point and Interval Perceptions of Automobile Risks in the Top-down and Bottom-up Designs

1. Introduction

Automobiles are practically an everyday item in our modern life, entailing both convenience and risks. Their familiarity would help reduce difficulty in risk assessment by ordinary people as compared to very large systems like a nuclear power plant. Yet, their decent complexity will illustrate the basic nature of perceptions about a system and its components. Note that a system of their size or larger seldom breaks down as a whole, even though it may cease functioning. For instance, a car may stop running and become inoperable due to malfunctioning of the engine, the distributer, the gear-box, the transmission or any other part, or some combinations of them. In most cases, it is a component (or components) of a car that goes wrong, but not the whole system. Nevertheless, people somehow derive an overall impression of the system reliability from personal experiences, reputations or public reports, which may affect their choice of a model in the next purchase. At other times, people infer reliabilities of parts from general impressions about a model. To the extent that people possess perfect, solid knowledge about the reliabilities of a system and its subsystems and are able to correctly express them, their risk evaluation should not vary by the direction of an inquiry, i.e., parts-to-whole or whole-to-parts. However, we anticipate some directional effects in such a task in light of the situation-dependent nature of human judgment emphasized in the past psychological studies (e.g., Fischhoff, Slovic & Lichtenstein, 1978; Slovic, Fischhoff & Lichtenstein, 1980; Slovic, Griffin & Tversky, 1990).

Concerning the perceptions of automotive troubles, it seems natural to assume that people have some sense of variations among manufacturers, models, regions and other conditions. It is also likely that they are aware of the insufficiency of their knolwedge that makes exact evaluaction difficult. In other words, their risk perception is basically distributional in nature rather than pointwise, perhaps with a vague idea about the form of distributions. Still, they will be able to indicate the lowest and highest possible values along with the most representative value within the interval when asked to do so (see, for a similar view, Hesketh, Pryor, Gleitzman & Hesketh, 1988). We expect this triple-value approach is also suitable for measuring judgments by expertise such as mechanics, engineers and auto-analysts (see Rosa & Humphreys, 1988) who should take into account the classificatory inconsistencies of automotive systems among records (MacGregor & Slovic, 1989) and the possibility of unreported cases known as the dark number.

Despite the remarkable quality control in the automotive industry, few models are free from recalls from manufactures. Although people ordinary do not continuously monitor these records, occasional observations of the news will create images of conjunctive and/or disjunctive risks about models one is interested in. From past experiences, people learn that automotive troubles could happen or are found simultaneously within a certain period of time. Sometimes they occur as if there were a chain-reaction meachanism. This does not mean that only conjunctive risks have bearings on personal life, because their purchase of a next model will be affected by the images of disjunctive risks derived from public reputaitons and recall records. Also, a consumer's decision may be affected by the form of a warranty, for instance, depeding on whether it covers only a single damage (or malfunctioning), conjunctive or disjunctive damages. Therefore, it will be of great interest to examine the nature of risk perceptions in the single and compound (conjunctive and disjunctive) events with an aid of the triple-value measurement in the top-down (whole-to-parts) and bottom-up (parts-to-whole) procedures.

Regarding the triple-value properties, two issues are worth consideration: the relative location of the most representative value (M) within a given interval; and, the length of an interval in terms of a measure of dispersion. These issues were left unexamined in the past studies that employed the triple-value ratings (Hesketh, Pryor, Gleitzman & Hesketh,1988; Rosa & Humphreys, 1988).

The first issue is to find out λ in the following formula:

$$M = (1-\lambda)\, Lo + \lambda Up \quad (0 \leq \lambda \leq 1)$$

where M denotes the most representative value, Lo and Up the lower and upper ends of an interval, respectively. The simplest idea is to assume M to fall in the middle of an interval, i.e., λ=0.5. As a natural consequence, extreme values of M near the ends of a scale, are necessarily associated with very narrow intervals which reduces to 0 in the most extreme case, say for M=0 or 1 on a [0,1] scale. The exclusion of modest to wide intervals for extreme values of M can be avoided by assuming a wave-like form such as the one suggested by Gärdenfors and Sahlin (1983) in the context of a second-order probability. The wave model, in short, postulates that distributions be negatively (or positively) skewed near the lower (or upper) end of a scale, and be (nearly) symmetrical in the middle areas of a sacle. In terms of our triple-value measures, λ increases from 0 to 1 as M does, and λ is roughly .5 for moderate M.

Findings pertinent to the second issue were reported by Wyer (1973) and Birnbaum (1972, 1974) in their studies on personality impression formation, though there is a discrepancy of interst to us in their results. While Wyer obtained an indication of smaller dispersions around exteme ratings on both ends as compared to the intermediate ratings, Birnbaum found narrow ranges only on the negative end. Since their observations were based on the averaged figures across items, we will see if there is any such tendency at the individual item level. Also to be resolved is the duality in the meanings of negativity, i.e., substantive (or social) and numeric negativities. These are confounded in the studies of impression formation in which an adjective for a socially undesirable trait usually receives a low rating. The present work separates them by placing substantively negative ("risky") label on the higher end of a scale (numerically positive) and substantively positive ("riskless") label on the lower end (numerically negative). Our interest in dispersion, however, are not confined to these descriptive matters.

According to Mellers, Richards and Birnbaum (1992), the small dispersion of a negative item is responsible for the greater influence of a negative adjective in conjunctive judgments than a paired non-negative adjective with a greater dispersion. Their equal probability criterion predicts that a joint judgment falls in the region where the two distributions overlap. By analogy, we expect the most representative value of a conjunctive judgment to fall in the overlapped region of the constituent intervals. For non-overlapping distribtuions, they only made a passing note: Either the more dispersed information is discounted or the single adjective means are averaged. In essence, they maintained that the joint judgment would be pulled toward the constituent judgment with a smaller dispersion. We will analyze the effect of a smaller dispersion in overlapping and total cases, using the interval length as the measure of dispersion.

Before closing this section, a note seems necessary concerning the plausible range of values within which a compound judgment falls. Provided that the lower and upper ends of risk intervals represent lower and upper probabilities, the following rules serve as a benchmark (Murofushi, 1994):

For events A and B that are not necesarily mutually exclusive

(1.1a) $P_*(E)+P_*(F)-P^*(E \cup F) \leq P_*(E \cap F)$
$\leq \min\{P_*(E)+P^*(F)-P_*(E \cup F),\ P^*(E)+P_*(F)-P_*(E \cup F),$
$P^*(E)+P^*(F)-P^*(E \cup F)\}$

(1.1b) $\max\{P_*(E)+P^*(F)-P^*(E \cup F), P^*(E)+P_*(F)-P^*(E \cup F),$
$P_*(E)+P_*(F)-P_*(E \cup F)\}$
$\leq P^*(E \cap F) \leq P^*(E)+P^*(F)-P_*(E \cup F)$

(1.2a) $P_*(E)+P_*(F)-P^*(E \cap F) \leq P_*(E \cup F)$
$\leq \min(P_*(E)+P^*(F)-P_*(E \cap F),\ P^*(E)+P_*(F)-P_*(E \cap F),$
$P^*(E)+P^*(F)-P^*(E \cap F))$

(1.2b) $\max(P_*(E)+P^*(F)-P^*(E \cap F),\ P^*(E)+P_*(F)-P^*(E \cap F),$
$P_*(E)+P_*(F)-P_*(E \cap F))$
$\leq P^*(E \cup F) \leq P^*(E)+P^*(F)-P_*(E \cap F)$

where P_* and P^* denote the lower and upper probabilities, respectively. Between these two lies the true probability, P, i.e., $P_* \leq P \leq P^*$. Apparently, (1.1a)-(1.2b) subsume the less complicated rules suggested by Dempster (1967) for situations where $E \cap F = \phi$ holds (see also Good, 1962; Sugeno & Murofushi, 1993). In view of the interdependent automotive systems like the engine and the electric components, the exclusiveness condition is hardly met in the case of automobile troubles. It should be noted that P_* and P^* corresponds to *Lo* and *Up* explained earlier.

2. Method

Subjects. 67 students in introductory psychology courses at Doshisha University in Kyoto served as subjects. They were randomly assigned to Groups B (bottom-up) or T (top-down). Consequently, the groups consisted of 29 and 38 subjects, respectively. The experiment was conducted individually.

Procedure: Prior to the experiment, the subjects were carefully introduced to the idea of point and interval assessment. A diagrammatic picture of an automobile was shown at the beginning of the experiment in order to activate a whole-part scheme. The whole system was devided into 8 components (*engine, electricity, doors, steering, breaks, gauges, wheels* and *others*). The questionnaire items were phrased with an emphasis of (sub)systemness of these components.

The task for Group T (top-down) in the first-stage was to estimate the likeliness of having an automobile trouble with each component system and a car as a *whole*. In the second stage, the subjects were asked to estimate the chances of having troubles with components E AND F in conjuctive judgments (E OR F in disjuctive judgments) where *engine* was always used for E to maintain consistency in the item combinations. *Whole* and *others* were not included in the pairs. The procedure was reversed for Group B (bottom-up).

Instructions: The following instructions were given to the subjects.

> *More than 4 million new cars were sold last year in Japan. Please estimate the liekeliness of malfunctioning or damage that might happen to these cars in the 80 thousand kilometers operation. By the way, a round-trip distance between Osaka and Tokyo is approximately 1,100 km.*
>
> *For each item (whole or part) shown below, first indicate the lowest and highest possible values. Then, give a single value that would most represent the interval.* (This part was essentailly replicated in the assessment of compound events.)

λ Measure. The lamda measure was constructed as an index of the relative location of the most representative value, *M*, within an interval:

$$\lambda = \frac{M - Lo}{|Up - Lo|} \qquad (0 \leq \lambda \leq 1)$$

e.g.,

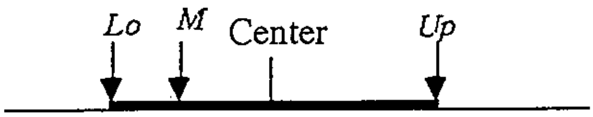

Figure 1. Relative position of *M*

where *Lo* and *Up* are lower and upper ends of an interval. Under the centrality model λ is 0.5 regardless of *M*. The wave model, in contrast, postulates a positive relation between *M* and λ: Roughly stated, small *M*'s would be leftwardly off-central ($\lambda < .5$), and large *M*'s would be rightwardly off-central ($\lambda > .5$). The medium *M*'s would be centrally located ($\lambda = .5$).

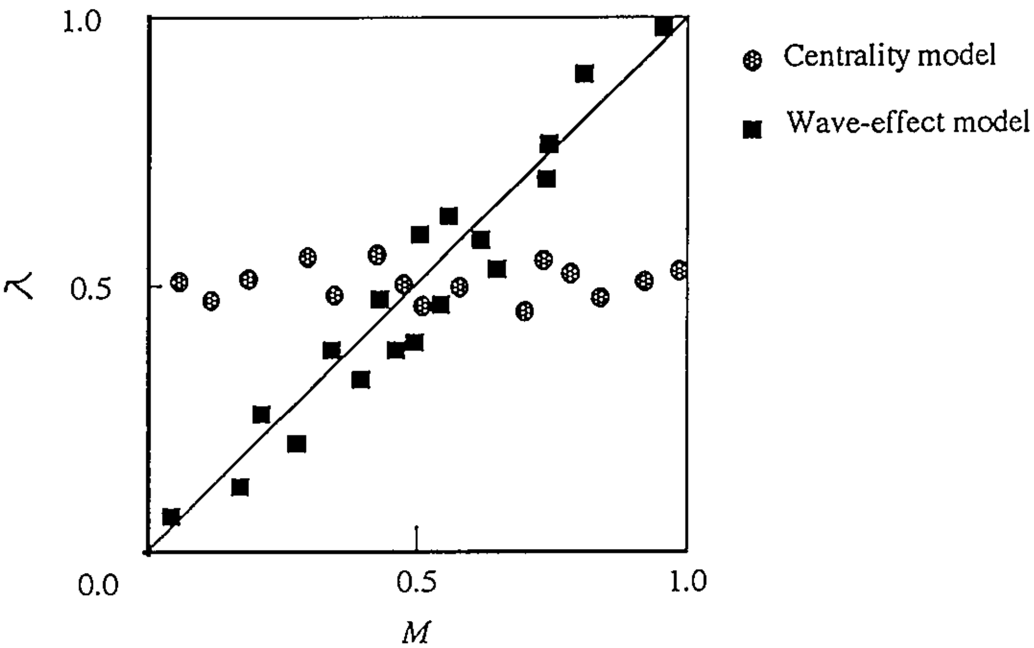

Figure 2. Hypothetical relationships of λ and *M* under the two models

Figure 2 illustrates the relationships of λ and *M* under the two models. We expect the regression line paralles the diagonal under the model, i.e., slope coefficient is 1.

3. Results

The section is divided into four parts: analysis of the single-event risks, analysis of the compound-event risks, tests of the Birnbaum's model, and a test of the intervalic probability rules.

3.1 Analysis of the single-event risks

Table 1
Mean scores of the point (M) and boundary evaluations (Lo, Up), interval length (IL) and λ by group

	B: Bottom-up (n=29)					T: Top-down (n=38)				
	Lo	*M*	*Up*	*IL*	λ	*Lo*	*M*	*Up*	*IL*	λ
Whole	0.281	0.416	0.557	0.276	0.494	0.225	0.362	0.482	0.257	0.535
Engine	0.601**	0.708**	0.805**	0.204	0.571	0.309**	0.398**	0.491**	0.182	0.485
Electricity	0.240	0.344	0.421	0.181	0.603*	0.289	0.370	0.462	0.172	0.462*
Doors	0.185	0.282	0.366	0.180*	0.553	0.177	0.237	0.307	0.130*	0.478
Steering	0.239	0.326	0.411	0.172	0.437	0.208	0.283	0.359	0.151	0.542
Breaks	0.318	0.415	0.509	0.191	0.560	0.285	0.375	0.459	0.174	0.514
Gauges	0.191	0.269	0.370	0.179*	0.418	0.167	0.226	0.294	0.127*	0.510
Wheels	0.394	0.506	0.596	0.201	0.587	0.382	0.451	0.527	0.146	0.481
Others	0.565**	0.706**	0.824	0.259	0.568	0.267**	0.359**	0.448	0.181	0.527

Note: Asterisks mark the significance levels of Mann-Whitney U-test between groups.
* $p < .05$, ** $p < .01$.

Analysis of group differences of means. Table 1 shows the mean scores of the most representative value (M), the lower (Lo) and upper (Up) boundaries of intervals besides the mean interval lengths (i.e., $IL=Up-Lo$) and the λ measures. Due to the lack of normality in some of the measures, Mann-Whitney U-test was used to test group differences instead of t-test.

Although, the mean M's are generally greater in Group B (bottom-up) than Group T (top-down), the significant differences ($p < .01$) are limited to *engine* and *others*: M(*engine*)=.708 and .398; and M(*others*)=.706, and .359 for Groups B and T, respectively. The higher risk perceptions of Group B than T about these are noteworthy, since the intervals of the former lie entirely to the right of those of the latter: B=[.601,.805] vs. T=[.309, .491] for *engine*; and, B=[.565, .824] vs. T=[.267, .448] for *others*. The boundary differences are significant only about these items ($p < .01$) except for *Up* about *others*.

The mean *IL*'s are small, varying from .172 (*steering* of Group B and *electricity* of Group T) to .259 (*others* of Group B). Although Group B generally produced wider intervals than Group T, only those pertaining to *doors* (.180 and .130, in order of Groups B and T) and *gauges* (.179 and .127) reach the 5% significance level.

The mean λ's of Group B vary more widely, [0.418, 0.603], than those of Group T, [.462, .542]. The significant group difference is limited to *electricity* (.603 and .462 for Groups B and T, respectively, $p < .05$). The mean λ's do not greatly depart from the central point, i.e., 0.5. This indicates the lack of or weak support to the centrality model as will be tested later.

Analysis of centrality. In view of possible errors in producing the centrality responses (λ=0.5) by mental computations, three allowance levels, α, around λ were introduced for the analysis: α=0, ±5, ±10% of the interval lengths, i.e., *Up* - *Lo*. Widening the centrality zone to $0.45 \leq \lambda \leq 0.55$ (i.e., α=±5%) bring about only limited changes in proportions, resulted from the shifts of single cases, (*doors* and *breaks* in Group T) as shown in Table 2. The proportions of centrality responses of Group B are lower than those of Group T in all items, although none of the between-group differences are significant at the 5% level.

The zone must be further widened to $0.40 \leq \lambda \leq 0.60$ (i.e., α=±10%) in order for Group B to have proportions exceeding 50%. The general tendency that Group T produces more centrality responses than B persist at this level (with a minor exception for *engine*). However, none of the percentage differences are statistically significant at 1% level.

Loglinear analysis is suitable for testing the importance of the centrality-noncentrality distinction in population. The simple independence model [Group Item] satisfies the requirement of the experimental design that the margins due to groups and items be fixed. The fit of the model is reasonable at both allowance levels: $LR(26)$=31.393, p= .214 for α=±5%; and $LR(26)$=16.692, p= .918 for α=±10%, where *LR* denotes the likelihood-ratio chi-square. The absence of the centrality-noncentrality distinction in the model means that the two responses are equally likely given the fitted marginals.

That is, the centrality model lacks strong support.

Table 2

Proportions of the centrality responses by group

	B: Bottom-up (n=29)			T: Top-down (n=38)		
Item	Exact	±.05	±.10	Exact	±.05	±.10
Whole	24.1%	27.6%	44.8%	34.2%	36.8%	52.6%
Engine	41.4	41.4	51.7	42.1	42.1	50.0
Electricity	27.6	27.6	37.9	39.5	39.5	47.4
Doors	41.4	41.4	58.6	60.5	63.2	65.8
Steering	31.0	31.0	44.8	52.6	52.6	60.5
Breaks	37.9	37.9	48.3	39.5	42.1	50.0
Gauges	44.8	44.8	51.7	39.5	39.5	55.3
Wheels	48.3	48.3	58.6	52.6	52.6	60.5
Others	44.8	44.8	58.6	44.7	47.4	63.2

Table 3

Correlation coefficients between λ and M

and the range of M by group

	B: Bottom-up (n=29)		T: Top-down (n=38)	
Item	r	range of M	r	range of M
Whole	.227	[0.05, 0.80]	.378	[0.01, 0.99]
Engine	.484	[0.12, 1.00]	-.066	[0.01, 0.99]
Electricity	.172	[0.03, 0.80]	-.017	[0.02, 0.99]
Doors	.126	[0.02, 0.70]	-.049	[0.01, 0.70]
Steering	.090	[0.02, 0.80]	.135	[0.01, 0.90]
Breaks	-.151	[0.04, 0.85]	.095	[0.01, 0.85]
Gauges	.191	[0.01, 0.80]	.018	[0.01, 0.80]
Wheels	.179	[0.06, 1.00]	-.107	[0.03, 0.99]
Others	.243	[0.10, 1.00]	.445	[0.03, 1.00]

Test of the wave model. The model requires the presence of extreme values of

M on the scale, say $M \leq 0.2$ or $M \geq 0.8$. As shown in Table 3, the requirement is met except for *doors* in both groups. However, the correlations between λ and M are lower than expected under the model: the coefficients range from -.151 to .484 in Group B, and -.107 to .445 in Group T. Retatedly, the fit of regression lines is generally poor ($R^2 < .235$). The 95% confidence intervals of the slope coefficients of the best two among these in terms of R^2 fall below 1: [0.110, 0.659] and [0.125, 0.659] for *engine* of Group B and *others* of Group T, respectively. Hence, the wave model is not compatible with our data.

Test of negativity and dispersion. Negativity in the numerical sense pertains to small values of point evaluation (say, $M \leq 0.2$), and to large values of M ($M \geq 0.8$) in the substantive sense (i.e., riskiness),. Examination of the mean IL in the three segments of M (see Table 4.1) reveals mixed patterns of associations between the negative evaluation and the dispersion measured by IL.

Table 4.1
Mean of interval length (IL) in three segments of
point evaluations (M) by group

	B: Bottom-up (n=29)			T: Top-down (n=38)		
	$M \leq 0.2$	$0.2 < M < 0.8$	$0.8 \leq M$	$M \leq 0.2$	$0.2 < M < 0.8$	$0.8 \leq M$
Whole	0.16 (9)	0.32 (17)	0.37 (3)	0.15 (15)	0.35 (21)	0.15 (2)
Engine	0.19 (3)	0.27 (10)	0.17 (16)	0.12 (15)	0.24 (19)	0.12 (4)
Electricity	0.13 (10)	0.22 (17)	0.20 (2)	0.10 (16)	0.23 (20)	0.10 (2)
Doors	0.14 (14)	0.22 (15)	-.-- (0)	0.10 (22)	0.18 (16)	--.-- (0)
Steering	0.09 (13)	0.23 (13)	0.28 (3)	0.10 (19)	0.21 (16)	0.13 (3)
Breaks	0.10 (7)	0.24 (17)	0.16 (5)	0.10 (15)	0.24 (20)	0.10 (3)
Gauges	0.13 (17)	0.23 (10)	0.35 (2)	0.09 (24)	0.19 (13)	0.10 (1)
Wheels	0.10 (5)	0.23 (15)	0.21 (9)	0.10 (15)	0.22 (16)	0.08 (7)
Others	0.10 (1)	0.33 (12)	0.21 (16)	0.10 (17)	0.27 (18)	0.10 (3)

Note: The number of cases are shown in parentheses.

First, the monotone increases of IL across the three segments of M in *whole*, *steering* and *gauges* of Group B are accompanied by the moderate to high correlations, .495, .594 and .613, respectively (see Tables 4.1 and 4.2).

The results are in accor with the numerical interpretation. The comparable correlation about *doors* of Groups B (.546) and T (.455) may not be regarded as supportive evidence, due to the lack of cases in the upper segment of *M*.

Second, the substantive interpretation requires a monotone decrease of *IL* associated with a negative correlation. There is no supportive evidence in the present data. However, the changes in *IL*, except for the cases mentioned above, are inversely V-shaped with the lower mean *IL*'s in both end-segments as compared to the middle one. The results suggest that both numerical and substantive negativity are effective, or, simply, that the extremity on the scale lead to narrow perceptions, regardless of their meanings. However, due to the insufficient number of cases at the upper segment of *M*, the above interpretation remains inconclusive.

Table 4.2
Correlations between *IL* and *M* by group

Item	Bottom-up (n=29)	Top-down (n=38)
Whole	.495	.419
Engine	-.240	.203
Electricity	.340	.241
Doors	.546	.455
Steering	.594	.256
Breaks	.288	.264
Gauges	.613	.417
Wheels	.215	.062
Others	-.370	.282

3.2 Analysis of the compound-event risks

In the compound-event judgments, *engine* was paired with another part in conjunctive and disjunctive manners. In view of the lack of normality in some data, Mann-Whitney *U*-test was applied. Table 5 shows a contrasting pattern of the procedural effects on *M*, *Lo* and *Up* between the types of judgment. While Groups B and T significantly differ in the *engine-wheels* pair in conjunctive judgment with respect to these measures, significant group differences in disjunctive judgment are found in the rest of the pairs. The mean scores of

Group B are higher than those of Group T in all these measures.

Table 5
Mean scores of the point (*M*) and boundary evaluations (*Lo*, *Up*), interval length (*IL*) and λ in the compound judgment by group

Item paired	B: Bottom-up (n=29)					T: Top-down (n=38)				
with *Engine*	*Lo*	*M*	*Up*	*IL*	λ	*Lo*	*M*	*Up*	*IL*	λ
Conjunctive judgment										
Electricity	0.312	0.440	0.581	0.269	0.495	0.275	0.389	0.483	0.208	0.502
Doors	0.124	0.227	0.333	0.209	0.497	0.211	0.280	0.367	0.157	0.454
Steering	0.182	0.272	0.378	0.196	0.399	0.241	0.335	0.436	0.194	0.413
Breaks	0.314	0.415	0.531	0.217	0.462	0.298	0.393	0.492	0.193	0.507
Gauges	0.161	0.250	0.360	0.199	0.443	0.229	0.307	0.396	0.167	0.465
Wheels	0.567**	0.704**	0.774**	0.208	0.620	0.362**	0.461**	0.543**	0.182	0.552
Disjunctive judgment										
Electricity	0.341**	0.448**	0.561**	0.222*	0.491	0.209**	0.290**	0.367**	0.158*	0.541
Doors	0.464**	0.564**	0.676**	0.212*	0.457	0.163**	0.222**	0.289**	0.126*	0.509
Steering	0.343**	0.443**	0.567**	0.223*	0.461	0.207**	0.263**	0.339**	0.133*	0.466
Breaks	0.372*	0.467*	0.566*	0.193	0.531	0.239*	0.314*	0.398*	0.159	0.504
Gauges	0.470**	0.560**	0.657**	0.186*	0.458	0.197**	0.249**	0.314**	0.117*	0.439
Wheels	0.369	0.447	0.552	0.183	0.436	0.279	0.358	0.432	0.153	0.489

Note: * $p < .05$, ** $p < .01$.

Particularly noticeable are completely riskier perceptions of Group B than T in the *engine-wheels* pair of the conjunctive judgment, and the *engine-doors*, *engine-steering* and *engine-gauges* pairs of the disjunctive judgment. The *Lo*'s of Group B of these pairs are higher than the *Up*'s of Group T in the mean values: 0.567 (*Lo* of Group B) vs. 0.543 (*Up* of Group T), 0.464 vs. 0.289, 0.343 vs. 0.339, and 0.470 vs. 0.314 in order of the pairs. Though less distinctively, Group B still tends to be riskier than T about the *engine-electricity* and *engine-breaks* pairs in the disjunctive judgments: In order of (*Lo*, *M*, *Up*), (0.341, 0.448, 0.561) and (0.209, 0.290, 0.367) for *engine-electricity* of Groups B and T, respectively; and (0.372, 0.467, 0.566), (0.239, 0.314, 0.398) for *engine-breaks*.

If the highly riskier perceptions about *engine* of Group B is solely responsible for the group differences, the results would have been more straightforward.

The procedural effects on *IL* are also present in the disjunctive judgments about *engine-electricity* (0.222 vs. 0.158), *engine-doors* (0.212 vs. 0.126), *engine-steering* (0.223 vs. 0.133), and *engine-gauges* (0.186 vs. 0.117) pairs. Hence, not only the perceptions of Group B tend to be riskier than T in these pairs, they have wider intervals.

Table 6

Proportions of centrality responses by group

Item paired with *Engine*	Bottom-up (n=29)			Top-down (n=38)		
	Exact	$\pm.05$	$\pm.10$	Exact	$\pm.05$	$\pm.10$
	Conjunctive judgment					
Electricity	41.4	41.4	48.3	39.5	47.4	57.9
Doors	34.5	34.5	51.7	44.7	44.7	57.9
Steering	37.9	37.9	44.8	31.6	31.6	47.4
Breaks	37.9	37.9	51.7	44.7	47.4	52.6
Gauges	55.2	55.2	72.4	52.6	52.6	60.5
Wheels	41.4	41.4	51.7	42.1	44.7	52.6
	Disjunctive judgment					
Electricity	41.4	41.4	55.2	50.0	50.0	55.3
Doors	27.6	27.6	44.8	52.6	52.6	60.5
Steering	44.8	44.8	58.6	47.4	50.0	57.9
Breaks	41.4	41.4	44.8	52.6	55.3	68.4
Gauges	37.9	37.9	51.7	44.7	50.0	60.5
Wheels	41.4	41.4	41.4	42.1	42.1	60.5

Analysis of centrality. Listed in Table 6 are the proportions of the centrality responses (λ=0.5) with three allowance levels about λ: α=0, ±5, ±10% of the interval lengths. The results are similar to those of the single-event risks. That is, broadening the centrality zone to $0.45 < \lambda < 0.55$ only slightly increase the proportions in half of the items pertaining to Group T (*electricity*, *breaks* and *wheels* in the conjunctive judgments; and, *steering*, *breaks* and *gauges* in the disjunctive judgments). Substantial increases in proportion are realized when the zone is further widened to $0.40 < \lambda < 0.60$. To test the dominance of centrality over noncentrality responses, the simple-most loglinear model ([Event-type Group Item]) that reflected the minimum requirement of the design was fitted to a four-way frequency table (Event-type x Centrality x Group x Item). The fit of the model is reasonable for both enlarged centrality zones: $LR(40)=26.873$, $p= .944$ for $\alpha=\pm5\%$; and $LR(40)=24.850$, $p= .971$ for $\alpha=\pm10\%$. The absence of the centrality-noncentrality distinction in the model means that two types of responses are equally likely in population given the fitted marginals. Hence, the centrality model lacks support from our data.

Although Group B tends to produce smaller proportions than Group T, none of the percentage differences are statistically significant at 5% level.

Test of the wave model. Moderate correlations between λ and M are found in four pairs of the disjunctive judgements (see Table 7): the *engine-breaks* (.446) and *engine-wheels* (.546) pairs of Group B; and, *engine-electricity* (.589) *engine-wheels* (.432) of Group T. The rest of the correlations are low (< .400).

Having assured the presence of extreme values of M in the four pairs, regression slope coefficients were computed as a further test of the wave model. Their 95% confidence intervals all fall below 1: [0.089, 0.770], [0.204,0.831], [0.306, 0.836], [0.101, 0.586] in order of the pairs mentioned above. The results along with the poor fit ($R^2 < 0.346$) are not compatible with the model.

Test of negativity and dispersion. To infer the numerical negativity, a moderate to high correlation between IL and M must be accompanied by a monotone increase of the mean IL across the lower ($M \leq 0.2$), middle ($0.2 < M < 0.8$), and upper ($0.8 \leq M$) segments of M. Three pairs of the conjunctive judgment are compatible with this requirement (see Tables 8.1 and 8.2): *Engine-steering* (r=.429), *engine-gauges* (.425) pairs of Group B, and *engine-doors* (.496) pair of Group T. However, due to the small increases of IL and the moderate correlations, these should not be taken as strong evidence.

Table 7
Correlation coefficients between λ and M
and the range of M by group

Item paired	B: Bottom-up (n=29)		T: Top-down (n=38)	
with *Engine*	*r*	range of *M*	*r*	range of *M*
		Conjunctive judgment		
Electricity	.224	[0.05, 0.90]	.206	[0.01, 0.99]
Doors	.260	[0.05, 1.00]	.052	[0.01, 0.80]
Steering	.283	[0.05, 0.80]	.018	[0.01, 0.79]
Breaks	.100	[0.03, 0.90]	-.164	[0.01, 0.85]
Gauges	.080	[0.03, 0.95]	.177	[0.01, 0.80]
Wheels	.101	[0.02, 0.80]	.278	[0.01, 0.99]
		Disjunctive judgment		
Electricity	.316	[0.05, 1.00]	.589	[0.01, 0.99]
Doors	-.011	[0.02, 0.60]	.231	[0.01, 0.95]
Steering	.375	[0.00, 0.60]	.128	[0.01, 0.90]
Breaks	.446	[0.01, 1.00]	.212	[0.01, 0.90]
Gauges	.020	[0.03, 0.60]	.147	[0.01, 0.90]
Wheels	.546	[0.05, 1.00]	.432	[0.03, 0.99]

Although the correlations pertaining to *engine-doors* (.837), *engine-steering* (.703) and *engine-gauges* (.762) pairs of Group B in the disjunctive judgment are quite high, the lack of cases in the upper segment of *M* prevents the inference of the negativity effect.

Compared to the case of the single-event judgments, there are fewer cases with inversely V-shaped changes of *IL* across the segments of *M* most of which are found in Group T. However, overinterpretation of the results should be refrained because of the generally small changes from the middle to the upper segments of *M*.

Table 8.1
Mean of interval length (*IL*) in three segments of point evaluations (*M*) by group

Item paired with *Engine*	B: Bottom-up (n=29) $M \leq .2$	B: $.2 < M < .8$	B: $.8 \leq M$	T: Top-down (n=38) $M \leq .2$	T: $.2 < M < .8$	T: $.8 \leq M$
			Conjunctive judgment			
Electricity	0.10 (4)	0.24 (22)	0.27 (3)	0.10 (20)	0.21 (17)	0.09 (1)
Doors	0.10 (5)	0.23 (18)	0.25 (6)	0.10 (23)	0.18 (14)	0.20 (1)
Steering	0.11 (7)	0.25 (19)	0.30 (6)	0.10 (21)	0.16 (17)	-.-- (0)
Breaks	0.15 (7)	0.21 (17)	0.18 (5)	0.10 (17)	0.22 (19)	0.15 (2)
Gauges	0.10 (6)	0.19 (13)	0.23 (10)	0.09 (22)	0.16 (15)	0.15 (1)
Wheels	0.14 (5)	0.20 (22)	0.15 (2)	0.10 (18)	0.22 (17)	0.10 (3)
			Disjunctive judgment			
Electricity	0.17 (5)	0.29 (19)	0.28 (5)	0.12 (10)	0.23 (25)	0.31 (3)
Doors	0.11 (16)	0.33 (13)	-.-- (0)	0.12 (20)	0.21 (16)	0.12 (2)
Steering	0.09 (13)	0.28 (16)	-.-- (0)	0.08 (16)	0.29 (18)	0.21 (4)
Breaks	0.08 (7)	0.26 (20)	0.25 (2)	0.08 (13)	0.27 (21)	0.17 (4)
Gauges	0.11 (16)	0.31 (13)	-.-- (0)	0.09 (17)	0.24 (19)	0.12 (2)
Wheels	0.15 (4)	0.20 (7)	0.22 (18)	0.08 (11)	0.27 (20)	0.10 (7)

Note: The number of cases are shown in parentheses.

Table 8.2
Correlations between *IL* and *M*

Item paired with *Engine*	Group B (n=29)	Group T (n=38)	Group B (n=29)	Group T (n=38)
	Conjunctive judgment		Disjunctive judgment	
Electricity	.247	.367	.226	.341
Doors	.214	.496	.837	.348
Steering	.429	.365	.703	.416
Breaks	.322	.525	.364	.301
Gauges	.425	.459	.762	.339
Wheels	.224	.346	.172	.185

3.3 Tests of Birnbaum's model

In this section, two key points of the Birnbaum's model will be examined: The joint (or conjunctive) judgment falls in the overlapped regions of the constituent distributions; and, the joint judgment is pulled toward the constituent judgment with smaller dispersion. Classification of overlapping types precedes the test.

Analysis of overlapping patterns. For a given conjunctive judgment, the intervals of the paired items (*engine* and another part) are classifiable into 5 overlapping and 2 non-overlapping patterns as shown in Figure 3. In patterns 1, 2 and 3, *Lo(engine)* is always greater than *Lo(paired part)*, but they differ in the location of the upper-end of the paired part relative to the interval of *engine*: *Up(paired part)* < *Lo(engine)*, *Lo(engine)* < *Up(paired part)* < *Up(engine)* and *Up(engine)* < *Up(paired part)* in order of patterns 1, 2 and 3. Their reversals are patterns 5, 6 and 7. That is, *Lo(engine)* is always smaller than *Lo(paired part)* in them, but *Up(paired part)* < *Up(engine)*, *Lo(paired part)* < *Up(engine)* < *Up(paired part)* and *Up(engine)* < *Lo(paired part)* in order of patterns 5, 6 and 7. In pattern 4, the two intervals coincide.

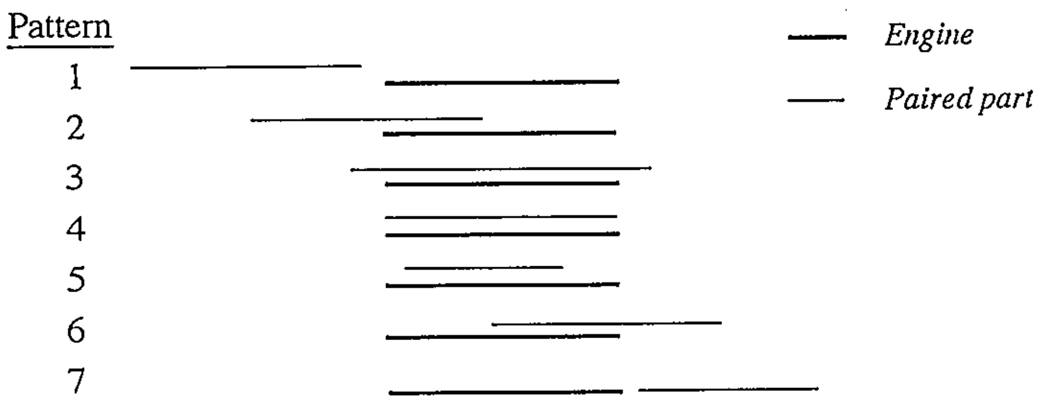

Figure 3. Seven overlapping patterns of risk intervals

Table 9
Relative frequencies (%) of the overlapping patterns by group

Item paired with *Engine*	B: Bottom-up (n=29)							T: Top-down (n=38)						
	Pattern							Pattern						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Electricity	58.6	34.5	0.0	3.4	0.0	3.4	0.0	13.2	28.9	5.3	13.2	10.5	21.1	7.9
Doors	65.5	27.6	0.0	6.9	0.0	0.0	0.0	39.5	31.6	2.6	15.8	5.3	5.3	0.0
Steering	69.0	17.2	0.0	3.4	3.4	6.9	0.0	28.9	26.3	10.5	10.5	18.4	5.3	0.0
Breaks	58.6	17.2	3.4	10.3	6.9	0.0	3.4	13.2	21.1	7.9	21.1	15.8	21.1	0.0
Gauges	72.4	10.3	6.9	6.9	0.0	3.4	0.0	39.5	23.7	2.6	13.2	15.8	2.6	2.6
Wheels	34.5	34.5	6.9	6.9	10.3	6.9	0.0	7.9	5.3	2.6	15.8	23.7	31.6	13.2

Listed in Table 9 are the proportions of patterns for each pair by group. In Group B, pattern 1 is predominant (exceeding 58.6%), probably due to the high risk perceptions about *engine* (see Table 1). The only exception is the *engine-wheels* pair in which patterns 1 and 2 equally share the largest proportion (34.5%). High concentration in patterns 1 and 2 is the characteristic of this group, ranging from 69.0% (*engine-wheels*) to 93.1% (*engine-electricity* and *engine-doors*). In contrast, there is no such concentration about Group T. Also the modalities in proportions across pairs are much lower than those of Group B, varying from 21.1% (patterns 2, 4 and 6 of *engine-breaks*) to 39.5 (pattern 1 of *engine-doors* and *engine-gauges*).

The Birnbaum's model presumes that the representative point evaluation of a joint judgment, *M* in our case, falls in the shared area if the two constituent intervals overlap. Hence, only cases with ovelapping intervals (patterns 2 through 6) will be used for testing this assumption.

Table 10
Proportions of *M* of the conjunctive judgments falling in the overlapped intervals by group

Item paired with *Engine*	Group: Bottom-up (n)		Top-down (n)	
Electricity	33.3%	(12)	60.0%	(30)
Doors	40.0	(10)	52.2	(33)
Steering	22.2	(19)	66.7	(27)
Breaks	18.2	(11)	45.5	(33)
Gauges	50.0	(8)	50.0	(22)
Wheels	26.3	(19)	23.3	(30)

Note: Enclosed in parentheses are the numbers

The proportions of the "true" cases under this principle vary from 18.2 (*engine-breaks*) to 50.0% (*engine-gauges*) in Group B and 23.3 (*engine-wheels*) to 66.7% (*engine-steering*) in Group T (Table 10). Loglinear analysis was performed to test the importance of interactions among Group, Item-pairs and True-False distinctions. The best fit in terms of *LR* and *AIC* (see Matsuda, Ihara & Kusumi, 1994, for a comment on the use of *AIC*) was obtained from a model with a single interaction, Group by True-False, and the associated main terms: $LR(20)=26.184$, $p = .160$; $AIC=128.938$. Note that the item differences need no consideration under the model. The true:false odds are 3.50:8.00 and 13.50:14.80 in Groups B and T, respectively. Hence, there is a counter-tendency to the Birnbaum's assumption which is enhanced in Group B. The group difference is of interest to us.

Relative effect of the dispersion. The responses were calssified as "true" if *M* for a conjunctive event is located closer to that for a constituent singel event with a narrower *IL* as compared to the other constituent *M*. Otherwise, cases were "false". As shown in Table 11, the proportions of the "true" cases of Group B are all below 50%. In contrast, more than half of the cases are "true" in four out of six pairs of Group T. The exceptional pairs are *engine-breaks* and *engine-wheels*.

Loglinear analysis was performed to test interactions among Group, Item-pairs and True-False distinction. The best fit in terms of *LR* and *AIC* was obtained from a model with a single interaction, Group by True-False, with the associated main terms: $LR(20)=21.318$, $p = .379$; $AIC=123.896$. The estimated true:false odds under the model are 3.83:7.67 and 15.00:12.50 in Groups B and T, respectively. Hence, the odds are in the opposite directions. Hence, the effect of a smaller dispersion holds for Group T, whereas the reverse is true for Group B.

Table 11
Proportions of the point evaluation, *M*, of the conjunctive judgments under the influence of small dispersion by group

Item paired with *Engine*	Group: Bottom-up (n=29)	Group: Top-down (n=38)
Electricity	8.3%	56.7%
Doors	30.0	52.2
Steering	22.2	63.0
Breaks	45.5	48.5
Gauges	37.5	68.2
Wheels	47.4	43.3

Note: See Table 7 for the number of overlapping cases.

The aforementioned tendency of Group T becomes reversed when we add nonoverlapping cases in the analysis. The experimental design requires to include the main effects due to Group and Item in testing loglinear models. Among the tested models with these effects, the best fit was obtained from the model with a single interaction between Group and True-False distinction: $LR(15) = 11.684$, $p = 0.703$, $AIC = 132.726$. The marginals of Item being equal, the presence of the term in the model need no substantive attention. The estimated true:false odds for the combined data are 10.67:18.33 and 18.17:19.83 for Groups B and T, respectively. That is, the point evaluation, *M*, of a conjunctive judgment tends to be pulled toward that of the constituent judgment with a larger dispersion.

3.4 Test of the intervalic probability rules

Table 12
Proportions of the cases in compliance with
the intervalic probability boundaries by group

Item paired with *Engine*	Bottom-up (N=29) Boundary Lower	Upper	Both	Top-down (N=38) Boundary Lower	Upper	Both
			Conjunctive judgment			
Electricity	55.2	51.7	48.3	73.7	65.8	60.5
Doors	58.6	48.3	44.8	63.2	55.3	50.0
Steering	55.2	37.9	37.9	65.8	57.9	52.6
Breaks	37.9	41.4	34.5	76.3	73.7	73.7
Gauges	65.5	55.2	51.7	60.5	47.4	44.7
Wheels	51.7	48.3	41.4	52.6	47.4	42.1
			Disjunctive judgment			
Electricity	58.6	48.3	48.3	73.7	68.4	60.5
Doors	51.7	51.7	44.8	68.4	50.0	50.0
Steering	44.8	37.9	37.9	63.2	60.5	52.6
Breaks	51.7	37.9	34.5	76.3	73.7	73.7
Gauges	58.6	58.6	51.7	63.2	47.4	44.7
Wheels	48.3	51.7	41.4	55.3	44.7	42.1

The figures in Table 12 are the proportions of cases whose *Lo* 's and *Up* 's (or P_*'s and P^*'s) of the compound judgments are in accord with Rules (1.1a)-(1.2b), the normative boundaries of the lower and upper probabilities of conjunctive and disjunctive events. The proportions were separately computed for the two boundaries of the rules and are listed in the columns Lower and Upper. The proportions of cases whose *Lo* and *Up* both comply with the rules are listed under Both. The closeness of the figures in the three columns of each item pair means that a case satisfying one boundary tends to satisfy the other whether the event is conjunctive or disjunctive. Therefore, only those under Both was subjected to further analysis by loglinear models.

It must be noted that the identical results in column Both between conjunctive and disjunctive judgment are the natural consequences of Rules (1.1a)-(1.2b). Due to this constraint, the type of judgment need no consideration in loglinear analysis. Reasonable fit was obtained from the simple-most model, [Group Item-pair], consisted solely of the main effects required by the experimental design: $LR(17) = 17.846$, $p = .399$. The model asserts that compliance and noncompliance with the rules are equally likely in population, and that there is no procedural effect.

4. Discussion

It goes without saying that the engine of an automobile is a vital component. Continuous combustion that takes place in it as well as the intricate coordination of fast-moving parts require occasional tuning and replacement of parts. These and related considerations seem to have produced the relatively high risk perception about the engine in the bottom-up procedure, whether stemmed from personal experiences or easily conceivable nature of the incidents. Troubles can also happen to many other parts such as wipers, seats and door-locks that fall into the '*other*' category in the present work. The availability or conceivability of incidents in the mind of risk assessors could be responsible for the observed group differences in these two categories. If the prominence of these categories had driven the representative heuristics, the group difference should have also appeared in the same direction about the *whole* category. However, the observed procedural difference was not significant. This suggests that our subjects applied a rule characteristic about the whole system, rather than deriving its risk by the representative heuristic or some aggregation rule. The idea resembles the old Gestalt doctrine: The whole is not the sum of its parts.

Obviously, the incident availability or conceivability principle is hard to apply to the evaluation of the whole, other than rare, fatal accidents. For the top-down group, the initial suppression (or non-utilization) of these principles seems to have laid the ground for the evaluation of subsystems. In other words, the initial evaluation about the whole might have worked as an anchor followed by little adjustment (see Kahneman, Slovic & Tversky, 1986, for studies on the heuristics by representativeness, availability and anchoring-adjustment). All these interpretations, nonetheless,will remain tentative until they are examined in future under a more suitable design.

Comparisons of the point evaluation, M, of the compound-event judgment with that of the single-event judgment in each group reveal the tendencies that run counter to the probability laws about conjunctive and disjunctive events: i.e.,

$$P(\mathrm{E}\cap\mathrm{F}) \leq \min(P(\mathrm{E}), P(\mathrm{F})) \text{ and } P(\mathrm{E}\cup\mathrm{F}) \geq \max(P(\mathrm{E}), P(\mathrm{F}))$$

Incompatible with the first law are the patterns of the *engine-electricity* and the *engine-wheels* pairs of Group B and all the pairs of Group T. The results of the disjunctive judgment are all incompatible with the second law in both groups. In light of the extant studies on the human judgment about uncertain events (see particularly, Hogarth, 1975; Tversky & Kahneman, 1986), the observed incompatibilities should not be attributed to the fault of our subjects, but rather to the inappropriateness of the application of the laws to the description of the natural, intuitive judgments about uncertain events. Nonetheless, the incompatibility about the *engine-wheels* pair of each group reached the extent to even disobey the most basic law: i.e.,

$$P(E \cap F) \leq P(E \cup F).$$

Were the levels of M much lower, this could be explained by an XOR-like mental operation, since the conjunctive judgment preceded the disjunctive one in the present design. Procedural considerations lead us to suggest the possibility that the incompatibilities might be attenuated if subjects could make judgments in view of their own previous, related responses. Triple-value evaluation (*Lo, M, Up*) over 27 items might have overloaded their mental capacity without a judgmental aid.

Another procedural problem stems from the meanings of the conjunctive and disjunctive occurrence of automotive troubles during a certain period of time. On one hand, conjunctive occurrence sometimes pertains to joint events like a personality portray by multiple traits or throwing more than one die. It also means, on the other hand, the successive or even non-successive occurrence of events. In the present study, it was left to the subjects' understanding that the conjunctive occurrence would entail all these possibilities. Having two non-successive events in a 'mental model' (Johnson-Laird, 1980) is a source of difficulties in the ensuing judgments of disjunctive occurrence. In this connection, an insurance coverage framework is planned in our forthcoming study as an aid to the comprehension of compound events about automotive risks.

Despite its intuitive appeal, the triple-value evaluation over many items, and, particularly related items such as the single- and compound-events used in the present study are indeed overtasking subjects mental work. Besides the reference to own previous records mentioned above, reference to some objectively derived values will serve well as a judgmental foothold or anchor. The test results of the intervalic probabilities seem to be promising owing to their neutrality to the compliance-noncompliance propensity as well as to the top-down and bottom-up manipulations.

The properties derived from the directly measured tripe-values were the interval lengths (*IL*) and λ. First, the mean values of the former fell in the relatively small range, i.e., [.117,.269]. This can be taken as an indication of the qualitative processing of uncertainties. Zimmer (1983, 1984) found that his subjects mostly used 5 to 6 verbal labels for the whole range of subjective probabilities. The observed range in our study fairly consistent with the Zimmer's findings, provided some overlaps of uncertainty categories. We do not, however, consider verbal expressions necessary for the underlying qualitative processing. Second, the mean values of λ varied in the vicinity of .5, i.e., [0.40, 0.62], across items of both single and compound judgments. We are, therefore, tempted to conclude that the point evaluation, *M*, would be located approximately in the middle of the intervals between *Lo* and *Up*. However, loglinear analysis made it clear that the central and noncentral responses were equally likely to happen in population. Taking these pieces of evidence together, we suggest a general tendency to place a point evaluation around the center of an interval, but not very close to it. Perhaps, this is related to the propensity of ambiguity preference (Matsuda, Ihara & Kusumi, 1994).

From the foregoing discussion it is clear that the centrality model lacks a descriptive power for risk perceptions. Nonetheless, its simplicity and the distributions of the mean λ's give an incentive to employ it as an anchor to which subjects can make adustments. In adittion to its merit as a judgmental aid, it offers a chance to test the propesnity of amibiguity preference in risk perceptions. As a matter of fact, it is implemented in our forthcoimg study by using HyperScaling technique (Matsuda, 1993). The wave model had little support from our data, either. Furthermore, visual examinations of the graphs found no supportive evidence, either. Due to the non-uniqueness in the function specification, the model is disadvantageous to the centrality model as an anchor.

Our tests of the Birnbaum's model with respect to its prerequisites obtained only partial support. Firstly, the numerical negativity was associated with the small dispersion, measured by interval length (*IL*) in a few items of both single- and compound-event judgments. However, there were more items with the narrow *IL*'s at the two ends of the scale, indicating that the numerical and substantive negativities were both effective. Alternatively, one can attribute the pattern to the extremity on a given scale like Wyer (1973). To resolve the issue, a study needs to be designed such that there will be sufficient number of cases for extreme values like a conditional probability framework. Otherwise, with the today's quality control in the advanced technologies, the risk perceptions tend to be low.

Secondly, Birnbaum proposed his model in order to account for the general observation that a joint judgment of a personality is located closer to the constituent judgment with a smaller dispersion. Group T in the present study produced the similar tendency when overlapping cases were analyzed, while the reverse was true for Group B. However, we observed the counter-tendencies in both groups when overlapping and nonoverlapping cases were considered together. Hence, the reverse effect of a dispersion holds for the automotive risk perception.

Thirdly, the equiprobability assumption of his model requires the joint judgment to fall in the shared area of the overlapping constitutent distributions. The odds of the present results disagree with the assumption. The group difference in the unfavorable odds seems to be attributable to the very high level risk perception about *engine* in Group B.

Let us conclude the discussion by pointing out the foundamental differences between the personality judgment studies and the present one, because of their bearings on the nature of human judgments about part-whole systems and conjunctive events. Personality, unlike the automotive system, is an intangible psychological entity that can be broken into aspects or attributes, but not into well-defined parts or subsystems. Note that in the tradition of personality judgment research, adjectives describe aspects of a person and the subjects rate the likableness of the person. In contrast, our subjects evaluated not only the whole system but also the parts on the same scale, i.e., risk. Simultaneity of conjunctive events is another point of departure. While a personality description by multiple adjectives is best to be interpreted as a simultaneous realization of attributes, conjunctive automotive troubles include non-simultaneous occurrence, too, as discussed above. Further points that merit attention include the problem domain (personalities vs. technological products), the nature of evaluation (affective opinion vs. objective risk) and the explicitness of uncertainty. Future research is expected to clarify these issues.

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