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The relative input of payoffs and probabilities into risk judgment**

The study was designed to investigate the relative input of payoffs and probabilities into risk judgment on the basis of the analysis of information search pattern. The modified version of MouselabWeb software (http://www.mouselabweb.org) was used as an investigative tool. The amount, the kind and the order of information accessed by subjects to evaluate risk was collected from ordinary respondents and respondents trained in mathematics and statistics. In the latter group were 75 students and young researchers working at National Aeronautics and Space Administration (NASA). The ordinary subjects were 67 Polish students of social sciences. As expected, the NASA group considered more information than ordinary students and searched for more information about probabilities. However, the ratio of information about payoffs to probabilities was close to 1 in both groups. Moreover, average risk rates were similar in both groups. It was also observed that risk rates were positively related with the amount of information about probabilities considered by subjects.

Keywords: *risk perception, risk judgment, holistic judgment, dimensional model*

Introduction

What is perceived risk? It is difficult to find its definition that is broadly accepted in a field of risk perception studies. Does it mean that people do not know which situation is risky and how to judge riskiness? It turns out that people intuitively are familiar with the concept of risk and, when asked to judge riskiness, they know what to do and do not have any additional questions. Moreover, judgments made by subjects from different countries are consistent (Keller, Sarin, M. Weber, 1986; Brachinger, Weber, 1997). The rates are also in agreement with basic logical rules, i.e. risk rates are smaller if the same positive amount of money is added to all payoffs (Keller, Sarin, M. Weber, 1986; Sokolowska, Swiatnicki, 2000). Despite these consistencies, numerous attempts to define perceived risk have not yielded a single, commonly accepted definition. One major point of controversy is related to the contribution of probabilities and outcomes into risk judgment (e.g. Slovic, 1967; Slovic, Lichtenstein, 1968; Payne, 1975 *vs.* Shapira, 1994; Huber, Wider, Huber, 1997; Brandstatter, Giegerenzer, Hertwig, 2006).

To clarify this controversy, the main purpose of this study is to investigate the relative input of payoffs and probabilities into risk judgment. Since the results of previous input-output research, in which respondents evaluated riskiness of gambles with different payoffs and probabilities, have been ambiguous, a different method – Mouselab (Payne, 1976; Willemsen, Johnson, 2006) – is used here. Mouselab is a process tracing method that enables following the whole process of risk judgment on the basis of information search patterns. This is in contrast to input-output experiments, which provide only the final result – how risk rates depend on the parameters of gambles.

Additionally, the influence of educational background in mathematics and statistics on attention focus on payoffs and probabilities has been checked. Finally, the focus on probabilities and risk rates in situations, which differed with respect to perceived control has also been investigated.

The relative input of payoffs and probabilities.

In quasi-laboratory experiments it has been found that perceived risk depends mostly on probability of loss (Slovic 1967; Slovic, Lichtenstein 1968; Payne 1975; Coombs, Donnell, Kirk 1978). Field studies, in contrast, indicate that the most important factor in risk perception is the magnitude of loss. For example, Shapira (1994) found that managers, who compared riskiness of two lotteries

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with different probabilities and magnitudes of loss, based their judgments on the latter. Furthermore, most executives asked for the 'worst possible outcome' or the 'maximum loss' and referred to it in defining risk. Similar finding was reported by Huber, Wider and Huber (1997). In this experiment, one group of participants was given a minimal description of a situation and could search for additional information. Only 22% of them asked for information about probability. Another group of respondents was given precise probability information. Less than 20% of them mentioned the word 'probability' or 'likelihood' in their verbal protocols.

One serious limitation in investigating the relative input of payoffs and probabilities into risk judgment is the fact that each aspect is measured on a different scale. Probabilities are measured on the scale from 0 to 1 and payoffs from minus infinity to plus infinity. In order to avoid this limitation, Kuhn and Budescu (1996) checked the relative impact of ambiguity about payoffs and probabilities on risk rates. In their experiments subjects evaluated riskiness of situations either with precisely described probabilities of loss (e.g. 5%) and with an ambiguous negative payoff (e.g. from $45 to $105) or with ambiguous probabilities (e.g. from 3 to 7%) and with a precise loss (e.g. $75). They demonstrated that vagueness of probabilities and outcomes affected perceived risk similarly and independently. However, in a follow-up study (Kuhn, Budescu, Hershey, Kramer, Rantilla 1999), they reduced the salience of the probability dimension by decreasing the probabilities and increasing the magnitude of the losses. They found that, in response to these modifications, most subjects became more concerned about vagueness of negative outcomes than about probabilities. Hence, again, one might express concerns about relative variability of each dimension.

In view of these concerns, one may propose an alternative approach to dealing with the scale effect. It relies on checking which information people use when they judge risk. Type, amount and order of searched information as well as reaction time can be registered by process tracing methods, e.g. Mouselab (Willemsen, Johnson, 2006). To take advantage of these capabilities, Mouselab is used here in order to investigate the relative importance of information about payoffs and probabilities in risk judgment.

Educational background and focus on payoffs and probabilities

As mentioned above, in field studies it has been found that risk rates are mostly determined by the amount of loss. One possible reason for this might be that estimating probabilities is difficult in the real world. Thus, people might believe that these estimates are inaccurate and instead prefer to rely on what they consider as more credible information, *i.e.* estimates of the worst outcome.

In line with the above thesis are empirical findings, which indicate that, in general, people use incorrect representation of random events (Kahneman, Tversky, 1972; Wagenaar, 1972). Instead of an 'inner random number generator' to estimate probable outcomes (e.g. lottery, random sequence of numbers), people use intuitive strategies like gambler's fallacy or law of small numbers to predict probabilistic events. Moreover, human predictions do not rely on formal logic. For example, subadditivity of probability for complementary events (e.g. Tversky, Koehler, 1994), as well as conjunction fallacy (eg. Tversky, Kahneman, 1983) were frequently observed. Since empirical results indicate that ordinary people cannot properly use information about probabilities, one might expect that they prefer to focus on other information, which they can use more correctly, i.e. information about payoffs. If this is the case it is expected that people who are trained in using probabilistic representation of physical world should be more effective in applying information about probabilities in problem solving. For such subjects one might expect that attention would be more equally divided between information about probabilities and payoffs.

To check this hypothesis, the experiments are carried out on two groups of respondents: ordinary people (students of social sciences and humanities) and subjects with good knowledge of mathematics and statistics (students and young researchers working for NASA).

Perceived control and risk rates

One of the factors that might influence the relative input of payoffs and probabilities is perceived control over situation, i.e. perceived relation between one's action and an outcome (Rotter, 1966; Weiner et. all, 1971/72). People perceive that they have internal control over a situation, when they believe that an outcome results from their own action. Examples are skill situations, such as playing chess. In contrast, when people attribute outcomes to external factors, such as weather, chance, fate or powerful others (e.g. flood, gambling, bad luck, political power), they perceive such situations as uncontrollable.

In a number of experiments (Brigham, 1979; Cohen, Hansel, 1959; Howell, 1971) it was found that people prefer situations perceived as controllable. For example, managers did not want to gamble, even though they were making business decisions in very uncertain situations as long as they believed that this uncertainty was related to inner sources (March, Shapira, 1987). Cohen and Hansel (1959) and Howell (1971) noticed that a majority of respondents preferred skill over chance situations. Heath and Tversky (1991) proved that people prefer betting on their skills rather than on chance. Respondents answered questions related to knowledge (e.g. population in a given city) and next declared confidence about the correctness of their answers. In the second part of this experiment respondents could either bet that they answered correctly or play a lottery with the probability of winning equal to their confidence that they gave the correct answer. A majority preferred to bet on their answers. However, the follow-up study showed that this was true only when people were pretty confident about their knowledge, e.g. they estimated the probability that they gave the correct answer at 70% or more. When confidence was low, e.g. 30%, they preferred to play a lottery.

The findings above have been formalized by Gonzales and Wu (1999), who claim that the probability weighting function proposed by Tversky and Kahneman (1992) should be shifted up for positive outcomes in situations, in which people believe that outcomes are attributed to their own actions. This shift illustrates higher weights put to these probabilities in such situations and may explain their higher attractiveness in comparison with situations, in which outcomes are attributed to external factors. This is in line with Edwards' claim that probability might be treated as "a weighting function … which weights objective probabilities according to their ability to control behavior" (Edwards, 1954, p. 398). Taking these considerations into account, one might expect greater focus on probabilities and higher risk rates whenever a situation is perceived as uncontrollable.

Method

Overview

The main purpose of this research is to investigate the relative input of information about payoffs and probabilities in risk judgment using a process tracing method, i.e. a computerized version of the information board – Mouselab (Willemsen, Johnson, 2006). The influence of educational background in mathematics and statistics on the relative attention focus on payoffs and probabilities is controlled. It is expected that ordinary subjects put more attention to payoffs than to probabilities, whereas subjects with good knowledge of mathematics and statistics divide their attention nearly evenly between both kinds of information. Finally, it is checked whether subjects increase focus on probabilities and assign higher risk rates to risky situation perceived as uncontrollable.

Subjects. Participants in the experiment were divided into two groups. In the first group – subjects with good knowledge of mathematics and statistics – were 75 students and young researchers who worked at NASA Ames Research Center in Mountain View, California in the summer of 2009. In this group there were 33 women and 42 men. Their average age was 29 years. In the second group, called 'ordinary subjects' were 67 Polish students, mostly in social sciences and humanities. This group consisted of 35 women and 32 men, the average age of which was 24. The research was anonymous and individual.

Stimuli. Respondents were presented with six risky situations related to financial risk: taking a real estate loan in foreign currencies, investing in stocks of different companies, investing inherited money in either stocks, gold or objects of arts, casino gambling, betting on soccer teams and on horses. It has been expected that ordinary subjects would perceive the first three situations as controllable and the last three as uncontrollable. This was confirmed in a pilot study with 100 Polish students as subjects.

Every scenario included description of the situation with three possible options. Each option contained five possible outcomes (two gains, two losses and a break even). The detailed information about all payoffs and their probabilities was presented on the information board.

Design. The board consisted of 10 detailed pieces of data about each option – the value and the probability of each of five outcomes. Since each scenario consisted of there were 30 pieces of data in total. At the beginning they were hidden in 30 separate boxes, each labeled to inform subjects which piece of information it contains. To evaluate risk respondents could open the boxes to reveal their content. Because of its dynamic character the information board technique, enables tracing how people acquire and analyze information during risk judgment (e.g. Johnson, Schulte-Mecklenbeck, Willemsen, 2008).

A computer-based information acquisition system *MouselabWeb* (http://www.mouselabweb.org/) proposed by Willemsen and Johnson (2006) was used. *MouselabWeb* is a computerized version of an information board (Payne, 1976). In the original *MouselabWeb* boxes are uncovered after respondent's click and then disappeared after clicking on another box. In the version used in this experiment, all uncovered boxes were available to a participant until risk judgment was completed.

Respondents' task

Respondents were presented with six scenarios and asked to estimate risk for each option. To do this they could search for detailed information within the information board, as many as necessary. The risk was rated on an 11-point scale (from 0 'not risky at all' to 10 'extremely risky').

Results

Cognitive effort and risk judgment: the amount of revealed information

As mentioned before, subjects could open any number of boxes up to the maximum of 30. On average respondents accessed slightly more than 50% of available information (M = 17,34; SD = 9,83). This fraction is higher for the NASA group (M = 19,29; SD = 9,74) then for Polish students (M = 15,08; SD = 9,46). Moreover, Polish students

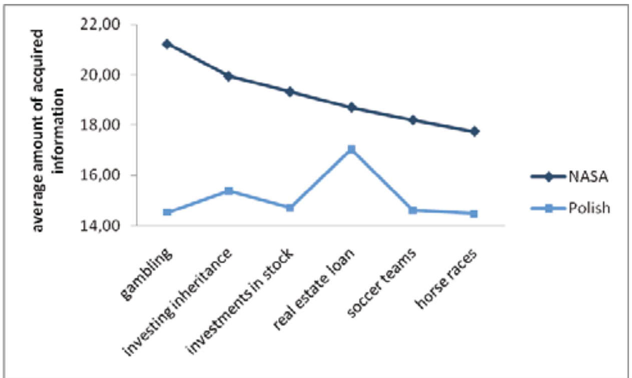

Figure 1. Differences in the amount of acquired information in two groups for six scenarios.

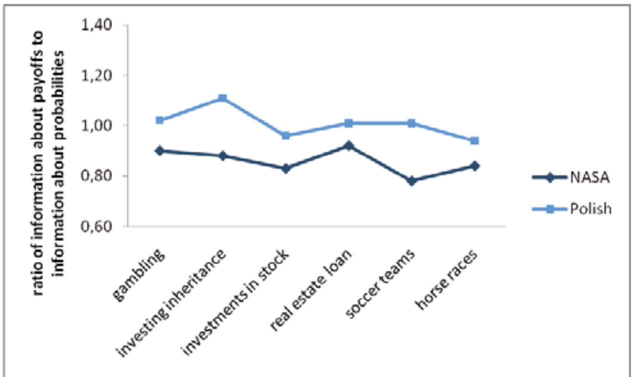

Figure 2. The ratio of the acquired information about payoffs to probabilities for six scenarios in both groups.

used approximately the same amount of information for all scenarios but one (real estate loan) whereas the amount of information considered by the NASA group was decreasing systematically with the length of the experiment. These observations are confirmed by ANOVA with one within-subject factor (6 scenarios: $F_{(5, 625)} = 2{,}66$; $p < 0{,}05$) and one between-subject factor (group: $F_{(1, 125)} = 7{,}69$; $p < 0{,}01$). All relations are shown in Figure 1.

The relative input of payoffs and probabilities into risk judgment: the ratio of both kinds of information searched

The research question addressed here is about the relative input of payoffs and probabilities into risk judgment. Since there is a difference between groups in the amount of information used, direct comparison of the amounts of information about payoffs and probabilities is not appropriate. Instead, the ratio of the amount of information about payoffs to those about probabilities is considered. As can be seen from Figure 2, this ratio is close to 1 in both groups, which means that similar amount of information about payoffs and probabilities was searched. However, for all scenarios Poles accessed slightly more information about payoffs (the ratio varies from 1,11 to 0,94), whereas the NASA group searched for more information about probabilities (the ratio varies from 0,93 to 0,78) – see Figure 2. This is confirmed by results of ANOVA with one

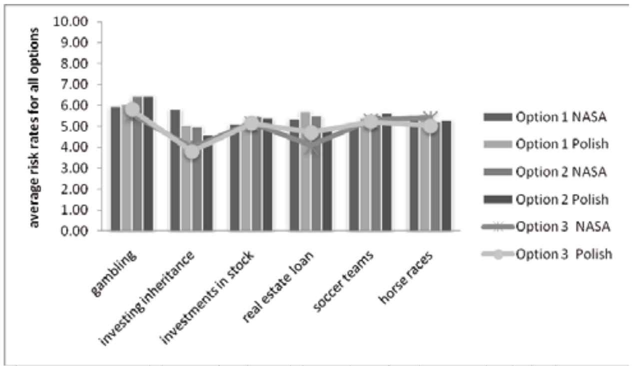

Figure 3. Average risk rates for three risky options for six scenarios in both groups.

within-subject factor (6 scenarios: $F_{(5, 520)} = 1{,}31$; $p = 0{,}26$) and one between-subject factor (2 groups: $F_{(1, 104)} = 4{,}69$; $p = 0{,}33$). The interaction effect is significant ($F_{(5, 520)} = 0{,}71$; $p = 0{,}62$).

Risk rates

As can be seen from Figure 3, in spite of the differences between groups described above, there is no difference in average risk rates in both groups.

This is confirmed by the results of ANOVA with one within-subject factor (6 scenarios and 3 measures - 3 options for each scenario) and with one between-subject factor (2 groups). The only significant effect found is the simple effect of scenario ($F_{(5, 625)} = 3{,}18$; 14,77 and 19,37 with $p = 0{,}008$ and $p < 0{,}001$ accordingly for Option 1, 2 and 3). Neither the group effect nor the interaction of scenario with group is significant ($F_{(5,625)} = 1{,}36$; 0,98 and 1,57 with $p > 0{,}05$).

For all respondents the significant correlations between risk rates and the amount of acquired information about values and probabilities were found: the more information about probabilities was collected the higher risk rates were assigned (see Equation 1). On the basis of the results of linear regression with average risk rates as dependent variable, one can state that the fraction of acquired information about probabilities explains 14% of variance in risk rates (*ad.j R Square* = 0,14 and $F = 23{,}88$; $p < 0{,}001$).

Avg Risk Rates = 3,85 + 0,382 (the fraction of information about p) Eq. 1

Similar solutions were obtained for both groups (*adj. R Square* = 0,16 and 0,12; $F = 14{,}79$ and 9,66 with $p = 0{,}003$ and $p < 0{,}001$ for the NASA group and for the Polish group accordingly) – see Equations 2 (the NASA group) and 3 (the Polish group)

Avg Risk Rates = 3,38 + 0,410 (the fraction of information about p) Eq. 2

Avg Risk Rates = 4,23 + 0,360 (the fraction of information about p) Eq. 3

Locus of control, focus on probabilities and risk rates

As mentioned before (see p. 48) the results of the pilot study with Polish students indicate that situations such as taking a real estate loan, investing money in stocks and investing inheritance are perceived as more controllable than gambling, betting on soccer teams and on horse races.

Table 1
Means and standard deviations of the fraction of the acquired information about probabilities to all information and average risk rates for Polish respondents.

Situations perceived by Poles as:	Fraction of information about probabilities	Std.	Average risk rates	Std.	N
controllable	0,47	0,17	4,91	1,03	67
uncontrollable	0,51	0,18	5,64	1,15	67

Averages of the fractions of information about probability to all information and average risk rates for situations perceived as controllable and uncontrollable for Polish respondents are presented in Table 1.

As can be seen from this table, the fraction of accessed information about probabilities is similar for controllable and uncontrollable scenarios ($t(66) = 1{,}77$; $p = 0{,}082$). Average risk rates, however, are higher for situations perceived as uncontrollable ($t(66) = 5{,}62$; $p < 0{,}001$).

Conclusions

The main research question in this study regards the relative input of payoffs and probabilities in risk judgment. As stated in the introduction, results of previous research are ambiguous. One serious limitation in investigating this issue is relative variability of each dimension, i.e. each aspect is measured on a different scale. In order to avoid this limitation, a process tracing method is used in the present experiments. Unfortunately, the results obtained here do not yield clear conclusions about the relative input of payoffs and probabilities into risk rates. However, on the basis of the results obtained here, several conclusions have been made: (1) respondents reveal similar amount of information about payoffs and probabilities, (2) the more information about probabilities is accessed, the higher risk rates and (3) respondents trained in mathematics and statistics (the NASA group) acquire more information about probabilities than ordinary subjects.

The second finding is interesting because it might suggest that, in line with the results of early experiments, risk is related to probability (e.g. Slovic 1967; Slovic, Lichtenstein 1968; Payne 1975; Coombs, Donnell, Kirk 1978) rather than to the amount of possible loss.

The finding that the NASA group searched for more pieces of data about probabilities than Polish students confirms the expectation that respondents with good knowledge of statistics and mathematics are more sensitive to information about probability than ordinary subjects. This is in agreement with the previously cited thesis that one reason for focus on payoffs in field studies might be that estimating probabilities is difficult in real world. Thus, ordinary people may rely more on what they perceive as more credible information, *i.e.* estimates of the worst outcome than on hard to estimate probability.

In agreement with previous findings, risk rates are higher when risky situations are perceived as uncontrollable situations. However, contrary to the expectation, respondents do not focus more on probabilities in such situations.

The presented results show that the NASA group searched for more pieces of data and acquired more information about probabilities than Polish students, even though risk rates were similar in both groups. One explanation of this result might be that risk rates are mostly determined by payoffs and probabilities of extreme outcomes, which were equally accessed by both groups. Additional information accessed by the NASA group, which is related to the other outcomes, might have only a minor influence on risk rates. However, another more general conclusion might be that different information search patterns led to similar results. Thus, once again in line with the research cited in the introduction, it is confirmed that people have a good understanding of the concept of risk and this concept is universal. In this context it is astonishing that neither results of input-output experiments nor results of process tracing studies can resolve the major controversy about the relative input of payoffs and probabilities into risk judgment and, as a consequence, do not yield a psychologically accurate definition of perceived risk. Taking these two conclusions into account, one might suggest that the hybrid approach combining input-output and process tracing research is needed in order to examine carefully the assumptions accepted in bilinear models of perceived risk (e.g. Coombs, Lehner, 1981, 1984; Luce, Weber, 1986).

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