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4. Heuristics and Biases for psychology and economics, Kahneman and Tversky in the 1970s

1. The Kahneman and Tversky collaboration

In 1969 Daniel Kahneman and Amos Tversky started a collaboration that would result in twenty-one collaborative papers and two co-edited books, including one published together with Paul Slovic. They continued to co-operate on different projects until Tversky's death in 1996, but the most productive and creative period was from 1969 to 1979, including the widely cited 1974 *Science* and 1979 *Econometrica* articles. The cooperation was initiated by Kahneman, who was looking for ways to experimentally test his intuition that an individual's cognitive apparatus often fails, and who tried to find a theory that might account for these cognitive errors [Krantz – interview (2008), Dawes – interview (2008), Kahneman (2002)]. But the ensuing program stemmed as much from the result of Tversky's growing doubts concerning Leonard Savage and Ward Edwards' assumption that, generally speaking, individuals decide according to the normative rules of logic, Bayesian statistics, and expected utility theory.

Although their collaborative work constituted an important part of their research, especially in the 1970s, it was never the only project they were engaged in. Kahneman continued to work on vision research and Tversky kept working on measurement theory and, sometimes, on elimination-by-aspects. The role that the collaborative work with Kahneman in Tversky's life played is nicely illustrated in fifteen letters which Tversky wrote to his close friend David Krantz between 1967 and 1977. His work with Kahneman is briefly mentioned for the first time in 1969, when Tversky, in an off-hand remark, notes that "I am working a little bit with Danny, on the problem of statistical intuition, which helped to reinforce my prejudices concerning the importance of statistics" [Tversky's letter to Krantz, October 5, 1969]. A month later, the work with Kahneman seems to have taken off seriously, as one project among a number of different projects Tversky was working on:

Danny and I got deeply involved in the problem of processing uncertainty: we are running a research seminar and a couple of studies on the topic [...] I am working now on the Chapters of our book [*Foundations of Measurement I – FH*]. The editing apparently takes much more time than I realized, but is certainly worth doing. What has happened to our MDS paper submitted to JMP?²⁵ [Tversky’s letter to Krantz, November 2, 1969].

When two years later he wrote about the re-organization of the psychology department he and Kahneman were seeking to advance, Tversky briefly mentioned what would become the famous 1974 *Science* publication. “Danny and I are writing a sort of review paper on our work for someplace like *Science*, and I returned to Chapter 16 [of *Foundations of Measurement II – FH*]” [Tversky’s letter to Krantz, November 14 1971].

The foundation for their collaborative fame in psychology, as well as the basis for their influence on economics from the early 1980s onwards, was laid in the 1970s. Between 1971 and 1979 Kahneman and Tversky co-authored eight articles. The first seven articles form part of the Heuristics and Biases approach, a new approach in behavioral decision research developed in the early 1970s. The prospect theory paper, published in 1979 in *Econometrica*, further developed the Heuristics and Biases program and was aimed explicitly at entering and influencing the economists’ debate on individual human behavior. In what follows, I will first set out the Heuristics and Biases approach, and show in what way this approach was a mix of the earlier work done by Kahneman and Tversky. After this, I will set out prospect theory and explain how this was intended to plead an argument in economics. The conclusion infers what consequences Kahneman and Tversky’s theories had for the conception of rationality in psychology and economics.

2. Heuristics and Biases

When in 1969 Kahneman and Tversky started to cooperate, their joint work became a mix of their earlier individual research. Tversky’s work on decision theory, with its distinction between the normative and descriptive realm, became coupled with

²⁵ “MDS paper” and JMP referred to Tversky and Krantz (1970) “The dimensional representation and the metric structure of similarity data,” published in the *Journal of Mathematical Psychology* (JMP) [email Krantz to author August 11, 2008].

Kahneman's psychology of mistakes. The first Heuristics and Biases articles showed that human beings in the real world display behavior that in all kinds of ways systematically deviates from what is normatively correct.

For their first article Tversky posed a set of questions to eighty-four participants who attended the 1969 meetings of the American Psychological Association and the Mathematical Psychology Group that meant to capture Kahneman's personal experience of incorrect research planning and unsuccessful replications, as discussed in Chapter three. "Suppose," Kahneman and Tversky asked, "you have run an experiment on 20 Ss, and have obtained a significant result which confirms your theory ($z = 2.23$, $p < .05$, two-tailed). You now have cause to run an additional group of 10 Ss. What do you think the probability is that the results will be significant, by a one-tailed test, separately for this group?" [Kahneman and Tversky (1972), p.433]. The answer depends on the interpretation of the information provided. However, it should be below but close to 0.50, Kahneman and Tversky argued. Nine out of the eighty-four participants gave answers between 0.4 and 0.6, which Kahneman and Tversky interpreted as "reasonable." The other seventy-five, however, gave answers that exceeded 0.60. The median response of all participants was as high as 0.85. Thus, even those professionals who were trained and who were explicitly asked to give the normatively correct answer failed to calculate it correctly. Kahneman and Tversky felt justified in inferring the strong and bold thesis "that people have strong intuitions about random sampling; that these intuitions are wrong in fundamental respects; that these intuitions are shared by naïve subjects and by trained scientists; and that they are applied with unfortunate consequences in the course of scientific inquiry" [Tversky and Kahneman (1971), p.105].

Kahneman and Tversky found it appalling and fundamentally disturbing to see that even trained professionals failed to behave according to the dictates of normative theory. Why did the majority of them fail? As set out in Chapter three, Tversky's answer earlier would have been that either there had been something wrong with the experiment, or that the normative theory was wrong. This time, however, Kahneman and Tversky took a different route. Building on the work of William Estes (1919-), a mathematical psychologist renowned for work on learning theory he conducted while at the University of Minnesota during the 1940s-1960s [e.g. Estes (1964), Bower (1994)], Kahneman and Tversky hypothesized that individuals have the tendency to suppose that a sample from a population must represent the population in its general

characteristics. In other words, they accounted for their results by supposing that human nature makes individuals ignore the possibility that a sample of a population may not be an accurate representation of that population. Kahneman and Tversky hypothesized that human nature sometimes provides individuals with the wrong intuition and that as a result they fail to give the right answer. However, Kahneman and Tversky took the research of Estes a step further by concluding that if one considers a sample to be representative of its population, then it could be thought of as a “heuristic.” They advanced the idea the human mind uses this heuristic to base decisions on.

It is not clear where Kahneman and Tversky derived the term ‘heuristic’ from. It appeared for the first time in 1971 without any precursors in either Kahneman’s or Tversky’s earlier work, and from the beginning it was used as a natural term for an intuitive response. The same term was used by Herbert Simon [e.g Heukelom (2007)], leading one to suppose that Kahneman and Tversky had obtained the term from him. But Simon used the term differently (on which more below in section 4.3) and is not mentioned in Kahneman and Tversky’s research of the early 1970s. Thus, it seems that the term ‘heuristic’ was a general term that psychologists could use to refer to intuitive, automatic behavior of individuals [Krantz – interview (2008), Dawes – interview (2008)].²⁶

The reason, according to Kahneman and Tversky, why the majority of scientists and lay persons systematically deviated from the norm-answer that was given in Tversky and Kahneman, “Belief in the Law of Small Numbers” (1971), and further developed in Kahneman and Tversky, “Subjective Probability: A judgment of representativeness” (1972) was that human beings, in general, do not base their decisions on the normative laws of, in this case, probability theory and statistics, but instead use a “representative heuristic.” Kahneman and Tversky described the representative heuristic as the phenomenon that “[t]he subjective probability of an event, or a sample, is determined by the degree to which it: (i) is similar in essential characteristics to its parent population; and (ii) reflects the salient features of the process by which it is generated” [Kahneman and Tversky (1972), p.430]. As a result of this representative heuristic, most of the professional psychologists mentioned in

²⁶ The use of the term ‘heuristic’ needs more investigation. Note in this regard that also the term ‘behavioral economics’ was used by Kahneman and Tversky and their followers from the 1990s onwards without (hardly) any reference to the already existing behavioral economic program in the Herbert Simon and George Katona traditions.

the example estimated the probability requested to be much higher than it actually was (the median estimate was 0.85). Because human beings have much more faith in small samples than they should, Kahneman and Tversky half jokingly labeled this phenomenon the “belief in the law of small numbers,” in reference to the law of large numbers. The analogy with faith and belief expresses Kahneman and Tversky’s view that an individual’s erroneous behavior is the result of false beliefs for which the unenlightened individual cannot really be blamed. The “deviations of subjective from objective probability seem reliable, systematic, and difficult to eliminate” [Kahneman and Tversky (1972), p.431], and “[t]he true believer in the law of small numbers commits his multitude of sins against the logic of statistical inference in good faith.”²⁷ The representation hypothesis describes a cognitive or perceptual bias, which operates regardless of motivational factors” [Tversky and Kahneman (1971), p.109].

3. Kahneman’s case-based reasoning

Kahneman and Tversky employed a case-based reasoning that finds its origin in Kahneman’s research of the 1960s. Kahneman’s research on the semantic differential, in particular, was never far away. For instance, the reason that people’s judgments systematically deviated from the correct solution was because of the individual’s connotation of the event of which the probability was to be judged: “Although the “true” probability of a unique event is unknowable, the reliance on heuristics such as availability or representativeness, biases subjective probabilities in knowable ways” [Tversky and Kahneman (1973), p.231]. The way in which an individual’s connotation of words in semantic differentials research systematically deviated from the average, and thus “true” connotation, was the same way in which the individual’s connotation of the probability of events systematically deviated from the objective, and thus “true” probability of those events. Given that framework, different explanations in terms of fixed cognitive rules could and were then put forth.

Typically, the argument in Kahneman and Tversky’s research was made not so much by giving theoretical explanations for why such and such was a good theory or account of observed behavior, but by supplying examples of the experimental

²⁷ The notion of subjective probability does not always have the same meaning. In Savage (1954), for instance, it is the rationally calculated probability of and by the individual. In Tversky and Kahneman, it is the subjective perception of objective probability.

questions subjects had been asked which were meant to give the reader an intuitive understanding of the point they were trying to make. Similarly, Kahneman and Tversky's adversaries have often proceeded by deconstructing their examples and illustrations, or by giving counter-examples. In the typical counter argument it was shown that a different conclusion could be inferred from the observed behavior, or that responses to another set of hypothetical questions falsified Kahneman and Tversky's conclusions [e.g. Gigerenzer (1991,1993,1996), Hertwig and Gigerenzer (1999), Lopes (1991)]. For a good understanding of Kahneman and Tversky's work one needs first to have a feeling for the kind of questions they asked, the examples they gave, and how they inferred general conclusions from them. Therefore, I will briefly introduce and discuss Kahneman and Tversky's most frequently used examples and illustrations.

Assuming that the probability of a new-born to be a boy or a girl is 0.5, consider the following question.

All families of six children in a city were surveyed. In 72 families the *exact order* of births of boys and girls was G B G B B G.

What is your estimate of the number of families surveyed in which the *exact order* of births was B G B B B B? [Kahneman and Tversky (1972), p.432, emphasis in the original]

The normatively correct answer is 72, as any sequence of boys and girls is equally probable. However, average estimates of the second sequence were systematically lower than the first. People, in other words, incorrectly believed the first sequence to be more probable than the second, from which Kahneman and Tversky concluded that “[p]eople view chance as unpredictable but essentially fair” [Kahneman and Tversky (1972), p.435]. An alternative, but related explanation was that people judged the first sequence to be more probable than the second because it better represented their image of a family with six children (representativeness), or that an image of a family with three boys and three girls was more readily available than an image of a family with five boys and one girl (availability).

In another experiment to test human's capacity to reason probabilistically, subjects were posed the following question.

A cab was involved in a hit-and-run accident at night. Two cab companies, the Green and the Blue, operate in the city. You are given the following data:

- (i) 85% of the cabs in the city are Green and 15% are Blue.
- (ii) A witness identified the cab as a Blue cab. The court tested his ability to identify cabs under the appropriate visibility conditions. When presented with a sample of cabs (half of which were Blue and half of which were Green) the witness made correct identifications in 80% of the cases and erred in 20% of the cases

Question: What is the probability that the cab involved in the accident was Blue rather than Green? [Tversky and Kahneman (1980), p.62]

The majority responded 80 percent, which was probably based on how often the witness had identified the color correctly. However, again they failed to take into account the base-rate distribution. Using Bayes' theorem the normatively correct answer is just over 41%.

The most well-known question amongst the many experimental questions of Kahneman and Tversky has become the so-called 'Linda problem,' no less because it has often been used by Kahneman and Tversky's adversaries. The Linda problem is as follows:

Linda is 31 years old, single, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

Which of the following two alternatives is more probable:

- 1) Linda is a bank teller
- 2) Linda is a bank teller and active in the feminist movement. [Tversky and Kahneman (1983), summarized from pp.297 and 299]

On average, there was a strong bias towards judging 2) to be more probable than 1), this despite the fact that 2) is logically contained in 1). Because this bias is an

illustration of the failure to see that the probability of the conjunction of two or more events can never exceed the probability of one of the events, this bias was labeled the conjunction fallacy.

From 1972 to 1974, on the basis of these and similar examples, Kahneman and Tversky developed the conclusion that their experimental evidence contradicted Edwards' behavioral decision research view that despite some unresolved issues, the normative models generally worked well descriptively. Extending further Tversky's earlier work, Kahneman and Tversky argued that the normative models worked descriptively far worse than had previously been thought. But instead of arguing that either the experiments were flawed or that the normative theory was wrong, the two options available in Tversky's research on human decision making in the 1960s, they now argued that the experimental results were perfectly valid and that there was nothing wrong with the normative theory. Instead, the new conclusion that was drawn was that when individuals make their decisions intuitively, they systematically deviate from the rational norm. The argument was thus directed explicitly against Tversky's former mentor and collaborator. With respect to Bayes' rule, Edwards had mistakenly assumed "that man, by and large, follows the correct Bayesian rule, but fails to appreciate the full impact of evidence, and is therefore conservative" [Kahneman and Tversky (1972), p.43]. However, the mainstream representatives of signal detection theory were also criticized.²⁸ "Peterson and Beach (1967), for example, concluded that the normative model provides a good first approximation to the behavior of the Ss who are 'influenced by appropriate variables and in appropriate directions'" [Kahneman and Tversky (1972), p.43]. Kahneman and Tversky had come to fundamentally disagree with them. "[In] his evaluation of evidence, man is apparently not a conservative Bayesian: he is not Bayesian at all" [Kahneman and Tversky (1972), p.449].

The alternative theory Kahneman and Tversky proposed was their Heuristics and Biases theory, first labeled as such in Tversky and Kahneman (1974), "Judgment under Uncertainty: Heuristics and Biases." In this theory, people do not use the normative theories of probability and logic to make decisions under uncertainty, but instead rely on a number of heuristics, heuristics that sometimes lead to systematic

²⁸ As said above in Chapter two, Signal detection theory (SDT) is a branch of psychophysics that investigates the individual's ability to distinguish between signal and noise. In other words, it investigates decision making under noisy conditions. See e.g. Green and Swets (1964).

deviations. In the often quoted definition of the theory, Heuristics and Biases “shows that people rely on a limited number of heuristic principles which reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations. In general, these heuristics are quite useful, but sometimes they lead to severe and systematic errors” [Tversky and Kahneman (1974), p.1124]. Kahneman and Tversky emphasized the importance and functioning of a few heuristics, such as representativeness, availability, and anchoring. But by no means was the Heuristics and Biases theory meant to remain confined to these few heuristics. There was no limit to the number of heuristics that possibly could be discovered in humans’ minds. The Heuristics and Biases program summed up the many violations of the normative models Kahneman and Tversky had found, and provided a small, non-exhaustive list of explanations that might account for these violations.

4. How to understand Heuristics and Biases

4.1 The collaboration

Kahneman and Tversky’s collaborative work in Heuristics and Biases was a combination of the research conducted by them in the 1960s. Heuristics and Biases was closely related to Tversky’s earlier work. It was about human decision making and referred to much of the same literature as Tversky’s work in the 1960s. Moreover, the psychological community considered Heuristics and Biases to be a part of behavioral decision research [Phillips and Von Winterfeldt (2006), p.8]. The link with Kahneman’s earlier work is less obvious; Heuristics and Biases had little to do directly with vision and attention research, optometry, semantic differentials or personnel psychology. But Kahneman had a profound influence on a conceptual level; the adjustments of Edwards’ behavioral decision research made by Kahneman and Tversky were the result of the psychological framework developed by Kahneman in the 1960s.

In Chapter three I showed how towards the late 1960s and early 1970s Tversky became increasingly dissatisfied with the approach and theory of behavioral decision research and decision theory. The normative models were consistently violated by subjects, and there did not seem to be an explanation for this. Elimination-by-aspects was an attempt to solve this problem by providing a new normative theory of rational decision making. However, its merits had not yet been tested and its implications for measurement theory were not clear. Kahneman suggested an

alternative route by introducing the idea that in every decision situation there is but one optimal, or normative, solution. To Kahneman it did not make sense to test a number of different normative models to see which, if any, fit best. When a decision problem under uncertainty occurred, there was always only one normative solution and that was the solution determined by logic, Bayesian statistics, and expected utility theory.

Kahneman emphasized that there was absolutely no reason to doubt these normative rules, as Tversky had become inclined to do. Irrespective of whatever people think of the norms or in whatever way they behave in daily practice, the normative rules of logic, Bayesian statistics and expected utility theory were the fixed rules of rational behavior. Kahneman proposed the view that when people were observed to violate the normative rules, this meant that they had made an error, a mistake. Kahneman, in other words, introduced his psychology-of-mistakes view to Tversky's behavioral decision research. If people were observed to violate the normative rules, this meant that people made consistent and systematic errors.

Contrary to Tversky's earlier work and contrary to the framework as set out by Edwards and Savage, experimental violations no longer implied there might be a problem concerning the normative rules. Thus, Kahneman saved the normative basis of decision theory and measurement theory. Instead of placing the burden on the theory, as was done by Savage and Edwards, Kahneman proposed that the burden of the violations be placed on the human beings in the experiments. *Heuristics and Biases* was a research program in behavioral decision research that built directly upon the earlier work done by Tversky in the 1960s, and still drew on the same authoritative sources. However, after it became inspired by Kahneman's work of the 1960s, the approach had changed conceptually in fundamental ways.

Heuristics and Biases took Tversky in a very different direction than his elimination-by-aspects theory. In elimination-by-aspects Tversky had started from the position that the experimental results were valid and that, by and large, the normative theory should account for observed behavior. Given Savage's assumption that all rational people should behave in accordance with the normative theory, Tversky concluded that Savage's normative set of axioms must be wrong and set himself to developing a new normative theory. In *Heuristics and Biases*, however, Kahneman and Tversky departed from Savage and Edwards' starting point in a different way. They reasoned that Savage's normative axioms for rational decision making were

valid irrespective of what decisions human beings actually made. They now concluded that the experimental results were valid, but that at the same time Savage's normative rules were the one and only set of rules for rational decision making. As a consequence, behavior that deviated had to be considered an erroneous deviation from the rational norm. Kahneman pulled Tversky in a different direction than Tversky had initially chosen. That said, *Heuristics and Biases* was a psychological program that Kahneman and Tversky developed together. At no point during his career did Tversky's deep commitment to his joint research with Kahneman waver. Neither did he seriously continue to develop elimination-by-aspects or other accounts of human decision making. *Heuristics and Biases* was a joint product and enjoyed the continued support of both its authors.

4.2 Kahneman and Tversky's experiments

In their collaborative research during the 1970s, Kahneman and Tversky conducted different kinds of experiments than the two had done individually in the 1960s. In their 1960s research the experiments were done in laboratories, or laboratory-like settings. That was in line with received experimental practice in psychology. From the early 1970s onwards, however, the experiments consisted of questionnaires with hypothetical questions which mainly students were asked to fill out. These questionnaires could be distributed anywhere, to participants at conferences, to students during a course at the university, and in a shopping mall on a Saturday afternoon.²⁹ These questionnaires consisted of hypothetical questions and were cheap and easy to conduct.

Laboratory experiments required a setting in which all of the variables could be carefully monitored. However, Kahneman and Tversky's questionnaire experiments required only copies of the questionnaires and pens to fill them out. No separate laboratory space was needed and no payment of the experimental subjects was required, filling out the questionnaires took a few minutes at the most. The advantages of conducting questionnaire experiments compared to using previous experimental psychological methods were clear, but Kahneman and Tversky's departure from received practice in experimental psychology required a rationale. In 1979, Kahneman and Tversky defended their new method of experimentation and

²⁹ It is outside the realm of this dissertation to examine to what extent this new type of experiment was part of a more general development in psychology.

contrasted it with two other methods of investigation. First they distinguished the possibility of “field studies,” which used “naturalistic or statistical observation.” Evidently, this category referred to the practice of correlational psychology, such as Kahneman’s experiments for the Israeli army, although Kahneman and Tversky did not use this term. Field studies, according to Kahneman and Tversky, could yield important insights when a new field of research was opened, but in the end they could only provide “crude tests of qualitative predictions, because probabilities and utilities cannot be adequately measured” [Kahneman and Tversky (1979), p.265].

Secondly, they recognized the method of laboratory experiments, a reference to experimental psychological practice although, again, Kahneman and Tversky did not call it as such. Despite all of its advantages in the particular case of decision theory, laboratory experiments had the disadvantage that stakes could only be relatively small. In a laboratory experiment with real pay-offs it was for financial reasons difficult to conduct an experiment in which the subjects were asked to choose between, say, \$300 for certain or a 0.8 chance at obtaining \$400. A set of hypothetical questions did not have to reckon with this constraint. Laboratory experiments in psychology had furthermore been set up to measure probabilities and utilities as precisely as possible and therefore often large sequences of very similar decision problems were required. This characteristic feature of laboratory experiments, Kahneman and Tversky argued, made it questionable whether the results obtained in the laboratory could be related to behavior in the real world. It complicated “the interpretation of the results and restricts their generality” [Kahneman and Tversky (1979), p.265]. The third method, that proved to be the best for solving the problem they were investigating was “the method of hypothetical choices.” It solved both the immeasurability problem of field studies, and the external validity problem of laboratory experiments. It did however rely on the assumption that people “know how they would behave in actual situations of choice” and that they “have no special reason to disguise their true preferences” [Kahneman and Tversky (1979), p.265].

Tversky’s experiments conducted during the 1960s were in the ‘small world’- ‘grand world’ setting, an experimental requirement Edwards had obtained from Savage. In this setting, the crucial, but only requirement for experiments was that both the utilities and probabilities should be unambiguously clear to both the experimenter and the subject. As earlier set out in Chapter two, this entails that a designated space qualifies as a viable laboratory environment when the utilities and probabilities have

been defined and when it is clear to both experimenter and subject that each have the same figures in their minds, and thus that the subjects have been convinced they are not being deceived. This could, for instance, be done by tossing the dice in front of the subject and by showing that the possible pay-off (in the form of money, cigarettes or anything else) was at hand and could be offered immediately. When these requirements were fulfilled, experiments could be conducted everywhere: in prisons, in classrooms or in specifically designed laboratories.

The Savage-Edwards experiments were often long and repetitive in order to allow for initial adjustment behavior, or alternatively, to investigate learning capacities. Kahneman's psychophysical experiments during the 1960s on the visual system, on the other hand, were brief experiments in highly-controlled laboratories. The subjects had to distinguish between letters, digits or other visual stimuli, but a few observations per subject was generally considered sufficient. In Kahneman's experiments it was important that the value or "energy" was precisely the same for the experimenter and the subjects. But compared to Tversky's choice experiments, this meant that the experimental setting needed to be controlled as much as possible. Hence, Kahneman's visual experiments could only take place in laboratories which were specially built for this purpose.

In Kahneman and Tversky's collaborative experiments the small world requirement was abandoned. They no longer required that there be absolute certainty that the stimuli be understood in the same way by the experimenter and the subject. There did not need to be an actual draw from an urn or a toss of a dice in the presence of the individual, a hypothetical question about uncertainties sufficed. Repeated trials could be avoided on the grounds that most decisions were only taken once or twice, and not five hundred times in a row – although, admittedly, this point remained largely implicit. Furthermore, as the experiments could be done everywhere and all the time, no special laboratory controls were required. Answers to hypothetical questions obtained in the street from passers by were just as valid as the responses obtained from first-year students who had to participate in experiments to obtain their credits, or from subjects in controlled laboratories who were paid according to their performance. Finally, responding to hypothetical questions concerning decision problems produced enough evidence on which to base conclusions, and subsequently theory. Although Kahneman and Tversky considered experimental data based on real stakes better, answering hypothetical questions, in principle, sufficed.

There is not a direct link between the Heuristics and Biases program and the new, more relaxed standards of the experimental method. That is to say, Heuristics and Biases could, in theory, have been developed without the new means of conducting experiments. But the new standards of the experimental method facilitated Kahneman and Tversky's research in fundamental ways. It is safe to say that, without the method of hypothetical questions they could not have developed Heuristics and Biases. For instance, it would have been almost impossible to assemble eighty-four professional psychologists in a single laboratory in order to ask them what their opinions were on a statistical draw which was performed in front of them. Questions in which subjects were asked to choose hypothetically between a weekend in Paris or a week on a beach in Florida would have been impossible, if Savage's small-world requirement had still remained the standard. Thus, although there is not a direct link between Kahneman and Tversky's Heuristics and Biases theory and their experimental method, it is difficult to see how the theory could have been tested and developed without this new method.³⁰

4.3 Kahneman and Tversky versus Simon

It is tempting to view Kahneman and Tversky's heuristics as being similar to Simon's rules of thumb [cf. Heukelom (2007)] although this would be a mistake. In Simon's view, individuals use rules of thumb or heuristics to make decisions. An example of a heuristic could be when hearing the alarm clock in the morning, one gets up, takes a shower, and makes a cup of coffee. To Simon, the heuristic exists because the individual over time has learned that this is the best response to the stimulus of the alarm clock. In Kahneman and Tversky's approach, the function of heuristics was to simplify and reorganize the decision problem in such a way that it was manageable for a not very sophisticated decision maker. The heuristics determine how the new information of the stimulus is understood. The heuristics do not yield the decision, but reorganize the informational input in such a way that a decision making process is possible.

In the Linda problem, for instance, the individual intuitively believes it to be more likely that Linda is a bank teller and a feminist, as opposed to being just a bank

³⁰ I do not discuss here the question of whether different experimental methods yield different data and phenomena on which to construct theories. Obviously, someone such as Savage considered the experimental method crucial, whereas Kahneman and Tversky, as indicated above, considered it to be of much less relevance.

teller because he or she associates the information about Linda more with being a feminist than with a bank teller. In terms of the availability heuristic, ‘feminist’ is more available than ‘bank teller’ for the individual. Hence, the individual makes his or her intuitive decision on the basis of his or her understanding of the information presented. If it is given more thought, he or she may opt for the bank-teller-only option, particularly if he or she has just taken a course in logic. But the individual’s intuitive initial response will always be the bank teller plus feminist option.

In addition, in Kahneman and Tversky’s account the individual could not adjust his or her heuristics, as he or she could in Simon’s approach. The Simon individual might replace coffee with orange juice when he or she learns that it is healthier. After a brief period in which extra effort is required to change the heuristic, the new heuristic will be to get up, take a shower, and drink a glass of orange juice. For Kahneman and Tversky, it appears to be the contrary, since the heuristics seem to be considered to be part of a given, unchanging human nature. Availability, representativeness, and so on, are seen as components belonging to the human information processing machinery that cannot be changed. They can be overridden by means of conscious, rational effort, but they always are determined by how the individual will behave when he or she is making decisions intuitively. To mathematical psychologists and behavioral decision researchers such as Coombs, Edwards, Luce and Tversky, a human, when acting intuitively, was acting as a statistician. In Kahneman and Tversky’s research man was an intuitive statistician, an intuitive optimizer of utility, and an intuitive logician, although an imperfect one. The individual used the normative models, but only after the heuristics had reorganized the input. In many ways, this was a very different theory compared to Simon’s theory of bounded rationality.

5. Prospect theory: Heuristics and Biases for economics

In 1979 Kahneman and Tversky published their famous article on “Prospect Theory: An Analysis of Decision under Risk” in *Econometrica*. The article marked a shift in emphasis away from probabilistic decision problems to an investigation of people’s capacity to behave according to the normative theory of expected utility theory. It was the first attempt to produce a more complete descriptive theory of human decision making under uncertainty. Prospect theory has often been presented as being different

from Heuristics and Biases [e.g. Kahneman (2002)]. It is certainly true that prospect theory brought the different heuristics into one overarching framework, but the foundation still was the idea that human beings relied on a set of heuristics for their decision making and that the use of these heuristics sometimes leads to systematic deviations from the normatively correct decision. In this regard it is to be noted that it took Kahneman and Tversky some five years to get the article published in *Econometrica*, and that the last four of these five years were used to tweak a, for the most part, finished argument to fit an economic audience [Kahneman (2002)].

This continuity between Heuristics and Biases and prospect theory is illustrated by the remarks made in Tversky's letter to Krantz, April 10, 1975. In this letter Tversky, for the first time, devotes more than just one line to his scientific work with Kahneman, and he is clearly enthusiastic about the project. The letter illustrates that the basic argument of prospect theory had crystallized in the spring of 1975:

Danny and I are working primarily on decision making and we believe for the first time that we understand the basic principles governing choices between gambles. [...] The key elements in the theory we propose are: 1) an S-shaped utility function defined on differences from status quo rather than on total asset position and 2) uncertainty weights (not to be confused with subjective probability) by which the utilities are weighted. We are collecting empirical data which seem to provide very strong support for this model. [...] I will send you a draft of the paper in the very near future.

[Tversky's letter to Krantz, April 10, 1975]

In 1975, four years before prospect theory would be published, Kahneman and Tversky were in the middle of developing their Heuristics and Biases theory. Prospect theory, then, is best understood as an extended version of their Heuristics and Biases theory that focused on applications in economics. Its rhetoric was specifically designed to convince economists. Kahneman and Tversky's attempt to enter economics during this period is also illustrated by a workshop Tversky co-organized with Daniel McFadden, econometrician and 2000 co-winner of the Nobel memorial prize in economics. The workshop, held in October 1977 and entitled "Cognition,

Choice, and Economic Behavior,” was supported by the Mathematical Social Science Board and the National Science Foundation and was intended to bring together psychologists and economists interested in cognition and choice theory [McFadden and Tversky’s letter to Luce, June 20, 1977].

Kahneman and Tversky made the connection with their earlier work in the first few lines of the 1979 article, which set out the conception of expected utility theory as a normative theory which also makes descriptive claims:

Expected utility theory has dominated the analysis of decision making under risk. It has been generally accepted as a normative model of rational choice, and widely applied as a descriptive model of economic behavior. Thus it is assumed that all reasonable people would wish to obey the axioms of the theory and that most people actually do, most of the time.

[Kahneman and Tversky (1979), p.263].

In a clever way these opening sentences alluded to both the psychological and the economic framework. To psychologists these sentences restated the well-known normative-descriptive framework and signaled a contribution to an already established field of research. Positivist economists on the other hand might have raised their eyebrows at the injunction of the ‘normative,’ but they would certainly have agreed that reasonable people prefer to obey the axioms of expected utility theory and do so, or at least most of the time. Note, furthermore, that Kahneman and Tversky carefully avoided the term ‘rational,’ and used ‘reasonable’ instead. Evoking the term ‘rational’ might have suggested that this was an article in the line of critique of economics. The use of ‘rational’ would certainly have induced some economists to think that these two psychologists had the same research program as Simon, who had won the Nobel memorial prize the year before. From the start, prospect theory had been carefully constructed so as to be able to convince economists especially.

As in *Heuristics and Biases*, Kahneman and Tversky based their argument on a series of hypothetical questions they had presented to experimental subjects, in this case psychology students at Hebrew University. The problems the subjects were presented with were decision problems, involving different utilities and different

probabilities. Most of the questions were reformulations or variants of Maurice Allais' decision problems. After Allais had shown that even Savage himself had violated his own axioms, resulting in Savage making a distinction between a normative and an empirical domain, as set out in Chapter two, the "Allais paradox" in the 1960s and 1970s had become the iconic demonstration of a violation of expected utility [Jallais and Pradier (2005)].

One example of Kahneman and Tversky's use of an Allais-type approach is in the question where subjects were asked to state which of the following options they preferred.

A: (4,000, .80) or B: (3,000)

That is, they were asked whether they preferred 4,000 shekel with a probability of 0.8, or 3,000 shekel for certain.³¹ Most of the subjects in this case chose B. Assuming that the utility of the outcome equaled its monetary outcome this implied that they did not maximize expected utility. However, opting for the choice B could be the expected utility maximizing choice, if the decision maker was risk averse. Then subjects were asked which of the following two options they preferred.

C: (4,000, .20) or D: (3,000, .25)

In this case, most of the subjects chose C and hence maximized expected utility. This was problematic in combination with the first choice as it implied that subjects were sometimes risk averse, but on other occasions they maximized expected utility. Note that the second choice is equal to the first with probabilities divided by four. With such examples, Kahneman and Tversky illustrated that despite its normative status, expected utility theory as a descriptive theory was invalidated. In specific circumstances people systematically deviated from the norms of expected utility theory. A new descriptive, "alternative account of individual decision making under risk," was therefore required. The alternative account was christened "prospect theory" [Kahneman and Tversky, (1979), p.274].³²

³¹ At the time of the experiment, 4000 shekel was about one third of the modal monthly Israeli income.

³² Kahneman (2002) recalls that they deliberately looked for and chose a name that did not refer to any other theory or phenomenon in economics and psychology.

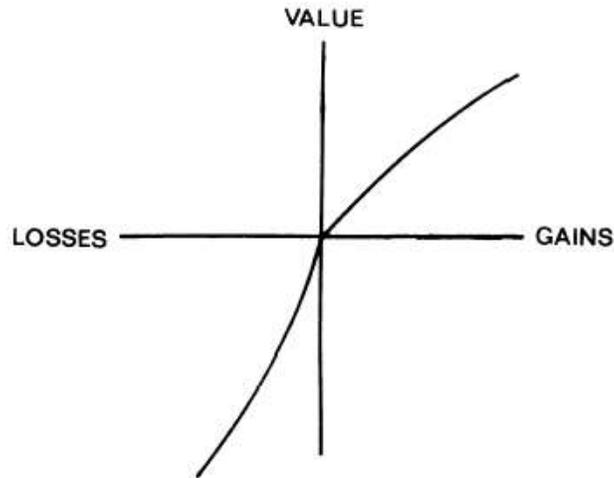
According to prospect theory, a human decision maker first employs a number of heuristics to make a decision problem manageable. This process is called the editing phase. Complicated decisions are broken down into different simpler decisions, different decisions are lumped together into one big decision, a benchmark is set with which the decision was compared, and so on. The purpose of this editing phase was to make the decision manageable. After this, the decision was evaluated in what was referred to as the evaluation phase. The evaluation phase had the same structure as the maximization of expected utility, but instead of the objective values of utility and probability, it used the individual's subjective perception of utility and probability. The subjective perception of utility was referred to as value (denoted v) and the subjective perception of probability was referred to as decision weight (denoted π). In expected utility theory, a subject who is faced with a choice between outcome x that occurs with probability p and outcome y that occurs with probability q derives utility according to the following function.

$$U(x, p; y, q) = p \cdot u(x) + q \cdot u(y) \quad (1)$$

In prospect theory, a subject that following the editing phase faces the exact same choice values this choice according to this function.

$$V(x, p; y, q) = \pi(p)v(x) + \pi(q)v(y) \quad (2)$$

Following the editing phase, value in prospect theory was a function of the outcomes; decision weight was a function of probability. The estimated relation, the relation based on the experimental results, between value and outcomes can be seen in the following graph.

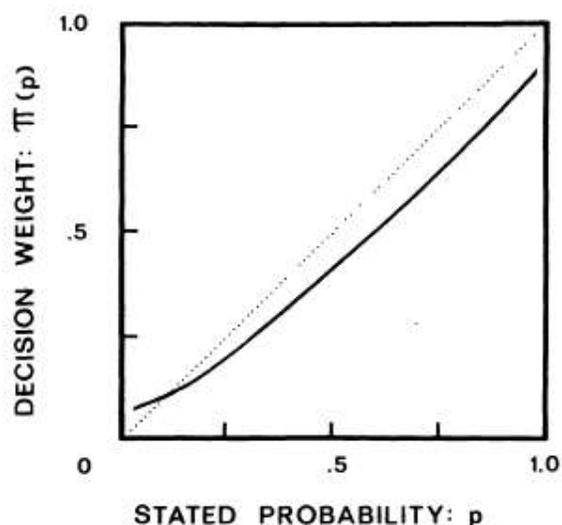


Kahneman and Tversky (1979), p.279

This relationship, in which the decrease in value from losses is larger than the increase in value from gains, held for each individual. It was, in other words, assumed that there was one functional form of the outcome-value relation that held for each human being.

At first sight it seems unnecessarily confusing to label the subjectively perceived outcome of a choice ‘value,’ instead of utility. But if we recall that in the second chapter it was set out that the Lewinian notion of ‘valence’ in psychology was used to denote the attractiveness or averseness of an object or choice option to the individual, we can see that by making ‘value’ instead of ‘utility’ the term that refers to the subjective attractiveness of a choice option, Kahneman and Tversky were able to design a framework that could be accepted by both psychologists and economists. To psychologists, the value framework matched the Lewinian valence framework; to economists it preserved the expected utility framework, while at the same time it allowed for the possibility that individual economic behavior deviates from the expected utility framework. In addition, the term ‘value’ was historically a central concept in economics that could be used very well to denote the pleasure an economic agent derives from choosing a specific option.

In prospect theory, individuals were believed to be similar in their subjective valuation of outcomes. Moreover, also regarding the relationship between probabilities and decision weights individuals were considered to be similar. Both the functional form and the numbers were equal for each individual. The estimated relation between decision weights and probability is depicted below.



The weighting function, Kahneman and Tversky (1979), p.283

In the figure, the dotted line represents the normative relation between the objective “stated probability” and the subjective “decision weight.” The dotted line connects the points in which the two are equal. This is the line one would find in the experimental measurement of the decision weights of the rational individual: for the rational individual perceived probabilities are the objective probabilities. The second, unbroken line shows the average of experimental measurements of reported decision weights of different objective probabilities by experimental subjects. The figure shows, that for small probabilities subjects over-perceive the objective probability, but for all probabilities above approximately 0.1, they under-perceive objective probabilities.

In Chapters two and three I discussed the connection between the theory of individual perception in psychology and the theory of scientific measurement. I recalled that they were two sides of the same coin in the days of Gustav Fechner, and showed that they continued to be two sides of the same coin in postwar mathematical psychology and behavioral decision research. However, now they were subject to the extra dimension of rationality. The value-utility and the decision weights-stated probability relations as presented by Kahneman and Tversky in their 1979 *Econometrica* article provides a clear example of this continued connection between the psychology of perception and the theory of measurement. First, the figures demonstrate how individuals perceive the objective stimuli of the choice, and thus

facilitate the theorizing of human decision making by demonstrating which information the human being uses to make his or her decision. But, second, the figures also show how the human measurement instrument deviates from its ideal functioning. It demonstrates how the human measurement instrument systematically deviates from the norm and provides a detailed relationship between the ideal measurement instrument and the actual measurement instrument. In other words, for prospect theory the psychological theories of human perception and decision making and theories of measurement are two sides of the same coin.

Kahneman and Tversky did not make this link explicit in their 1979 article in *Econometrica*, but a clear indication is that prospect theory is related to what is essentially psychophysics, although they did not use the term psychophysics as such. Kahneman and Tversky argued that “[a]n essential feature of the present theory is that carriers of value are changes in wealth or welfare, rather than final states,” and that “[t]his assumption is compatible with basic principles of perception and judgment.” This basic principle was that

[o]ur perceptual apparatus is attuned to the evaluation of changes or differences rather than to the evaluation of absolute magnitude. When we respond to attributes such as brightness, loudness, or temperature, the past and present context of experience defines an adaptation level, or reference point, and stimuli are perceived in relation to this reference point. Thus, an object at a given temperature may be experienced as hot or cold to touch depending on the temperature to which one has adapted.

[Kahneman and Tversky (1979), p.277]

Kahneman and Tversky extended this basic argument to other attributes: “The same principle applies to non-sensory attributes such as health, prestige, and wealth. The same level of wealth, for example, may imply abject poverty for one person and great riches for another – depending on their current assets” [Kahneman and Tversky (1979), p.277]. This principle of psychophysics, Kahneman and Tversky argued, was a fundamental aspect of economics.

The use of heuristics and the framework of psychophysics allowed Kahneman and Tversky to construct a theory in which individuals behaved rationally, and yet could often be observed as making irrational decisions. Man is rational, but because

human beings apply heuristics to reconstruct decision problems to manageable proportions, and because they have a specific perceptual system, their reasoned decisions may deviate from the normatively correct solution. Kahneman and Tversky had to cut the link between the normative and the descriptive theory in order to maintain the normative theory, while at the same time allowing for the conclusion that people systematically and persistently deviate from the norm. Human beings, who in Savage and Edwards' accounts were capable of rational reasoning, i.e. normal healthy adults, could no longer be expected to behave according to the normative rules. Therefore, also the arguments against the normative theory by normal rational people were potentially no longer valid arguments.

Prospect theory based its reasoning on mathematics. It took the mathematical principles of decision theory as the norm for behavior, and developed the mathematical measurement framework so that the experimental observations would fit. Deviations from the mathematical norms were understood as errors or mistakes, and they bore no implications for the norms. Because of the clear separation between the normative and the descriptive, it was now possible to construct a separate mathematical account of decision making in the descriptive domain, without making implications for the normative theory. In prospect theory, human beings were understood as having a biased perception of the relevant input of uncertainties and utilities, just as they had a biased perception of sensory inputs such as temperature and weight. Because of these imperfections, Kahneman and Tversky argued, their behavior would often deviate from the optimal norms of normative decision theory.

6. Economics and psychology

In economics, prospect theory has been understood as an attempt to apply a psychological theory to an economic question. It has been viewed as a theory taken from another discipline that has traveled across the scientific border in order to plead its arguments in a neighboring discipline. In other words, prospect theory has been understood by economists in terms of their own understanding of the relationship between economics and psychology. This has been set out Chapter one and will be further discussed in Chapters five, six, and seven. However, working as psychologists, Kahneman and Tversky understood economics, insofar as it concerned individual decision making, as a subfield of psychology. Moreover, following Edwards they regarded behavioral decision research as a psychological research program that

derived much of its inspiration from economics. Hence, Kahneman and Tversky regarded prospect theory, not as the application of a psychological theory to a question in the neighboring field of economics, but as an attempt to unify psychology and economics, and in particular as an attempt to unify behavioral decision research and economics. To acquire an understanding of prospect theory's reception in economics, it is therefore important to understand first how Kahneman and Tversky themselves understood prospect theory's relevance for economics.

6.1 Normative versus descriptive

In prospect theory Kahneman and Tversky employed their normative-descriptive distinction, and assumed that economists would employ the very same distinction. This partly reflected the standard understanding of economics in behavioral decision research and psychology. It should not be forgotten that Edwards understood economics' theories of individual human behavior as being normative theories. A valid conclusion would therefore be that Kahneman and Tversky were not familiar with the economists' use of positive and normative, and thus assumed them to mean the same as descriptive and normative in behavioral decision research, therefore employing the terms as they had been accustomed to.

But Kahneman and Tversky's use of normative and descriptive can also be seen as a very clever way of trying to convince economists of the relevance of prospect theory for economics. Note, that in their earlier *Heuristics and Biases*, their changing use of normative and descriptive played an important role. In prospect theory, Kahneman and Tversky did not tell the economists that their theory was complete nonsense or useless. Instead, they claimed to understand economics as using one theory to cover both the normative and the descriptive realm. For the normative part they fully agreed with economists, which fitted in neatly with practice in behavioral decision research. But, Kahneman and Tversky argued, economists had been mistaken in using that same theory in the descriptive domain.

Kahneman and Tversky's approach differed in a subtle but fundamental way from Simon's, the other main psychological critic of economics. Just as Kahneman and Tversky, Simon understood economics to have both normative and descriptive ambitions, but unlike Kahneman and Tversky, he considered economics to have embarked on the wrong track entirely. According to Simon, economics failed to distinguish correctly between descriptive and normative, had an inappropriate theory

in both domains, had an absurdly restrictive notion of rationality, and was much too narrowly focused on the mathematical advancement of its theories.³³

Kahneman and Tversky were much less hostile. In fact, they were in favor of the current practice in economics – after all, behavioral decision research and measurement theory were considered to be at least partly based on economics – and they only meant to suggest that a few adjustments be made to improve it. Contrary to Simon, Kahneman and Tversky argued that there was nothing wrong with the economists’ theory of expected utility maximization. It was only that this was the normative theory, and not an accurate description of actually observed human behavior. Economists did not need to abandon the theory of expected utility maximization, but instead they should seek a proper descriptive counterpart to this normative theory. Prospect theory was then suggested as serving as such a descriptive theory.

6.2 Prospect theory as unification of economics and psychology

Prospect theory was aimed at economists. Unlike Heuristics and Biases, which was aimed at psychologists, prospect theory aimed to make an argument in economics. It was, however, a specific type of argument. Kahneman and Tversky were not attempting to travel across the psychology-economics border, to become economists and to make a contribution to economics. What they intended to do, was rather to shift the economics-psychology border in such a way that their work and economics would become part of the same science. Subsequently, they could then argue that their paper had proved existing theories wrong, and had provided a viable alternative. For their argument it did not really matter whether one understood the move as shifting the border so that parts of economics became part of psychology and behavioral decision research, or as shifting the border so that behavioral decision research became part of economics. The message would remain the same, namely, that behavioral decision researchers and economists were all part of the same scientific program, and that although prospect theory showed that many economists had been partially mistaken, the problem had been solved. With prospect theory, Kahneman and Tversky made a claim of unification; they implicitly argued that behavioral decision research and economics were really one and the same.

³³ e.g. Simon (1956, 1959, 1987). For overviews and discussions of Simon’s position regarding economics see Sent (2005), Augier and March (2004), and Heukelom (2007).

In the discussion of prospect theory above a number of instantiations of this claim to a unification of economics and psychology have been mentioned. To begin with, the first few lines of the 1979 prospect theory article drew a distinction between normative and descriptive that was acceptable to both psychologists and economists, and thus bridged the gap between psychologists' normative-descriptive framework and economists' positive-normative distinction. Psychologists could read the remark about expected utility as having both normative and descriptive claims as referring to the standard framework in behavioral decision research. Economists could read the remark as saving the utility maximizing framework upon which all their theories were built, while at the same time opening the door to behavior that deviates from utility maximizing. Second, Kahneman and Tversky argued that the main problem of economics was that it did not include psychophysics in its account of individual behavior, in effect implying that economists should study individual behavior the way psychologists did. This meant that economists had mistakenly believed that economics and psychology were different disciplines, where in fact the two used the same behavioral foundations. Third, the distinction Kahneman and Tversky made between the objective 'utility' and the subjective 'value' of a choice appealed to both psychologists and economists. For psychologists it meant that they could understand prospect theory in the common Lewinian valence framework whereas to economists it was acceptable because Kahneman and Tversky had stayed within the bounds of the different ways in which these terms were used in economics.

The reason that prospect theory became so successful was that it had succeeded in combining and using conceptual frameworks from behavioral decision research and economics in such a way that scientists involved in decision making in economics found it useful. Economists could account for empirical anomalies without having to sacrifice their theories. Critics of economics could refer to prospect theory when arguing that economics was descriptively wrong, and behavioral decision researchers felt justified in their belief that economics was directly involved in, if not part of behavioral decision research.

7. Assessing Kahneman and Tversky

Throughout their collaborative career Kahneman and Tversky met with a range of opposing arguments.³⁴ As I will show in Chapter six, economists who initially enthusiastically adopted the Kahneman-Tversky framework in the 1980s, in the 1990s and 2000s gradually departed from this framework. Yet, in spite of this, their work has been tremendously influential over the years. Moreover, part of the opposition they have met with can probably be explained by their success and influence itself.

With their conceptual framework, Kahneman and Tversky offered a rationale for science as the ultimate foundation of rational decision making and of scientists as the ultimate experts of rationality. This has been arguably the most important part of the theoretical framework that Kahneman and Tversky exported to economics, and has given rise to behavioral economic paternalism, to be dealt with in Chapter six. For Kahneman and Tversky, as well as for the behavioral economics that grew out of their research, scientists were the ultimate experts on rationality, and thus ultimately decided what a rational decision is and is not.

In nineteenth and twentieth century psychophysics and experimental psychology the scientist was the ultimate expert regarding the objective value of the stimulus because it was the scientist who determined the value of the stimulus. Experimental psychologists wanted to know how an individual perceived the different stages in the brightness of a light bulb, and in these experiments experimental psychologists naturally knew what the objective values of the different stages of brightness were because they themselves had set up the experiment. Savage and

³⁴ The most often repeated claim has been that Kahneman and Tversky believed people to be irrational. The argument was that if human beings can send people to the moon and return them safely, they cannot be that irrational. One of the most remarkable exponents of this view has been Edwards, who wondered how it is possible that people are so poor assessing uncertainties, as they were in Kahneman and Tversky's theory, and yet, at the same time, could be so skilled in driving their cars. Edwards has never elaborated upon his reservations with respect to the work of Tversky and Kahneman, perhaps from fear of losing the image of coherence of his program, yet it is no secret that he disagreed with their work [e.g. Phillips and Von Winterfeldt (2006), Krantz – interview (2008), Dawes – interview (2008)]. The 1980s and 1990s have given rise to a whole surge of criticism regarding Kahneman and Tversky's approach to human decision behavior. The most prominent philosophical critique was provided by Cohen (1981). The most extensive criticisms from within experimental psychology came from Gigerenzer [see e.g. Gigerenzer (1991,1993,1996), Gigerenzer and Murray (1987), Sedlmeier and Gigerenzer (1997,2000), Hertwig and Gigerenzer (1999)]. These are summarized and discussed in Heukelom (2005)]. Gigerenzer has been the only critic to whom Kahneman and Tversky have explicitly responded [Kahneman and Tversky (1996)]. Other critics include Lopes (1991) and Cosmides and Tooby (1996).

Edwards applied this experimental psychological program to decision making, but limited the superior knowledge of the scientist. Savage emphasized that all normal healthy adults could evaluate the axioms of rational decision making, and assumed that everyone would agree with his axioms after some careful thought. Edwards adopted Savage's framework, and he equally assumed that human beings in principle make their decisions in accordance with the axioms of rationality.

Following the repeated experimental evidence of violations of rationality in Tversky's experiments in the 1960s, combined with the outcome of Kahneman's psychophysical research that human beings are fundamentally flawed decision makers, Kahneman and Tversky in the 1970s developed a theory that assumed that human beings often and systematically deviate from what is rational and normative. Heuristics and Biases and prospect theory detached the normative from the descriptive, and constructed a theory for understanding what happened in the descriptive domain. One consequence of detaching the normative from the descriptive was that normal healthy adults were no longer qualified judges of the axioms of the normative theory in rational decision making. The only person still qualified to judge whether a specific decision was rational or not was the scientist who possessed a thorough training in logic, statistics and decision theory.

Although prospect theory was about decision making, the link with measurement theory can still be detected. The link shows up in the utility-value curve and the stated probability-decision weight curve very clearly. These curves describe how the individual perceives the objectively given utility and probability of choice, and they thus provide the basis for understanding decisions in the descriptive domain. However, by describing how individuals perceive objective stimuli in the form of utilities and probabilities, it also provides an account for the deviations found in the human measurement instrument, and thus provides a correcting factor that ensures the possibility of using the human being as a measurement instrument.

In different ways, the joint work of Kahneman and Tversky constituted a break from Tversky's earlier work on decision making and measurement theory of the 1960s, although it was a relative break. In his joint work with Kahneman, Tversky took a different approach to human decision making and, as a consequence, took a different approach to measurement. No longer did he maintain that human beings on average are rational decision makers, and no longer did he assume that the human

measurement instrument on average is unbiased. But decision making and measurement were still two sides of the same coin. What had changed was that Tversky now understood human beings to deviate systematically and predictably from what is normatively correct.