Anticipation as a Consequence of the Assignment of Meaning

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Abstract
We motivate the Thesis: More knowledge is obtained by belief than from logical reasoning.
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1 The Anticipation Principle

The question: "Why is my knowledge true ?" is a very old question. Already Hume has posed the question: "Why can I be sure, that the sun will rise tomorrow ?".
A first attempt, to explain our knowledge uses the Induction Principle which states: "An event, that always had occurred in the past, will also be true into the future".
But this attempt leaves many questions open:
(1) Is every knowledge, in the last consequence, obtained with the Induction Principle ?
(2) What is the role of observation and understanding ?
(3) Does objective knowledge exist, that is independent from the observer ?
(4) Is an observation possible that excludes any prejudice ?
To be free from prejudices, our methods for the acquisition of knowledge has to be as general as possible. The main result of this paper states that belief offers a more general base for knowledge acquisition than logic. The relevance of this observation will be demonstrated with examples form quantum mechanics and psychology.
The basic ideas for knowledge acquisition are: observation and understanding.

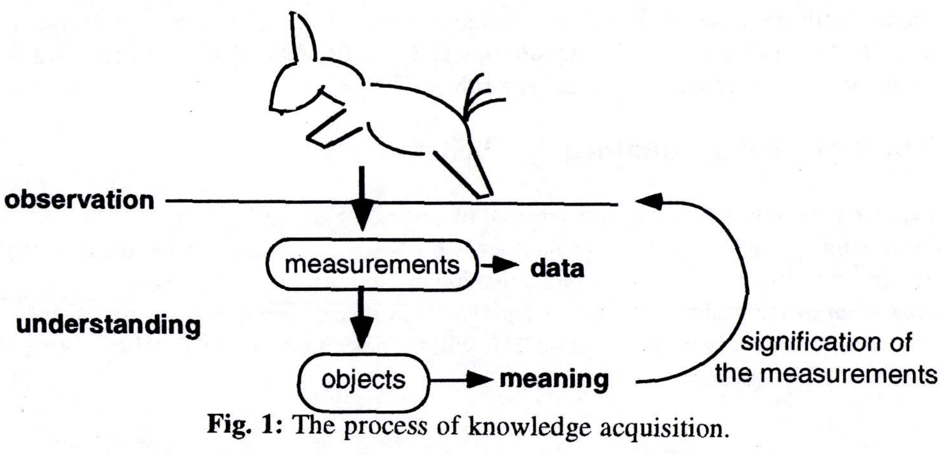

Fig. 1: The process of knowledge acquisition.

An observation is realised by measurements. A measurement assigns to an effect in our world a tuple of values. This assignment can consist in our simple perception of the colour of a bird, but also in the complex operations of a measurement apparatus in a physical experiment. An event is defined by the measurements, we obtain from its appearance. These measurements constitute the effects produced by the event.
Objects are related to effects by the Pragmatic Maxim that had been formulated by Charles S. Peirce (Peirce, 1878) : "Consider what effects, which might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object."
The simplest phenomena that may characterise measurements are: "an event happened" or "an event did not happen". These two events: "to be" (= 1) and "not to be" (= 0) are the basis of our possibilities to think and therefore also of our ability to construct models of our reality.
Understanding is the ability to describe huge quantities of measurement data by simple models. The effects in our world are therefore ordered by us, to form objects, because thereby understanding is enabled. By our understanding, meaning will be assigned to our observations.This conception of reality implies a strong dependency between understanding and the knowledge of future events. The ability to forecast future events is called anticipation. As this ability depends on models that are constructed in the process of understanding, we are limited to weak anticipation. It is our objective to demonstrate that these models are not arbitrary but uniquely determined by our measurements.
The grounding of anticipation on understanding will be called Anticipation Principle. This idea has been discussed extensively by Robert Rosen (Rosen, 1985). The Anticipation Principle states: "Anticipation is created by the assignment of meaning."

In this paper we present a formalism that converts the Anticipation Principle into an algorithm that can be applied to real world problems. This formalism is based on belief theory. It will be demonstrated that belief theory offers a more general foundation for cognition than logic and that the Anticipation Principle is essentially stronger than the Induction Principle. Phenomena from quantum mechanics and from psychology will be explained with these principles of knowledge acquisition.We discuss here a completely unrestricted form of knowledge acquisition, which is independent from a special context and time or memory restrictions of the algorithms.

2 The knowledge obtained by belief

Typical questions that had been answered by engineers are of the form:
"Will this bridge, whose behaviour had been measured in the last weeks, remain stable during the next five years ?", or if the meaning of "stability" has been fixed:
"Will a pillar of the bridge move more than two centimetres during the next five years?".
With the algorithm given in section 2.2, it will be possible to find the most believable answer to the last question.

2.1 Dempster-Shafers Belief Calculus

The meaning of "belief" will be defined with Dempster-Shafers Belief Calculus (Larsen & Yager, 2000).

Definition: Let X denote a set of possible measurements and $X_i, (i = 1,...,N)$ Fuzzy subsets of X with weights $m(A_i) \in [0,1]$. For every Fuzzy subset B of X a belief measure $Bel(B)$ is defined by the equation: $Bel(B) := \sum_{i=1}^{N} \mu(B \subset A_i) \cdot m(A_i)$,

where $\mu(B \subset A_i) \in [0,1]$ means the degree of truth of the statement $B \subset A_i$.

2.2 The most believable answer to a welldefined question

The questions we discuss in this section are of the following type:

Question (Q): Given a set of measurements $w_k(t_j) \in I\!R$ with $k = 1,...,M$ and time instants $t_j, j = 1,...,\rho$. Is it believable that in the time interval $t \in [t_a, t_b]$ a value $w_k(t)$ will increase over a bound S ?

The algorithm (ALG), which will be presented in this paper, calculates a belief measure BEL which assigns to the possible answers:

A_+ := "A value will cross the bound."

and $A\_$:= "No value will cross the bound."

degrees of belief : $BEL(A_+), BEL(A\_) \in [-1,1]$

where $BEL(A) \approx \begin{cases} 1 & \text{for a very believable answer A} \\ -1 & \text{for a very unbelievable answer A} \end{cases}$.

The answer with the highest degree of belief is called **the most believable answer**.

Algorithm (ALG) for the calculation of the credibility $BEL(A)$ of an answer A to question (Q):

This algorithm (ALG) provides an answer that is independent from the solution theory.The principles of the algorithm are explained in five steps (Sommer, 2000) :

Step 1: Fix Fuzzy subsets in the sets of possible measurement values and time instants. This Fuzzy subsets are selected very fine in regions where high precision is needed and wider in other regions .

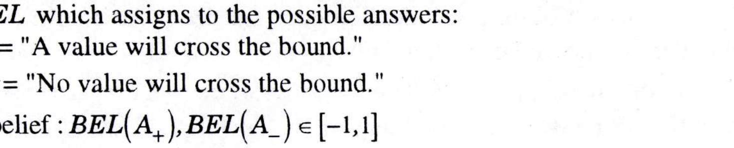

Fig. 2: Definition of the accuracy needed in the question.

Step 2: Calculate the confirmation of tuples of Fuzzy sets defined in Step 1 through the measurements. Each measurement $\left(w_1\left(t_j\right),\ldots,w_M\left(t_j\right)\right)$ contributes with its membership degree in the tuple of Fuzzy sets to the confirmation, where the various contributions are aggregated with a Fuzzy or-operator (Yager, 1994).
Step 3: If we restrict all values to the set $\{i\cdot\Delta | i\in\mathbb{Z}\}$ with $\Delta\in\mathbb{R}, 0<\Delta<<1$, than all models for the representation of the measurements can be defined by Turing machines and there exist an enumeration of all this models. In analogy to Step 2, we can calculate for every model, the correspondence to the confirmed Fuzzy tuples. This correspondence value is the confirmation value for the model behaviour.
Step 4: The Kolmogoroff-complexity of a model is defined by the length of its shortest description (for example with Turing tables). From the confirmation of the model behaviour that had been obtained in Step 3, we can now deduce a confirmation value of the elements in the shortest model description. This (uniquely defined) value characterises the confirmation of the model.
As the confirmation of the models decreases with increasing complexity, all strongly confirmed models are in a finite model set. (A theorem of Kolmogoroff shows that the complexity of the models is independent from the representation and therefore a strongly confirmed model will be confirmed in every universal model-representation.)
Step 5: For any answer A to a welldefined question, from the confirmed models, a confirmation $Bel(A)$ and a confirmation of its negation $Bel(\neg A)$ can be obtained.
The credibility in the answer A is: $BEL(A) = Bel(A) - Bel(\neg A) \in [-1,1]$.

Remark 1: It can be demonstrated, that the belief-function BEL is unique up to rescaling and the aggregation of confirmations and negations (Sommer, 1995).

2.3 Basic knowledge

The believable statements that had been obtained as answers to our questions from the empirical data constitute the basic knowledge. This knowledge is objectively, or independent from ourselves. It provides a frame to discuss the meaning of the empirical data and to revise them. The expression "empirical" has therefore only a provisional meaning which changes with all new informations.

2.4 Higher order knowledge

The production of knowledge can not only be based on measurements but also on knowledge which had already been obtained. The structures of learned knowledge form the templates for the construction of new knowledge. We call knowledge obtained from knowledge, higher order knowledge. Higher order knowledge will influence also the credibility of basic knowledge. Some phenomena that may occur in the learning process of section 2.1, will be summarised:

(1) Knowledge over knowledge may provide us rules to produce new credible sentences from other confirmed sentences (Sinha & Jensen, 2000). The conformity of these new sentences with empirical measurements offers a very important test for the

usability of our knowledge. (Many accidents in technical systems were caused by the deduction of new knowledge, which did not correspond to the real plant, from the instruction manual.)

(2) It may happen, that new measurements do not provide a better confirmation, but a stagnation or even an oscillation of the believe values of the sentences in the knowledge. This effect can only be avoided by a total revision of the meaning of basic facts and measurements.

(3) Knowledge is not allowed to provide statements that are definitely unobtainable. For example in indistinguishable experiment environments, the certainty of all statements has to be equal. (This principle was used by Einstein to deduce Relativity theory.)

Remark 2: In the pragmatic view, no reality exists behind our knowledge from which an image can be constructed in our mind. Knowledge means the ordering of all events and ideas such that recognition will be maximally simplified. This is the meaning of "truth" that had already been detected in Phenomenology by Husserl and Heidegger (Heidegger, 1986) : "Knowledge is true if it enables discoveries and false if it hides discoveries". (No Cartesian mind/body dualism exists in this view.)

Remark 3: Higher order knowledge contains those rules and facts that are objectively the most believable for us, relative to the knowledge we already have. This knowledge is different for beings from different worlds, but identical for those beings that share the same basic knowledge. If the uniformity of the basic knowledge is obtained by the conversation between the beings, we obtain Watzlawik's Postulate:
"Reality is constructed by our communication."
On the other hand, Schopenhauer's Postulate (Satz vom Grunde): (Schopenhauer, 1977) "Nothing exists without a reason for its existence" is not true in our framework. An example from fluid dynamics will be given in Insertion 1 that demonstrates the existence of phenomena, which can be predicted, but where it is not possible to present the exact reason which is responsible for their existence. Different optimality criteria can be claimed for our knowledge: correctness, simplicity, conformity with other values and many others. Knowledge that depends on these criteria is subjective. Our reality depends on the meaning we assign to the measurements and on the importance we give to this criteria. The dependence of our knowledge from the assignment of meaning will be examined in the next section.

Insertion 1: The prediction of vortexes in a turbulent fluid.
In a turbulent fluid, the emergence of vortexes can be predicted, but there exist no causal chain of arguments which relates this forecast to our knowledge of the initial and boundary values. A prediction of the exact region and time of a vortex can not be given.. This phenomenon is a counter example to Schopenhauers Postulate.
Flows are determined by Navier Stokes equations:

$$(NS)\quad \frac{\partial u(x,t)}{\partial t} \underbrace{- a(u(x,t)) \cdot \frac{\partial u(x,t)}{\partial x}}_{\text{transport}} = \underbrace{\varepsilon \cdot \frac{\partial^2 u(x,t)}{\partial x^2}}_{\text{diffusion}} + \underbrace{S(u(x,t))}_{\text{chemical reactions}}$$

where $u(x,t) \in I\!R^3$ *denotes the velocity of the fluid in the spacepoint* $x \in I\!R^3$ *at time* t.

In the turbulent case, chaos effects cause a separation of parts of the fluid from the boundary and from the initial conditions. It is not possible, to predict the behaviour of the fluid when the connection to the known boundary values had been lost. A chain of causal reasons does not exits, which connect our necessarily imprecise observations with the behaviour of the fluid in a region of turbulence (Greiner & Stock 1978; Sommer 1998). On the other hand, simple methods provide some information about the turbulent fluid. Neglecting the chemical reactions and using $a(u) \equiv u$, *the remaining effects are determined by the following equations:*

(D) diffusion: $$\frac{\partial u(x,t)}{\partial t} = \varepsilon \frac{\partial^2 u(x,t)}{\partial x^2}$$ *(T) transport:* $$\frac{\partial u(x,t)}{\partial t} + u \cdot \frac{\partial u(x,t)}{\partial x} = 0.$$

Equation (D) describes a mingling of the flow and equation (T) represents a shift in the direction of u. *The impact of these effects on a vortex in the fluid is drawn in Figure 3:*

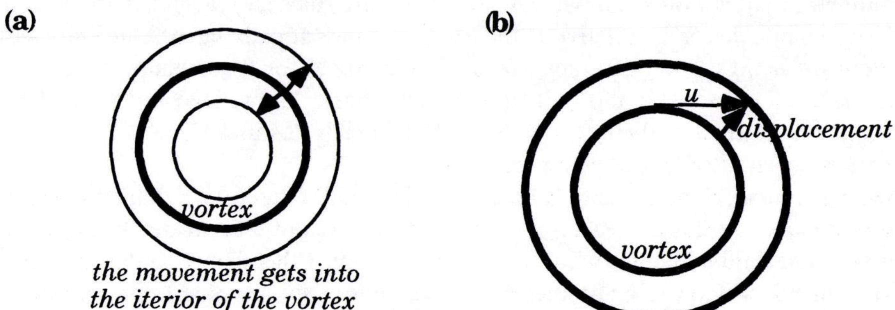

Fig. 3: Impact on a vortex produced by the diffusion process (a) and by the transport process (b).

Let O_D *denote the solution operator of the diffusion equation and* O_T *the solution operator for the transport equation. (* $O_{D/T}u(x,t) = u(x,t+\Delta)$ *for a solution* $u(x,t)$ *of (D)/(T).) The solution operator* O *of the (NS)-equation (with* $S(u) \equiv 0$ *and* $a(u) \equiv u$*) can be factorized:* $O = O_D \circ O_T$.

As O_D *contracts the vortex into its interior and* O_T *extends the vortex, vortexes exist that remain stable for an instant under the action of the operator* O. *(A more detailed examination of these arguments shows the decay of the vortexes into small eddies.) During an observation of the fluid, these stable vortexes are longer visible than other forms. We can therefore predict the emergence of vortexes but this prediction does not include any information over the time and the exact spacepoint of their appearance. We are unable to deduce the appearance of vortexes in a turbulent fluid from a sequence of causal rules that connects the reason for there existence with there appearance.*

3 Dependence of the knowledge from the assignment of meaning

In this section, we discuss the consequences for our understanding, if the meanings of the events are not a priori fixed. For example, in the double slot experiment in quantum mechanics (without measurements on the slots), it is not possible to identify unequivocally from the disposable measurements, the slot that had been passed by the particle. This event is therefore not completely specified in the experiment.

3.1 The transition from belief to propositional logic

If we use the following definitions, then parts of the knowledge, obtained with the algorithm of section 2, can be interpreted in two valued propositional logic:
Very believable statements are called "true" and very unbelievable statements are called "false". By a restriction to true and false statements, two-valued propositional logic is obtained.
The Transition from belief to propositional logic is carried out by a defuzzification of the belief functions. For a belief-measure $bel : W \to [-1,1]$ over a set W (of sentences), the fact w^* that corresponds to bel is defined:

$$w^* := \begin{cases} arg \ \max\limits_{w \in W} \ bel(w) & \text{for } bel(w) > \alpha \\ not \ \ arg \ \min\limits_{w \in W} \ bel(w) & \text{for } bel(w) < -\alpha \end{cases} \text{,with } 0 << \alpha < 1 \text{ close to } 1,$$

if such a w^* exists and undefined else.
Propositional logic describes therefore only a part of all possibilities of knowledge processing (or thinking). We call knowledge that is based on beliefs **general knowledge** in contrast to **logical knowledge** which is only obtained from logical arguments. Insertion 2 shows the necessity of general knowledge for a discussion of the double slot experiment in quantum mechanics. In the history of science, we observe that logical knowledge enters more and more in all sciences. By this means, the processing of the knowledge is considerably simplified, but we have to ask if there do not exits phenomena whose explanation will be prevented by this restriction. Nancy Cartwright writes (Cartwright, 1999): "It seems to be in the nature of how we do exact science that what it can cover is very limited in scope."

Insertion 2: The double slot experiment (Fick, 1968).
From a source, (light-) particles are passing trough one of two slots and are than received on a screen and counted by a measurement devise (Figure 4). From the experiment design we deduce a credibility $BEL(\text{slot } 1)$ *for every particle which leaves the source to pass through slot 1, and a credibility* $BEL(\text{slot } 2)$ *to reach slot 2. But this knowledge is not equivalent to the information that a particle will pass either through slot 1 or through slot 2:* $BEL(\text{slot } 1 \ \dot{\vee} \ \text{slot } 2)$*, that will be obtained in a second experiment with an additional measurement on one of the slots.*

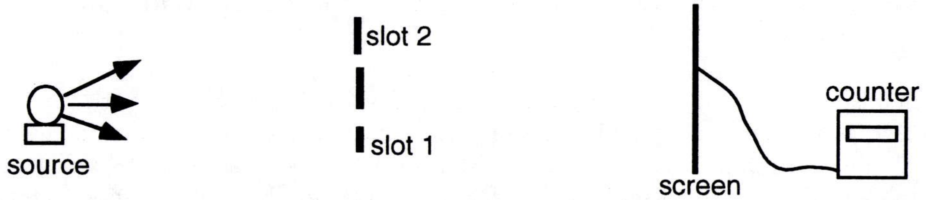

Fig. 4: The double slot experiment.

The measurement in one of the slots adds the alternative

$\hat{\mathbf{A}}$:= (**slot 1** $\dot{\vee}$ **slot 2**) *=(slot 1 or slot 2) and not (slot 1 and slot 2)*

to our knowledge.

This alternative $\hat{\mathbf{A}}$ *is also necessary for an explanation in propositional logic. To arrive at the screen, a particle has to pass one and only one of the slots. The alternative* $\hat{\mathbf{A}}$ *is a consequence of the description of the experiment in propositional logic. It is then impossible to distinguish between the two cases:*

(I) The double slot experiment without measurement in one of the slots.

and (II) The double slot experiment with a measurement in one of the slots.

On the other hand, from belief theory, no credibility can be deduced in case (I) for the alternative $\hat{\mathbf{A}}$:= (**slot 1** $\dot{\vee}$ **slot 2**) *from the measurements whereas in case (II) the experiment design directly implies* $\hat{\mathbf{A}}$.

The description of the double slot experiment is therefore different in case (I) and case (II). We have two different experiments, and it is not astonishing to obtain different measurements on the screen from different experiments.

A measurement on one of the slots does not change the experiment because of the disturbances that are produced by the measurement. (The second result can also be obtained without additional measurements. If we double the duration of the experiment and shut slot 1 from time t=0 until t=T and slot 2 from time t=T until t=2T, then the result on the screen is equal to an experiment with duration T, two open slots and a measurement on slot 1.)

The results on the screen are different, since the assignment of meaning was different in the two realisations of the experiment. With the measurement on a slot, the meaning of the event: "a particle passes the slot" is defined that had been undefined before. The logical structure of quantum mechanics originates from our necessity to order our knowledge in such a way that understanding is enabled.

3.2 The characteristics of general knowledge

In the knowledge obtained from belief, unspecified events exist which are only defined by its effects on other specified events. An event may be favourable or unfavourable to other events. The unspecified events provide us only "reasons" for the occurrence of future facts. In contrast to facts that are characterised by the values 1 (the fact is true) and 0 (the fact is not true), for the description of a reason (the influence of an event on another event), positive values (for confirmations) and negative values (for negations) are needed (Atanassov, 1998). General knowledge consists of beliefs in beliefs.

For a representation of general knowledge, the values of the models $\{i \cdot \Delta | i \in \mathbf{Z}\}$ (defined in section 2.2 step 3) must be replaced by belief measures $\{bel_\sigma : \{i \cdot \Delta | i \in \mathbf{Z}\} \to [-1,1] | \sigma \in \text{Indexset}\}$ which are defined over this values.

Not all logical conclusions are true in the general knowledge obtained from belief. To think, that all knowledge can logically be formulated, is a prejudice. The idea that there must exist an alternative between the two paths of the particle through slot 1 or slot 2 in the double slot experiment (Insertion 2) is only a consequence of a description of the experiment in classical logic. This assumption is absolutely unnecessary for an understanding with a belief theory of the empirical data that had been obtained in the experiment. Quantum mechanics is based on a logic of "reasons". In this more general logic many phenomena find a natural explanation (Bitbol, 1998; Esfeld, 1999; Sommer, 1999). There exists no freedom for a learning system, to influence the most believable answers to well-defined questions. The unique possibility to influence reality consists in the process of the assignment of meaning. Every forecast depends on this assignment.

The algorithm of section 2, which formalises the Anticipation Principle, is considerably much stronger than the Induction Principle, because it recognises regularities that are not represented by simple repetitions. These results are independent from empirical cognition and physical experiments. We deduce the structures of our knowledge exclusively from the process to "understand measurements" or from "the assignment of meaning".

3.3 Kinds of human knowledge

Human knowledge is general knowledge and therefore composed by logical knowledge and beliefs or feelings. The basic principles of knowledge processing in the brain are explained in Figure 5. The activated, conscious knowledge is changed by rules of the rational knowledge or by feelings as long as it does not correspond to the motivations (Dürrbaum & Sommer, 1995). (The activated knowledge of a hungry person is changed until a plan to get food will be found.)

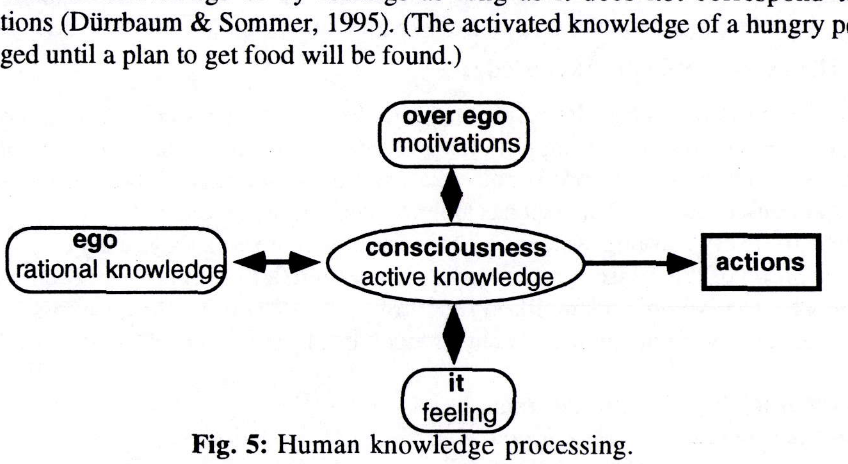

Fig. 5: Human knowledge processing.

A plan that corresponds to the motivations will be executed.
(If a chess player feels to have attack and calculates that a move will give him many threats, than he will execute this move that satisfies his motivation (to win the game).)
Feelings can intensify the credibility of rational statements. A concretisation or rationalisation of a feeling (defined by a belief function bel_σ) is realised by an activation of a rational idea that had been obtained from this feeling by means of its defuzzification. Feelings represent knowledge that can not be replaced by rational arguments. Feelings may produce thinking barriers and compulsions that destroy a rational life of a patient. The rationalisation of traumatic reminiscence is necessary to overcome the problems that are produced by the feeling which originates from a trauma. Many methods had been developed in psychology to realise the rationalisation of feelings and to compensate bothering knowledge.

The modes of human knowledge processing are controlled by moods (Rage produces a very rapid but imprecise processing mode and melancholy is a mental block for positive thinking). The effects of moods are at great length discussed in literature (Dörner, 1993; Sizer, 2000). Here we restrict our considerations to properties that can be explained only from the different kinds of knowledge obtained by belief. We discuss the consequences, universal principles have on cognition and not the special conditions of human cognition.

3.3.1: Subjectivity of human knowledge

Human knowledge depends on the personal experiences and history of every individual. A psychoanalyst has to accept the reality of the patient, this reality has to be changed in such a way that the patient will be able to live with it, but there exists no objective true reality which may convince the patient (Dreyer, 2000).

3.3.2: Uncertainty of the measurement of human knowledge

Every question, a psychoanalyst poses to its patient, produces necessarily a rationalisation of the patients knowledge. The patient is only able to answer, if he rationalises his feelings. This rationalisation changes the active knowledge in the same way, as the concretisation of the sentence "a particle passes slot 1" by a measurement had changed our knowledge in the double slot experiment.

3.3.3 Humans belief in their knowledge

Due to the Anticipation Principle, humans believe in the simplest solution. Their forecasts necessarily leave unpredictable events out of consideration. The basis for human knowledge is therefore simpler than reality. Humans (and every other learning systems) think to simple. This fact has an important consequence:
Humans (or every learning systems) believe to know more than they really do.
An illustration of this consequence is given in insertion 3. The situation is even worse for people who receive only a simplified report of scientific results. Because in accordance with belief theory, from simplified data stronger results are obtained.

Insertion 3: The sword trick
What the spectators see (Figure 6):

1) The magician shows a solid boulder with a hole (a).
2) His assistant will be tied above the boulder (b).
3) A curtain is put over the boulder (c).
4) The magician moves his sword over the boulder and cuts his assistant and the stone (d).
5) When the curtain is raised, the sword sticks in the hole of the boulder and the assistant is uninjured lying on the stone (e).

What really happens:

The upper part of the boulder was raised behind the curtain, the magician inserts his sword into the hole and pushes the boulder down (Figure 7).

The spectators believe in the simplest explanation for their observations. They deduce from their data that the boulder will remain fixed and have no explanation for the rescue of the assistant.

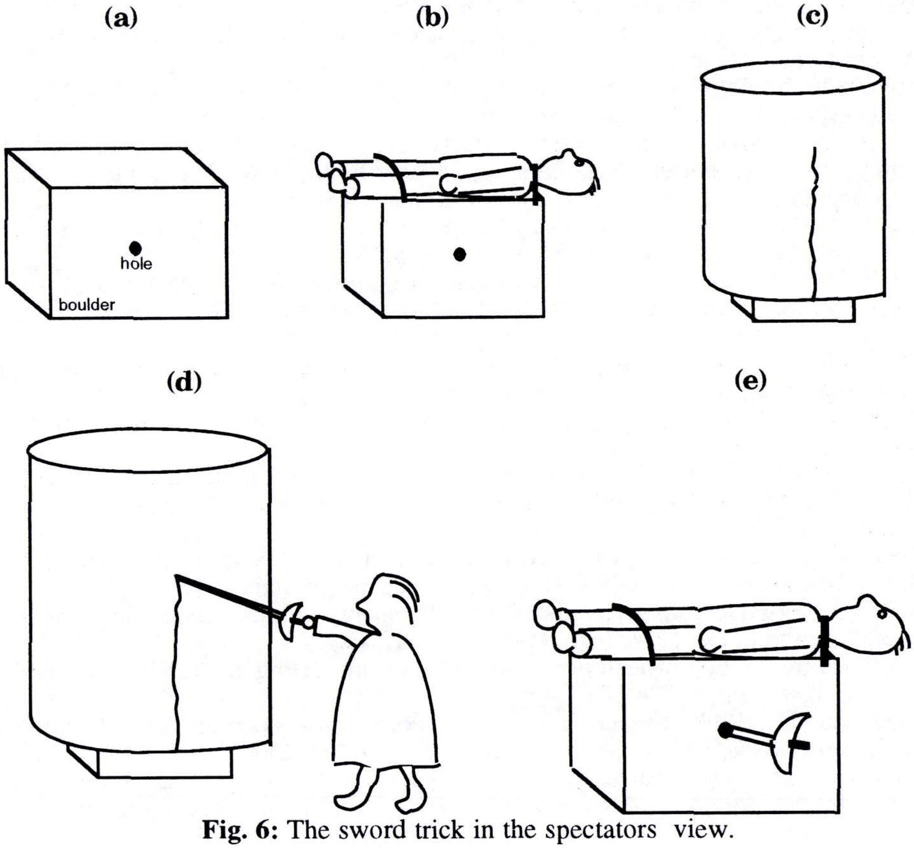

Fig. 6: The sword trick in the spectators view.

4 Conclusions

Every knowledge depends on the assignments of meaning. We have shown that knowledge obtained from belief is more independent from prejudices than the knowledge provided by rational reasoning. This more general method of understanding is necessary for an explanation of many phenomena from quantum mechanics and psychology. No other method to obtain knowledge which is more general than belief, is imaginable to the author.

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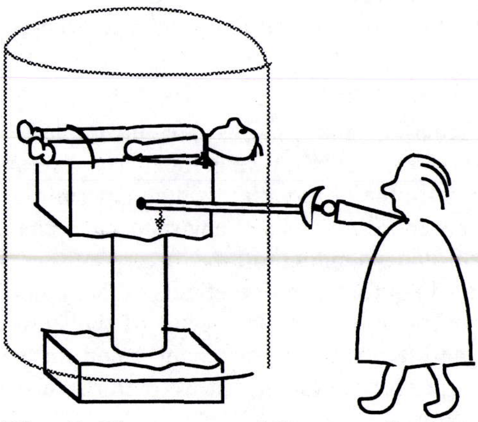

Fig. 7: The secret of the sword trick.