Non Conscious Processes Preceding Intuitive decisions

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Abstract
A new method is described for the assessment of several factors contributing to intuitive decisions. Technically, the method monitors the pupil dilation preceding choices made in an artificial grammar task. The analysis focuses on the acquirement of implicit knowledge related to a some somatic marker. Results indicate that with the new method we can unequivocally show that a somatic marker preceding a decision is a driving 'force' for the final choice. Thus the basic ingredient of the 'somatic marker' model is supported. In a highly speculative extension we also explored the potential contribution of explicit information from the future. It is shown that there is sufficient evidence in this research and also in already published main stream data to continue exploration of this controversial factor possibly contributing to intuitive decisions.

INTRODUCTION

Cognitive psychology has long neglected the topic of intuition. Intuition was considered to be largely inferior to analytic decision making. Damasio's best seller 'Descartes Error' (Damasio, 1994) did change that situation considerably. Damasio argues that patients with prefrontal damage are missing something to help them make advantageous decisions and that that something is not analytic in nature. Rather some emotional component, apparently helping the decision process, is lacking. Patients who performed well on different kind of tests tapping their intelligent reasoning, did systematically make disadvantageous decisions in their daily lives. Damasio is cautious to call this missing capacity only intuition if the emotions involved are unnoticeable. However, since the popular notion of intuition also involves 'gut feelings' one can make a case that, even if the emotions helping the decision process are consciously perceived, we are dealing with intuition. Thus in Damasio's book the focus of Cognitive Science on 'intelligence' as the major concept in decision making was questioned and this largely non-conscious aspect of (advantageous!) decision making came to the foreground.

If we define intuitive decision making as 'making decisions based upon a *feeling* rather than based upon intellectual reasoning' then it is obvious that our concept of intuition overlaps and maybe even coincides with the type of decision making that, according to Damasio, is affected through damage in the prefrontal cortex (Bechara et al, 1997). A model for intuitive decision making is given in figure 1.

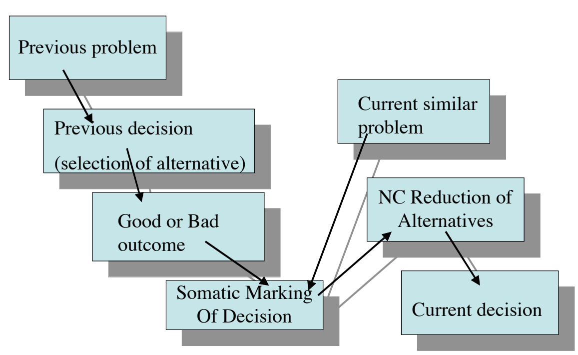

Figure 1: Model of the steps resulting in intuitive decisions

For each decision taken the model claims that the outcome is labeled (associated) with a positive or a negative emotion. Thus the decision becomes marked and since this emotion has a bodily component the marker is called a 'Somatic Marker'. The marking is an automatic, and not necessarily conscious, process. Thus in the course of a life time several decision outcomes are marked and each time a problem similar to an already encountered problem presents itself, the somatic markers become activated in such a way that basically the non optimal solutions are repressed resulting in an effective reduction of the solution space.
A good illustration of this process in healthy subjects is the chess player who generally combines the two types of decision processes.
" When I have to make a move a few of all possible moves do present themselves more or less automatically, the others do not feel good. Then I will further elaborate these few moves to 4 or 5 levels deep. But in that process again some of the options seem to be repressed automatically....."

Instinct as Intuition
This model can be extended for problems that haven't been encountered before by the individual but that might have been encountered by previous generations of the species and might have become encoded in genetic information. Thus what is generally called instinct is also a kind of 'intuition'. Basically the implicit learning selection phase from figure 1 is omitted because it has been done already in the generation before.

Psi as intuition
Finally the concept of intuition has been used as a disguise for assumed paranormal or anomalous processes. In this case the feeling, restricting the search space, is not driven by the implicit knowledge from the past nor by the genetic information from the species but it is assumed that this 'information' stems from the future. This aspect is returned to in the second part of this article.

Empirical Support for the Somatic Marker model.

Damasio's group provided empirical support for the Somatic marker model through a simple gambling task where subjects had to choose a card from four blind decks of cards. (e.g., Bechara et al., 1997). Each card was either winning or loosing and two of the 4 decks were disadvantageous in the long run. Damasio [1996, p.1417-1418] describes this task as follows:
(…)*The task is an attempt to create in the laboratory a realistic situation in which subjects gradually learn how to play a card game, to their best advantage, in situations of limited knowledge about the contingencies, and under the control of rewards and penalties,(…) the task operates as follows: the subject sits in front of four decks of cards [A, B, C, and D] equal in appearance and size and are given a $2000 loan of play money. They are told that the game requires a series of card selections, one card at the time., from any of the four decks, until they are told to stop. The subjects are told that (1) the goal of the task is to maximize profit on the loan of the play money, (2) they are free to switch from one deck to another, at any time, and as often as they wish: but (3) they*

are not told in advance how many card selections must be made. (...) the ultimate yield from each deck varies (...). In short, decks A and B are equivalent in terms of over-all net loss over the trials. ..... Decks A and B are disadvantageous because they cost the most in the long run, while decks C and D are 'advantageous' because they result in an over-all gain in the long run

The results of these experiments indicated (1) that subjects started selecting cards from the advantageous decks before they were able to verbally motivate and explain their choices, and (2) that they exhibited a larger skin conductance response (SCR) just before taking a card from a disadvantageous deck. Thus, differential SC responses to advantageous and disadvantageous decks appeared before subjects were able to motivate their decisions, as if their body knew which decks are risky before the relevant knowledge was available for verbal reports. In contrast, patients with damage in the prefrontal cortex failed to exhibit anticipatory SCRs and tended to continue to select cards from the bad decks even though some of them ended up being able to verbally describe the correct selection strategies

A NEW METHOD TO STUDY THE SOMATIC MARKER

The Gambling Task replaced by Artificial Grammar learning task

It can be questioned if the gambling task is a typical situation found in real life situations. In real life, we generally are confronted with problems that have many different aspects, each of which allows for some rational analysis. It is the complexity of the interacting factors that yield a kind of combinatorial explosion and hence prevents a full analytic approach. Here the proposed restriction of search space comes in as a great advantage. The gambling task has no underlying factors that are in principle open fore analytic approach. There is one ad hoc factor imposed on the task namely that in the long run two of the decks are more advantageous. The task does however allow for implicit learning of this fact and has a very well defined association of outcomes with emotions. Thus the task has all the necessary components to create somatic marking. However it can be argued that the validity of the task when it comes to real life decisions is low. We therefore created an artificial grammar learning task (Reber, 1967; Cleeremans et al, 1998).

The stimuli consisted of pairs of 'words', series of 6 symbols constructed according to two sets of rules, grammar A and B. The symbols [, #, * and + were used. For each stimulus exposure the two words were displayed on the screen. The location of the two words, one constructed according to grammar A, the second according to grammar B was randomized (left and right). The four possible symbols for the two grammars were identical, only the transition probabilities were reversed while the magnitude was always 0.25 (see fig. 2). The first symbol was also always selected at random. The self-transition probability reduced to zero after one self transition occurred. So words having three consecutive '#' and ']' (grammar A) or '*' and '+'(grammar B) characters could not occur.

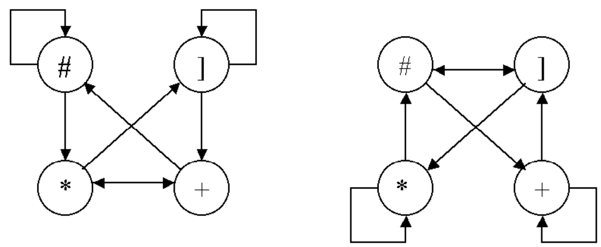

Figure 2: Transition probabilities for grammar A and B. The transition of a symbol to itself was only allowed once.

Pupil Dilation and Eye Movement recording instead of Skin Conductance

A weakness in the research using skin conductance as the dependent variable is the temporal resolution. Skin conductance variations are inherently slow. There is a latency time of about 2 seconds and changes in arousal that are faster than 1 second cannot be separated. We therefore decided to first add the measurement of pupil dilation as a dependent variable. This is combined with eye movement recording that allows us to get a fast arousal measure coupled to the knowledge which of the two alternatives the subject is looking at. If we may assume that the alternative where the subject is looking at is the alternative that is reflected upon then we can follow the arousal through the decision process (Janisse, 1974; Beatty, 1982; Hess, 1972; Partala, 2003).

Testing the Somatic marker model using the new method.

The goal of the current research was to test the Somatic Marker model using the artificial grammar task as context for the decisions and pupil dilation as potentially representing the Somatic marker. In order to compare the results with previous work we also included Skin Conductance as a variable representing the Somatic Marker.

Hypotheses

In this experiment we expect subjects to

1) Implicitly learn the underlying grammatical rules and make the right decisions with above chance rate well before they enter the conceptual phase and are able to explicitly formulate one or more specific rules of one of both grammar sets (implicit learning hypothesis).

2) Show a larger skin conductance response before making an incorrect decision than before making correct decisions in the pre-conceptual period (somatic marker hypothesis).

3) Have larger pupil size looking at 'incorrect' and thus negative emotionally marked words, than looking at 'correct' and thus positive emotionally marked words in the pre-conceptual period (somatic marker hypothesis).

4) The relation between final decisions and preceding somatic markers (arousal values) will also be explored.

Participants

Thirty-three subjects, 11 male and 22 female participated in this study. Their age ranged from 18 to 23 (mean=19.1, sd=1.67). The subjects were either friends of the experimenter, or freshmen psychology students who participated for course credits. Data from one subject was discarded before any analysis due to inattention during the session and failure to do the task appropriately.

Procedure

First, the laboratory was introduced to the subject and then s/he received a written instruction form describing the goal of the experiment as a learning task and providing information about the possibility to earn prizes. After this, the subject was comfortably seated in an adjustable chair in front of the computer screen. After attaching the electrodes to the middle and index finger of the left hand, this hand was positioned on the left armchair. Isotonic paste was used. The response of skin conductance on a deep breath was measured. The subject was instructed that her/his eye-movements would be measured. An adjustable headrest was used to keep the eyes at a distance 60 cm from the center of the computer screen. The eye-tracker was manually installed to exactly fit the pupil. The subject was instructed to look at a fixation cross at the center of the screen as a part of the calibration procedure. Subsequently, a demo trial was started to familiarize the subject with the type of words used in this experiment. If no questions remained, the experimenter started the experiment by clicking the mouse. This resulted in a display of the two 'words'. The location of the correct word (left or right) was truly random. The subject could take as much time as s/he needed to determine which of the two words was from planet Mars. The experimenter stayed in the room without having a view on the display. The lighting in the laboratory was kept at a constant level for all subjects.

Feedback

After the choice was entered by a single key press, the computer marked the chosen word in black. Three seconds later the computer showed if the choice was correct or incorrect and generated a visual and auditory feedback by specifying the amount of pseudo Euros that were won or lost. For incorrect choices there was a 50/50 random 'punishment' of either –10 or –100 Euros. For correct choices there was a 50/50 random reward of +10 or +100 Euros. The display showed both the reward or punishment as well as the cumulative score. Feedback remained on the screen for 6 seconds. Four seconds later the next pair of words was shown (see Fig. 3).

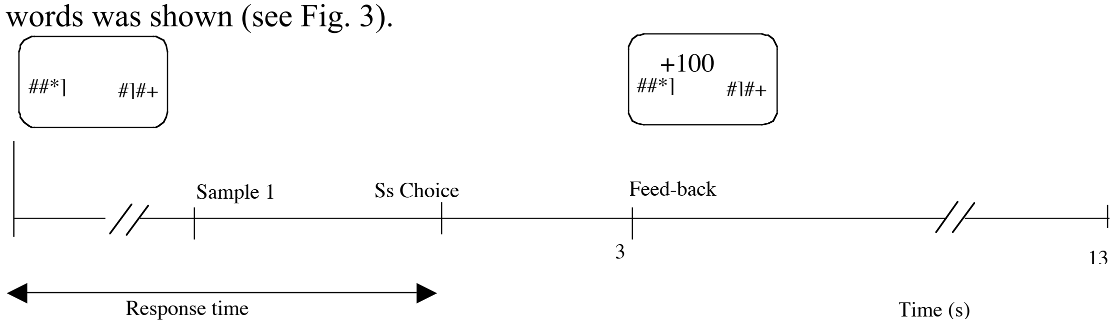

Figure 3. Timing of a single trial. Data are stored from 4 seconds before, till 13 seconds after the choice has been made.

Elicitation of explicit knowledge
After each 10 trials, the computer generated the question: *How do you come to a choice between the two words?* The response was written by the experimenter on a standardized score form. Knowledge of the grammar was scored to have become *explicit* when the subject correctly formulated at least one rule and did not relapse to a state where the rule disappeared. Conservatively, another 5 trials were subtracted because the knowledge formulated at for instance trial 50 could have become explicit anywhere between 41 and 50, so 45 was taken as the best estimate.

Equipment
Skin conductance measurement
Two Ag-AgCl electrodes were attached to the middle and index finger of the left hand. Isotonic paste was used. The skin conductance was measured using the Orion 4AD22 which measures skin conductance using a constant AC current method (10 microamps, 100 Hz). Epochs were stored from 4 seconds before the choice till 13 seconds after the choice has been made (see fig 3). The data were sampled on interupt basis with a sample frequency of 5 samples/s.

Pupil size and horizontal eye-movement measurement
Pupil size and horizontal eye-movements were monitored with a Viewpoint Eye-tracker. Viewpoint Eye-tracker software is running under windows on a PC computer. Data were continuously stored during experimentation. Eye-tracker data were sampled on interupt basis with a sample frequency of 30 samples/s.

RESULTS
The implicit learning hypothesis
For each subject the start of the conceptual phase (explicit knowledge phase) was determined using the method described earlier. This was compared with their performance curve. For most subjects the performance started to increase far before they entered the conceptual phase.
Seven subjects reported an explicit rule before trial 10. These subjects were eliminated for further analysis because their pre-conceptual period was too short. From the remaining 25 subjects eight subjects hadn't formulated any rule after 100 trials. The average trial an explicit rule could be formulated by the remaining 17 subjects was trial 58 (sd=23).

The somatic marker hypothesis
Skin conductance responses
Due to malfunctioning of the equipment, 3 subjects had to be removed. Baseline of the skin conductance was set to the first sample taken (4 seconds before the choice of the subject). The baseline corrected skin conductance samples were averaged over the period before feedback was given for each trial, resulting in a variable correlating with ‘arousal’ before feedback, i.e. during the decision and anticipation phase. This variable represents Damasio’s somatic marker (SM) for each choice. Subsequently, these ‘arousal’ values were separately averaged for the correct and incorrect choices per subject. To investigate the somatic marker effect in the pre-conceptual period only trials were used for which it

was assessed that the subject had no explicit knowledge with regard to the grammar rules. This was compared to the results of all subjects over all trials. This resulted in the dependent variables *SM_correct choice* and *SM_incorrect choice*.

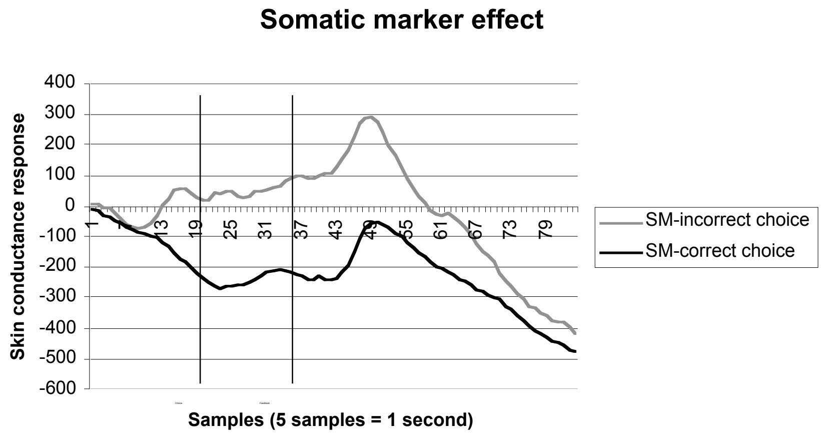

Figure 4 The skin conductance preceding, during and after feedback of correct and incorrect decisions in the *pre-conceptual period* for 24 subjects.

The skin conductance response before making an incorrect decision was significantly larger than the skin conductance before making a correct decision for trials in the pre-conceptual period (t = 2.31, df = 23, p = 0.015 (1-tailed)). However, the *SM_incorrect choice* was not larger than the *SM_correct choice* for trials in the conceptual period (t = 0.925, df = 20, p = 0.183 (1-tailed)). Non-Parametric statistics gave basically identical results.

Pupil size

Due to a failure to accurately fit the pupil, data of one subject has been discarded from further analysis. By taking horizontal eye-movements into account pupil size data were categorized as *SM-correct option*, the somatic marker when looking at correct options, and *SM-incorrect option*, the somatic marker when looking at incorrect options before actually making a decision. In a pilot study the largest difference in pupil size between negative emotionally and positive emotionally marked words was seen one second after stimulus presentation. So, for both data sets data were averaged over a one second time interval (30 samples) after each stimulus onset. For a smoothed visual timeline blinks and artefacts were removed by deleting samples with a pupil aspect ratio of 0.80 or lower. Trial averages were deleted when resulting from less than 20 samples.

The pupil size of subjects was significantly larger looking at incorrect options before actually making a decision than looking at correct options before actually making a decision in the pre-conceptual period (t = 1.87, df = 24, p = 0.037 (1 tailed)). In contrast, when taking only conceptual trials this effect disappeared. *SM-incorrect option* was not larger than *SM-correct option* (t = 1.17, df = 23, p = 0.13 (1 tailed)). The mean effect size in the pre-conceptual period was 0.22 %. Means and standard deviations are shown in table 1 (pre-conceptual period) and table 2 (conceptual period).

	Mean	Stdev
SM-correct option	0,1598	0.0192
SM-incorrect option	0,1602	0.0191

Tabel 1. Means and standard deviations of SM-correct option and SM-incorrect option in the *pre-conceptual period*

	Mean	Stdev
SM-correct option	0,1648	0.0160
SM-incorrect option	0,1651	0.0167

Tabel 2. Means and standard deviations of SM-correct option and SM-incorrect option in the *conceptual period.*

This result confirms and coincides the result obtained with skin conductance but the reason to use pupil size as representing the somatic marker was to investigate if the somatic marker actually influences the final decision on a single trial level.
If this task was no more than a simple guessing task and pupil responses should not influence the decision-making process the sum of both values of one diagonal minus the sum of both values of the other diagonal should be zero for every subject, or LPbias = (A + D) - (C + D) = 0 (see table 5). However, if pupil size does influence the direction of subjects' choices, the result of the formula above should be different from zero. Results were calculated for every subject for both pre-conceptual trials as well as conceptual trials.

	Response	
Largest pupil	Incorrect	Correct
SM-correct option	**A**	**B**
SM-incorrect option	**C**	**D**

Table 5. Explanation of the formula (A + D) - (C + B).

The table below summarize the responses of all subjects as a function of the largest pupil diameter on a single trial averaged over all pre-conceptual trials.

	Response	
Largest pupil	Incorrect	Correct
SM-correct option	12,1 %	35,3 %
SM-incorrect option	11,2 %	41,4 %

Table 4. Relative frequency of a Correct response in case that the largest pupil size occurred when looking at the correct option and when looking to the incorrect option. The same for the incorrect response.

In the pre-conceptual period, the ‘largest pupil induced bias’ of 18 of the 25 subjects was positive. Results differed significantly from 0 (t = 3.02, df = 24, p < 0.01) strongly suggesting that the final choice was driven by the Somatic marker represented by pupil size. In the conceptual period, the results of 11 of 24 subjects were positive, 12 were negative and one was zero. These results did not differ significantly from 0 (t = 0.91, df = 23, p = 0.37.)

INTUITION AND PSI

As was argued in the introduction, it is possible to integrate so called psi phenomena, like precognition, into a model for intuition. This can be done by not only allowing information from the past biasing decisions but also information from the future (see figure 5)

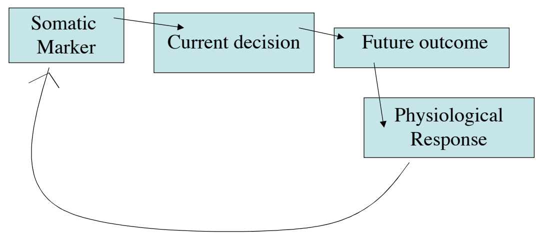

Figure 5: supposed anomalous component of intuitive decisions

Of course such a hypothesis is extremely controversial because almost all scientific modeling is based upon forward causality being the only possible driving factor. One can wonder if there are any data available that support entertaining this idea. Of course there is a lot of anecdotal material that claims that people have a pre-sentiment, e.g. that they feel that something bad is going to happen even if the bad event can't possibly be foreseen based upon past information. However anecdotal materials are hardly scientific evidence because it is generally based on human perception and memory, both faculties being extremely sensitive to errors.

Psi analysis of the gambling experiment

The hypothesized phenomenon if real should be present in a whole lot of hard scientific data where subjects are randomly presented with highly emotional and neutral events. Interestingly this is the case in Damasio's gambling experiment. One therefore could check his published data for this effect. In the analysis of these experiments the focus was on the 'somatic marker' averaged for specific decks of cards. Each deck contains winning and losing cards and hence one could also average separately for winning and loosing cards. According to Bechara the randomization is such that:

"....the players have no way of predicting when a penalty will arise..."(Science, **275**, 28 February 97, 1293-1295)

Thus the anticipation before the bad (losing) and good (winning) cards should be equal.

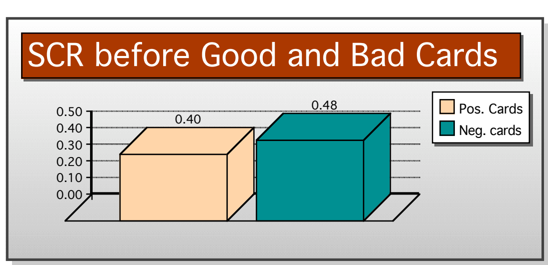

Figure 6 Results of re-analysis of Damasio's gambling experiments

However if one averages the anticipatory value over all bad cards, independent in which deck they are in, then the resulting value is marginally significantly higher than for the averaged good cards ($t = 1.63$, $df = 117$, $p = 0.053$). Such a result is far from convincing as evidence for an anomaly but it is sufficient to proceed with some further explorations.

Psi analysis of other main stream experiments

In a follow up we searched for data of already published studies of experiments where random emotional and neutral stimuli were exposed. We needed access to the raw data and these dat should also contain the skin conductance from the period preceding the exposure. Both conditions (access and a long baseline) are difficult to fulfill but we got access to the data of a study. However a study on the speed with which arises in phobics (Globisch, 1999) fulfilled the criteria. We re-analyzed the data clamping the data at 7 seconds before exposure rather that the clamping at exposure as was done in the original publication.

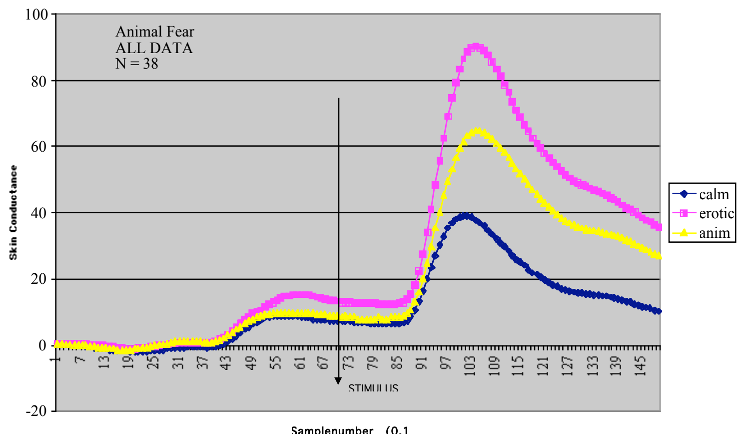

Figure 7: Results of re-analysis of skin conductance time course with clamping of the baseline at 7 seconds before exposure.

As shown in figure 7, the results showed a stronger anticipatory signal preceding the most emotional pictures (t= 2.7, df= p =).

We replicated this experiment using 48 similar pictures with 10 unselected subjects. In this study we randomized with replacement in order to avoid any strategic explanation of the results. Rather than measuring the skin conductance we measured the BOLD signal in an event related FMRI paradigm (for details see: Bierman & Scholte,). The BOLD signal is assumed to reflect brain activity. An example of one subjects results is shown in figure 8. Again there is a clear anticipatory signal preceding the most emotional pictures ($t=2.89$, $df=39$, $p<0.01$).

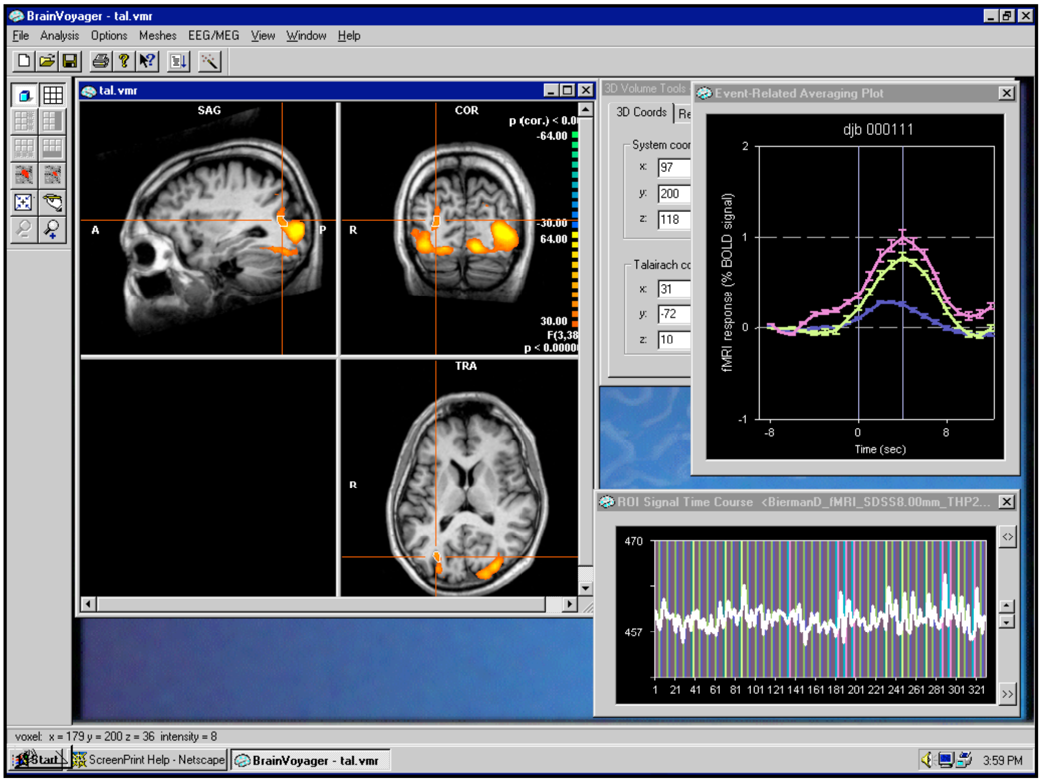

Figure 8: Screen dump of time course analysis. The upper right pane gives the average BOLD response for erotic, violent and neutral stimuli in a brain region around Tailarach coordinates (31,-72, 10). Note the increase before the exposure to erotic stimuli.

Psi analysis in the current experiment

Although emotions caused by pseudo monetary rewards are not as extreme as those caused by pictures we have already seen that there is some evidence in the gambling experiment re-analysis that pre-sentiment of a negative reward occurs in the form of a stronger somatic marker. Thus we might ask if we could also measure this in the artificial grammar task. To that purpose choice of the amount of money that would be gained or subtracted was determined in a truly random way. Subjects who made an incorrect choice lost either –10 or –100 euro's. Subjects have of curse no way to know which of the two amounts will be lost. So one should expect that their somatic marker for these two shouldn't differ. However if there is a pre-sentiment about the future loss, then we would expect the somatic marker to be larger preceding a loss of –100 than preceding a loss of –10 euro's.

In figure 9 the average time course of the skin conductance is graphed for the two different negative feedbacks. The upper trace is for the trials where a large amount was lost. This signal is larger before the feedback is given. The difference is however not significant possibly because the emotional differences between the two loosing conditions is not large enough.

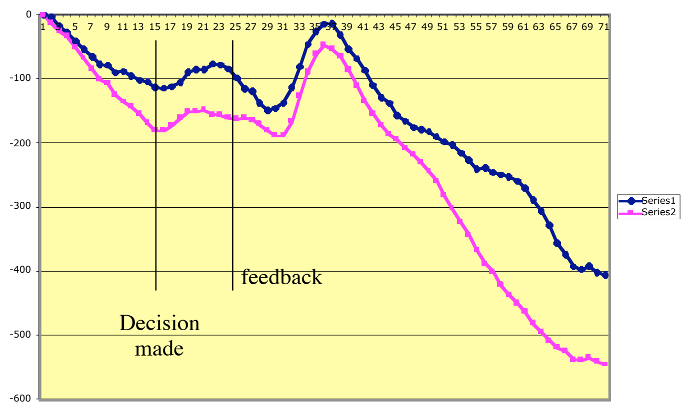

Figure 9: The average time course of the skin conductance preceding and after feedback of the amount lost in the artificial grammar task. The upper trace is for trials where 100 euro's were lost while the lower is for the small loss of –10 euro's.

CONCLUSION

In the current research program we have developed a method that allows us to separate the several factors contributing to intuitive decisions. These are:

1. implicit learning

   With regard to the implicit learning hypothesis it should be mentioned that there is still an ongoing debate if the measurement of explicit knowledge by simply questioning is not too insensitive. We therefore applied in a follow up study two levels of questioning. One was superficial by a simple question as in the currently reported study. The second level was an extended structured interview. Both methods resulted in identical results with regard to the moment subjects formulated correct explicit knowledge. Therefore we consider the simple method as a reasonable sensitive method for assessing explicit knowledge.

2. the development of a somatic marker associated with specific choices
3. the degree to which this marker influences the decision
4. the possible contribution of a psi factor.

In future research this new method using an artificial grammar task and eye movement – pupil dilation recording, should be transformed into an instrument to objectively assess these 5 factors in a quantitative way. This instrument would also allow us to train the third factor by bio-feedback techniques. If indeed the intuitive component in decisions can result in advantageous decisions then such a training might help people that over emphasize analytical thinking as the only useful contribution to human decision making.

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