ANOMALOUS SLOW CORTICAL COMPONENTS IN A SLOT-MACHINE TASK

Dick J. Bierman & Jenneke van Ditzhuijzen
University of Amsterdam

Abstract

Thirty-two subjects participated in a 128 trial slot machine task. The task was initiated by the subjects. With intervals of one second the three windows of the slot machine froze. There were three types of events: three subsequent different fruits (XYZ), two equal fruits followed by a different one (XXY) and three equal fruits (XXX). The events were selected randomly with replacement from a limited pool of possible events. The subject had to pay 0.5 euro (real money) for each trial and received 7 euro for winning (XXX) events. The a priori probability for an XXX-event was 12.5% throughout the experiment. The subject could not know nor learn what the next fruit to be displayed would be. The subjects kept the money they won at the end but never had to pay when they eventually lost money.

Following brain research with slot machines we analyzed the pooled medio-frontal signals from the Fz, Cz and Pz lead, using pre-processing parameters specified in the literature. There was a significant difference between the slow wave preceding a 'win' and preceding a loss (XYZ) (t= 2.76, df=31, p=0.01). This difference can be explained by the fact that after the first fruit has been 'frozen' the subject is aware that in the XYZ condition the possibility for a win has vanished. However the difference was observed to develop before the second fruit froze i.e. before there was any visible difference between the conditions. This anomaly was confirmed by a comparison of the XXY and the XXX condition where, for the relevant period from 1 to 2 seconds, there was no visible difference for the subject and nonetheless the brain signals differed by about 1.9 microvolt on average (t= 2.34, df=31, p=0.026). These results were not significantly associated with 'perceived luckiness' although the 15 subjects who perceived themselves as 'lucky' did have a much larger effect of ~ 2.9 microvolt compared with the other subjects (~0.6 microvolt). Exploratory analyses showed some suggestive evidence for the effect of sustained attention and of the belief to be able to 'influence' the slot machine.

These anomalous results are critically discussed in the light of similar findings in the psycho-physiological literature.

Introduction

Intuition and Anticipation

The concept of intuition can largely be understood in the framework of Damasio's somatic marker model (Damasio, 1996). Three processes are assumed to be relevant when it comes to intuitive decisions, i.e. decisions made on the basis of a feeling rather than an elaborate analytical evaluation. In the first place the knowledge driving the decision is assumed to be learned implicitly and often this knowledge is hardly accessible to the subject by explicit search. This knowledge is assumed to be 'labelled by' or 'associated with' the emotions and bodily state that occurred at the time the outcome of

the decisions were experienced. In the second place when a similar problem arises this knowledge and the associated emotion is non consciously activated. In the third place the emotion associated with previous outcomes of similar problem situations biases the decisions the person makes. So according to this framework for intuition, the processes involved are: implicit learning, somatic marking and biasing of the 'solution' space by non consciously activated implicit knowledge and emotions (Bierman et al, 2005).

However there is plenty of anecdotal evidence suggesting that sometimes people do seem to make what they call intuitive decisions, without having gone through the process of acquiring implicit knowledge because they haven't encountered the same situation before, either in person or in reading about it. For instance people might report an uncanny feeling when driving on a highway resulting in a decision to slow down. A few moments later a deer crosses the highway just in front of the driver. Such a decision driven by no knowledge, either explicit or implicit, from the current context or the past is generally assumed to be a pure chance decision. And of course random decisions can sometimes have a positive and sometimes a negative outcome. Thus these anecdotes can easily be accounted for. However in experimental situations the probability for calling behavior random can be calculated. For instance in Damasio's famous card selection gambling experiment subjects showed a larger skin conductance (presumably correlating with a larger arousal) before they selected a 'loosing' card compared with the skin conductance before selecting a 'winning' card. This in spite of the fact that the order of the winning and loosing cards in the decks was random and according to the authors (Bechara et al, 1996) that the subjects had no way to infer anything about this order. The probability of that difference in skin conductance preceding the feedback of the card occurring by chance was smaller than 1 in 20. (Bierman, 2002)

Although this specific experiment was not set up to test the claim of 'an unexplained uncanny feeling before a loss', there have been an number of studies who were specifically designed to do so. In these studies subjects were presented with random events that could have a positive (or neutral) outcome and a negative outcome. In some of these studies subjects were exposed to random positive and negative pictures and in other studies to alarming or neutral sounds (Spottiswoode & May, 2003). In those studies there appeared to be a small but consistent baseline difference with regard to the future condition. Note that these baseline values were generally taken during the time that the subject was building an expectation about the subsequent stimulus condition. However these baseline (or anticipatory) differences were unexplainable because, given the proper randomization with replacement of the conditions, there was no way that the subjects could infer the future condition (Bierman & Radin, 1997, 1998). The anomaly, dubbed "presentiment" has been replicated with several physiological variables like Skin Conductance Level (Radin, 1997, 2004), Skin Conductance Response (Spottiswoode & May, 2003), Heart Rate (McCraty et al, 2004 a,b), ERP (McCraty et al, 2004a,b), slow cortical potentials (Levin and Kennedy, 1975; Hartwell, J.W., 1978) and recently also BOLD (blood oxygenation level, the dependent variable in fMRI experiments) (Bierman & Scholte, 2002; Journal of ISLIS)

If the anomaly, by accumulating evidence, turns out to be a real effect then this effect might be a fourth process contributing to intuitive decisions. A process that could 'explain' the anecdotal evidence as mentioned above.

The conventional view of anticipation is that "in fact our view of the future is based upon our past experiences" (Brunia, 1999). This view is a direct consequence of assumed forward causality. Backward or retro-causality is seen as a logically incoherent concept resulting in paradoxes like the famous grandfather paradox. However discussions on time-travel in the physics community (Morris et al, 1988) have resulted in refinement of the logic and retrocausality might not result in logical paradoxes if some constraints are applied. Also all of physics is fundamentally time-symmetric and hence 'waves travelling backwards in time' are theoretically possible and do not cause paradoxes (under the condition that the information travelling backwards cannot be used to alter its source; see Price, 1996).

Anticipation has been studied by the measurement of slow cortical potentials in the brain since the 1960s (Walter, Cooper, Aldridge, McCallum, and Winter, 1964). The label CNV (continuous negative variation) was used originally and after it was discovered that a similar slow negative going potential occurred before preparing a motor response a second label Bereitschaftspotential was used (Deecke, 1987). In more recent years the motor component has been shown to be less relevant than Deecke suggested and stimulus preceding negativity was observed in several contexts. The conclusion of this work to date is that anticipation is "a state that is characterized by the activation of the brain areas required for the specific upcoming operations. For instance, anticipation of perceptual input may activate posterior areas, anticipation of affective input right frontal areas and so on" (Boxtel & Böcker, 2004). The work of Donkers (Donkers, Boxtel, 2005 & Donkers, Nieuwenhuis & Boxtel, 2005) used specifically a paradigm where no responses were required to support this line of thinking. In their experiments where they measured medio-frontal potentials, subjects were just observing a simulated slot machine where three digits would appear with about one second interval. When the consecutive three digits were identical the subject would win (or in another condition lose) money. In the present experiment we used basically the same paradigm to test if indeed the slow cortical potential preceding the final outcome would be different for different outcomes in spite of these outcomes being selected randomly.

Hypothesis

Following the literature on "presentiment" we expect that the brain signals preceding a 'win' will differ significantly from the brain signals before a loss. This will be tested by comparing the mean voltage during the one second preceding the outcome pooled from all three medio-frontal electrodes (Fz, Pz and Cz). We will also explore if there are differences between these three electrodes and the results obtained from other leads. Finally correlations between a potential "presentiment" effect and the responses upon questionnaires, measuring a.o. 'perceived luckiness' will be explored.

James Spottiswoode 1/17/06 8:05 AM
Comment: What does "a.o." mean?

Method

Participants

Thirty-two subjects, 22 female and 10 male, between the ages of 17 and 51 (mean = 23; sd = 7.5) participated in the experiment. Participants were students and could earn course

credit or money or a combination. The amount of money they could earn was determined by the outcome of the slot-machine task. (see details below).

Experimental Task and Procedure

Materials

Stimuli

The slot-machine was implemented using video clips. Each video clip contained a movie of a slot-machine with three windows with moving fruits (see fig.1). The subject had to press any key to run the clip.

Figure 1: Slot machine as presented to the subjects. The picture shows the final state after all three fruits had stopped spinning. This is an example of the XYZ condition (all three fruits different)

All the clips were identical (copies of a mother clip) apart from the key frames where a fruit appeared in one of the three windows. The mother clip initially shows all three windows in running mode. After 1 second the left-most window freezes into one of 4 possible fruits. We call this event S1. After another second the middle window freezes (S2) and after another 1 sec the last rightmost window freezes (S3). The slot-machine presentation software was written in RealBasic 5 and the clips were presented on an 17 inch LCD screen (LG Hatron 795FT 1024*768*32 bit) connected to a 3.0 GHz Pentium IV computer running Window XP. A *nvidia pcx 5300* videocard was used. Synchronization with the EEG data-acquisition was done using a photocell glued to a screen that mirrored the stimulus presentation screen. The video clip to be presented was copied randomly at button press time from a prepared pool of 128 slot-machine video clips. This pool contained 16 XXX, 24 XXY and 88 XYZ clips.

James Spottiswoode 1/17/06 8:11 AM

Comment: I know you are aiming at the main stream, but I do think you should describe the randomisation. I assume you used RealBasic's PRNG seeded by the subject starting the trial?

Perceived Luckiness Questionnaire

The PLQ was designed to classify participants as perceiving themselves as either lucky or unlucky as part of a larger project concerning the psychology of luckiness (Smith, 1998). To ensure that it was clear to participants how the terms 'lucky' and 'unlucky' were being

used, the questionnaire presented participants with the following two descriptions of 'lucky' and 'unlucky' people:

A. Lucky people are people for whom seemingly chance events tend to work out in their favor. For example, they seem to win more than their fair share of raffles and lotteries. Dice seem to roll in their favor and roulette wheels often choose their numbers. Other times they might seem lucky in everyday life. For example, they always seem to find a parking space when they need one, or they accidentally meet people that can help them in some way.

B. Unlucky people are the opposite: seemingly chance events tend to work out against them. For example, they never seem to win anything on games of chance. Sometimes they seem unlucky in everyday life. For example, they can never find a parking space when they need one, or they tend to be involved in accidents that are not their fault.

Emphasis was placed upon the consistency of outcomes of seemingly chance events. It was also emphasized that these events may be within or outside the context of games of chance and that they may relate to trivial or significant events.

For each description, respondents were asked to rate on a seven point scale how well it described themselves (where 1 = 'doesn't describe me at all' and 7 = 'describes me very well'). Confidence ratings for each of these responses were obtained on another seven point rating scale (where 1 = 'not at all confident' and 7 = 'extremely confident').

Participants who gave the 'lucky' description a rating of '4' or above, and gave the 'unlucky' description a lower rating (with confidence ratings of at least '3' for both of these responses) were classified as lucky. Respondents who gave the 'unlucky' description a rating of '4' or above, and gave the 'lucky' description a lower rating (with confidence ratings of at least '3' for both of these responses) were classified as unlucky. Respondents who could not be classified as either lucky or unlucky were classified as uncertain.

Exit Questionnaire

The Exit Questionnaire consisted out of a few questions dealing with among others gambling behaviour (if any), and the level of attention the subjects had paid to the task. The student participants who participate for course credits have to fulfil this requirement and are not always very much interested in the experiments they have to do.

Procedure

Participants were first informed about the EEG measurement emphasizing that the method is passive and doesn't bring any health risk. They signed the informed consent form and filled in the 'perceived luckiness questionnaire' (ref) before entering the experiment.

James Spottiswoode 1/17/06 8:23 AM

Comment: Did you use a known luckiness questionnaire (in which case it should be referenced) or did you write your own, in which case it should be briefly discussed.

At the beginning of the experiment the participant got a loan of seven pieces of 50 eurocents. The stimulus program started with an instruction page telling the participant that s(he) had to 'pay' 50 cents for each trial and that the outcomes were random. The XXX outcome would be winning and the experimenter would pay the subject 14 pieces of 50 eurocents in case of an XXX outcome. After the instruction a demo trial was shown to the subject. At the end of the 128 formal trials the subject was requested to fill in the Exit questionnaire.

Psychophysiological recording

The electroencephalogram (EEG) was recorded from 34 '*BioSemi*' sintered Ag-AgCl electrodes (i.e. A1:A30 plus). The active electrodes were mounted in a head cap according to a standard extended 10-20 system montage. The *BioSemi* system replaces the reference electrode(s) used in more conventional systems with a common mode sense (CMS) active electrode and a driven right leg (DRL) passive electrode (ref). In this way any electrode or combination of electrodes can be used as a reference. The choice can be made at any time during later analysis. The electro-oculugram (EOG) was measured from 4 sintered Ag-AgCl electrodes. One pair was placed on a horizontal line at the outer canthi of the left and right eye to monitor horizontal eye movements. The other pair was placed on a vertical line above and below the left eye to monitor blinks and vertical eye movements. Data from all channels were amplified with the *ActiveTwo* AD-box and were digitized with a 24 bit resolution at a rate of 512 samples per second and fed through a NI PCI-DIO-32HS card into a 2.8 GHZ Pentium IV computer running Windows XP.

Data Analysis

All raw data were first sampled down to 128 Hz using spline interpolation methods.

Following exactly the pre-processing procedure and pre-processing parameters as used in published research with a slot-machine task (Donkers et al, 2005), data were first filtered using a 0.01-25 Hz Butterworth zero-phase bandpass filter (24 db/oct) and then corrected for eye movements and blinks using the procedure described by Gratton, Coles and Donchin (Gratton et al, 1983). After segmentation on the basis of markers issued exactly at the freezing of the second fruit (which we call t=0, S2), artefacts were removed using an automatic rejection procedure: segments were excluded from further analyses when the minimum and maximum amplitude in a segment differed more than 100 Microvolt. Finally the means for the different conditions were baseline corrected using the interval of 200 msec preceding the freezing of the first fruit. Analyses were focussed on the medio-frontal electrodes Fz, Cz and Fp. The dependent variable used throughout was the mean value of the brain potential pooled over the three medio-frontal electrodes the

second before feedback. The main hypothesis was tested using a paired sample t-test. Exploratory analyses were done using a repeated measure MANOVA with the between subject variables 'Perceived Luckiness', and the responses on the exit-questions and the two conditions XXX and XXY as repeated within subject measures.

Results

Subjects

The data of one subject (Ss25) were unusable because after removal of segments based upon the predefined artefact removal criteria, there was not a single usable segment left. We therefore invited an extra subject to get to the pre-specified sample of 32 subjects.

EEG Signals

Figure 3 shows the medio-frontal EEG split for the three conditions (XYZ, XXY and XXX) for the pre-processed data pooled over all 32 subjects.

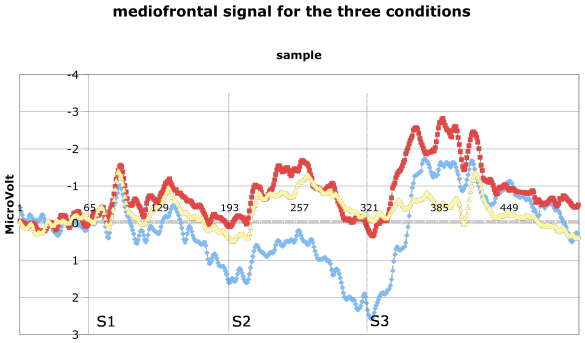


Figure 3. Average brain signal pooled from electrodes Fz, Pz and Cz. The slot machine freezes it's first fruit at -1.0 (s1), the second on 0.0 (s2) and the third at 1.0 seconds (s3). Yellow trace: XYZ condition (all fruits different). Red trace: XXY condition and Blue trace: XXX (win) condition.

Statistical analysis

Is there a difference between the XXY and XXX condition during the second before final feedback (S2-S3 interval)?

This main hypothesis was tested by a two sample paired t-tests. The mean difference of 1.88 microvolt has a *t*-value of 2.35 ($df = 31$, $p = 0.026$ two tailed).

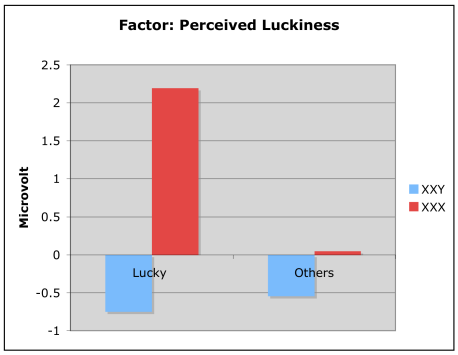
This result is not due to non normality of the score distribution as can be inferred from the non parametric Wilcoxon Signed Rank test. Giving a tied Z-value of 2.206 (p = 0.027 two tailed). The percentage of subjects with an effect in the predicted direction is 62.5% (# ranks > 0 = 20; # ranks <0 = 12. Mean ranks 19.1 and 12.167 resp.). Thus it can be

concluded that there is an anomalous difference between the XXY and the XXX condition during the last second preceding the final feedback.

Explorations

Is the effect dependent on Perceived Luckiness?

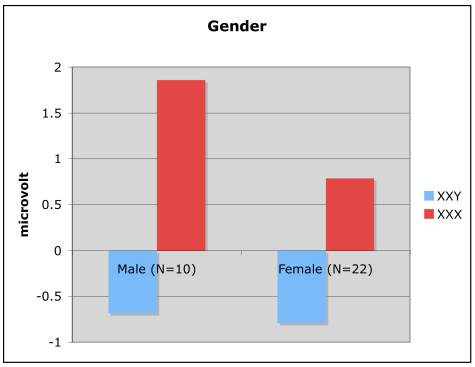
In order to evaluate this question we performed a repeated measure ANOVA with the conditions XXY and XXX as repeated measure and the 'perceived luckiness' personality variable as between subject variable. Data of the two first subjects were unavailable. We reduced the number of classes to the class of subjects that called themselves 'lucky' and those that were classified as 'unlucky' or 'uncertain'.



The 15 "perceived lucky" subjects did have the largest effect of more than 2.90 microvolt in contrast with the 15 subjects in the other groups with hardly any effect (~ 0.6 microvolt). However there is no interaction ($F=1.99$, $df=1$, $p = 0.17$) and we thus cannot conclude that these groups do differ.

Is the effect dependent on Gender?

In order to evaluate this question we did a repeated measure ANOVA with the conditions XXY and XXX as repeated measure and Gender as between subject factor.



The effect size is larger for male (~ 2.6 microvolt) than for female (~1. 5 microvolt) but the difference is not significant. Note that the difference in effect size is completely due to the XXX condition where the male have about twice as large an effect.

Is there a difference between different leads?

The medio-frontal leads

In order to answer this question we did a repeated measure with the three leads (Pz, Fz and Cz) difference signals as repeated measure.

The effect turns out to be independent of medio-frontal lead ($F=0.453$, $df= 2$, $p=0.64$). I.e. the effect is visible on each of these electrodes though mostly on Fz (mean difference is 2.14 microvolt) and Cz (mean difference is 2.30 microvolt)

The other leads.

Analysis of all leads shows that the neighbouring electrodes CP1, C3, and FC1 also show mean difference in the range of 2 microvolt while the other leads have substantially smaller effects. Interestingly the effect seems to extend to the right frontal lobe (Fp2) where a large mean difference of 5.28 microvolt between XXY and XXX is measured. This large mean effect however doesn't reach statistical significance due to the large variance.

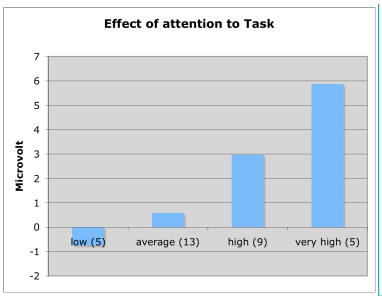
Is there a relation with being an actual winner or an actual looser?

There were 18 subjects ending the slot-machine game with a loss and 14 without a loss. The effect did not interact with membership of either of these groups ($F= 0.036$, $df=1$, n.s.)

Is there a relation with the responses on the Exit Questionnaire?

For these analysis we first calculated difference scores (between XXY and XXX) and entered these in a regular ANOVA with the answer on the exit question as a between subject factor.

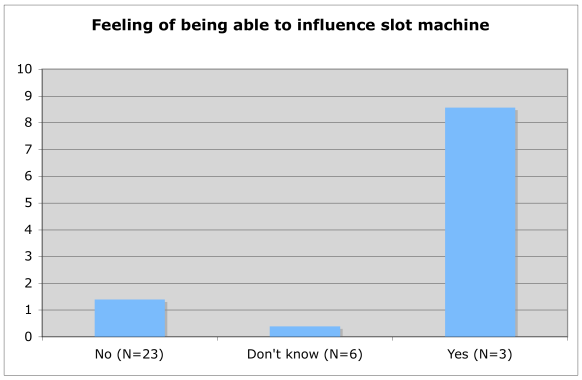
Question: Did you maintain attention (1-5; 1 = not at all)?
One subject responded with '1'. A cell with only one subject cannot be handled by the ANOVA so this subject was reclassified as '2'. The results are somewhat surprising and show a nearly perfect linear relation of the difference between XXX and XXY condition and sustained attention (F = 2.79, df = 3, p =0.06). Note especially the extremely large effect of 5.9 microvolt for the 5 subjects claiming to have sustained the highest attention level.



James Spottiswoode 1/17/06 8:26 AM
Comment: I would show the numbers of cases in each category of attention level.

This is an amazing result – almost too good to be true.

Do you think you were able to 'influence' the outcome?
There was a significant relation (F= 4.57, *df* = 2, *p* = .019) between the XXX-XXY effect and the belief of the subjects that they were able to influence the outcome of the slot-machine (which within normal assumptions of course would not be possible because the clips were selected randomly).



James Spottiswoode 1/17/06 8:27 AM
Comment: Heading should say "Feeling of being able to influence the slot machine"

Is there a relation with real gambling behavior?
There was no relation between 'how often people did gamble' and the XXX-XXY effect.

James Spottiswoode 1/17/06 8:27 AM
Comment: Give statistic.

Discussion

In order to get a general impression about the quality of the study we compared the current results with results from published similar slot machine experiments

Figure 4A gives the mean brain potentials of all subjects and all conditions of the data pooled over the medio-frontal (Fz, Cz and Pz) electrodes in the current experiment. When comparing these results with results from the literature (fig. 4B from: Donkers et al, 2005) there appears to be discrepancies, especially with regard to polarity and magnitude of the evoked potentials around – 0.8, 0.2 and 1.2 sec. However this could potentially be due to a different form of referencing that we used in the current study. In order to check if the discrepancy was indeed due to the different form of implicit referencing used in the Biosemi system, we re-referenced all channels to the combination of T7 and T8 which is closest to the mastoid electrode reference used by Donkers et al. After re-referencing the over-all results do indeed closely replicate the earlier findings in the literature (see fig. 4C).

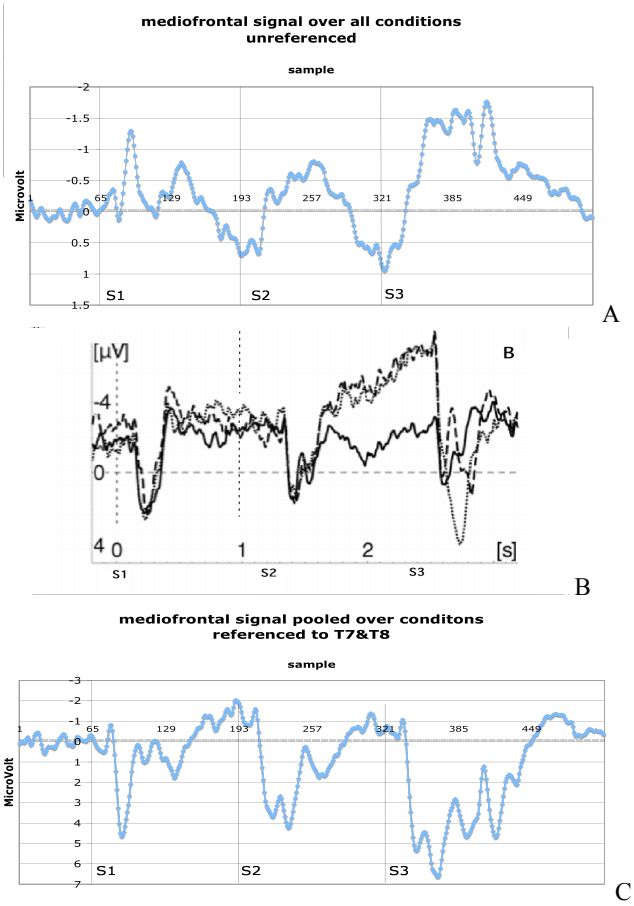


Figure.4: medio-frontal EEG signal in the slot machine task. A: original data referenced to the CMS lead. B: data as published by Donkers et al (2005); C: current data after re-referencing to the T7-8 leads.

To further evaluate these results we also calculated difference waves of the re-referenced data between the XYZ and the XXX condition and between the XXY and the XXX condition (see figure 5). The difference wave shows clearly that there is a different response after S2 in the XX and the XY situation with a larger response for XX because the thrill of a potential win is building up. The comparison of XXY and XXX doesn't show this peak after S2 because for both conditions the possibility of a win remains open. However there is a clear peak now at the end after S3 when the last fruit has frozen indicating the difference between a win and a non-win.

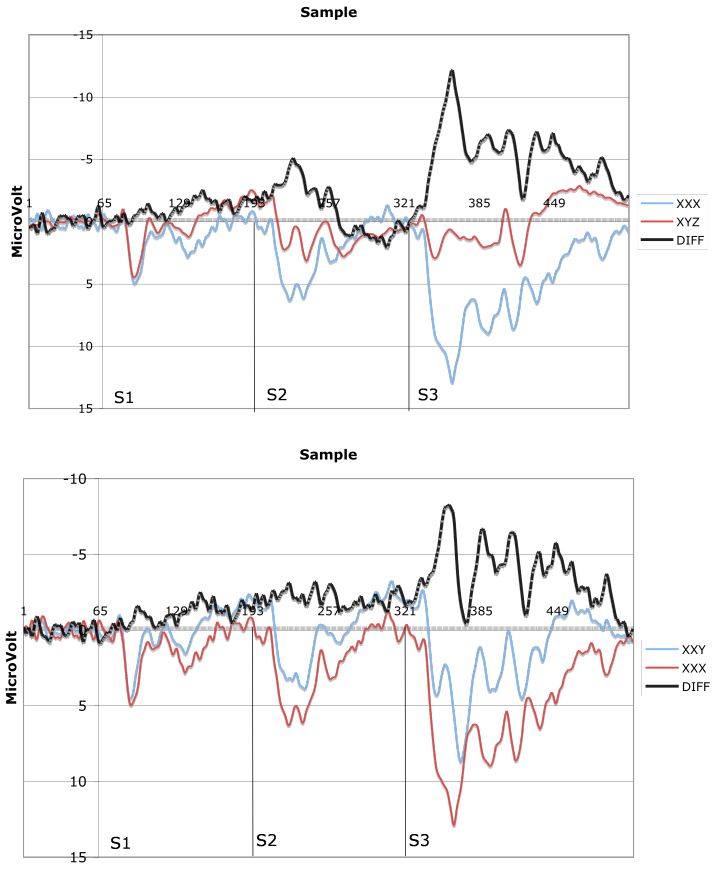


Figure 5: Medio-frontal signal rereferenced to T7-T8. Upper pane: comparison of XYZ (red) with XXX (blue) Black is the difference wave. Lower pane: comparison of XXY and XXX. The difference wave grows slowly from -1.0 sec.

These results unsurprisingly confirm the finding in fig.3 from the unreferenced analysis that brain activity preceding an event is dependent upon the final outcome of the event. This difference already starts after S1, i.e. when the first fruit has halted. The

randomization in the current experiment was set up in such a way that the subject had no means to infer if this would be a winning or a loosing event. Nonetheless the anticipatory signals (if that is how they have to be interpreted) appeared to differ significantly. Since this can't happen in a world with only forward causality the result is anomalous and requires extremely critical evaluation and of course independent replication.

Data acquisition and Preprocessing

The pre-processing of the EEG signals before averaging was standardized and all pre-processing parameters were specified in advance. The BioSemi data acquisition hardware and software has two filters. The first filter is an analog anti aliasing, first order, RC filter (3 db at 3.2 kHz) which, by its hardware nature, can only have a causal (i.e. forward in time) effect. After analog to digital conversion there is a 5^{th} order sinc filter (-3db at 20% of sampling rate). This filter only uses past samples to get the actual filtered value.

Nonetheless it could be that either the ocular correction, or the further digital filtering as described in the analysis section do introduce distortions. These distortions might be dependent on the maximum amplitude of the response after S3. Thus they could differ for the three conditions XXX, XXY and XYZ. To evaluate the whole sequence from the scalp to the final pre-processed signal (i.e. including the BioSemi filters) we used a signal generator that fed a precisely known test signal at the electrodes. This signal is shown in fig.6a and the final result after data-acquisition and pre-processing is shown in fig. 6b . This was done for two different test signals identical to the mean values in the XXX and XXY condition.

Randomization

The claim that there were no means by which the subject could infer the future outcome is based upon the randomization used and upon the claim that the presented materials did not contain any information that could be used to infer the final outcome.

In contrast with the general practice in psychophysiology the randomization in this experiment was not based upon shuffling of conditions. The latter procedure is generally used to guarantee a counterbalanced design so that conditions appear with equal frequency. It is known that with such a method of randomization subjects are able to entertain a correct estimate of the probabilities for a specific condition to appear in the next trial. This is because basically the next condition is not completely independent from the previous ones as is required for true randomization. In other words in a counterbalanced design the gambler's fallacy is not a fallacy.

The randomization used in the current experiment consists of the selection of a random clip from a pool of clips. The clip is not removed from the pool and hence the probabilities to select a winning or a loosing clip are, in principle, completely independent of the previous trials. We checked the actual produced sequences by looking at the autocorrelation of the condition sequence for all subjects with a lag from 1 to 10.

Only in one case we found a marginally significant correlation of 0.2 at a lag of 2.

Thus we believe that there is no discernable pattern in the actual condition sequences that could explain the fact that subjects brain signals correlate with a future condition.

To control if the subjects were using some pattern in the random sequence we compared the results for the first 64 trials of each subject with the last 64 trials. If the subjects do

learn and use what they learn to 'predict' the outcome of the slot machine then the effect should be larger in the second part of the 128 trials.

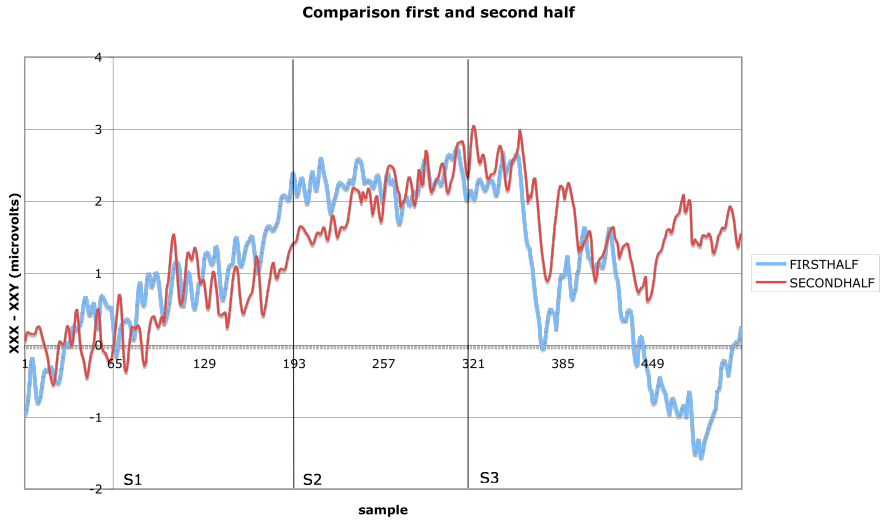


Figure x: The difference wave (XXX-XXY) for the first 64 trials and for the last 64 trials of the session, averaged over all subjects.

Figure x shows the mediofrontal EEG averaged over all subjects split for the first 64 (a) and last 64 trials (b). It is obvious that if there is any temporal effect it is a decline rather than an incline. We must conclude that the effect is not mediated by a mechanism mediated through learning.

Materials

The video clips were produced with the 'Adobe After Effect' package. This package uses layers that can be enabled or disabled. In one layer there is the spinning slot machine while in other layers the four different fruits on 3 positions are available. So basically all clips are identical only the enabling options are switched. This approach guarantees that all frozen fruits will always have the same positions.

In case there would be a difference the subject also need to learn those differences before he or she might use them. Therefore the test for learning of possible patterns in the randomization also tests for learning of differences in the material from which the final outcome could be inferred.

Exploratory Analyses

The exploratory analyses show a few relations that seem to make sense and therefore support the findings though not necessary the interpretation thereof. In the first place the relation with the sustained attention is quite impressive at least qualitatively. With 4 levels used in the assessment of the subject's attention the relation is marginally significant but if the lower half and the upper half are pooled the difference is quite significant (t=2.54, df=30, p = 0.016).

The relation of the effect with the belief of the subjects that they may be able to 'influence' the outcome of the slot machine is also remarkable. The three subjects claiming to be able to influence the slot machine do show a huge effect, so large that, even with their low number of 3, the interaction is significant.

Conclusion

It is good custom to await further replication if extraordinary claims are made. And indeed we are currently running two replications with other (student) experimenters. One of the two is a straightforward replications where some of the participants haven been tested in the current study, thus allowing for test-retest reliability assessment. The other study aims at comparing psi effects with implicit learning effects thus possibly extending the idea that intuition based upon implicitly acquired knowledge and psi based upon future knowledge are partly related.

Independent replications at other laboratories would add significant weight to the current findings. We suspect that in a number of cases these independent data are already available and just a new analysis of the old data is required.

The current results also add to the already significant body of experimental data where similar effects, apparently conflicting with forward causality, have been reported. These involve physiological variables like skin conductance, blood pressure, ECG and even BOLD. However it is far too early to conclude that these paradigms, often called presentiment effects, produce more robust data than other psi paradigms, although the consistent relations with personality and situational variables reported in this article do certainly increase the expectations. Results of the replications will be available at the conference.

References

Bechara, A., Tranel, D., Damasio, H., & Damasio, A. R. (1996). Failure to respond to anticipated future outcomes following damage to prefrontal cortex. *Cerebral cortex,* **6**-2, 215-225.

Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science*, **275**, 1293-1295.

Damasio, A.R. (1996). The Somatic Marker Hypothesis and the Possible Functions of the Prefrontal Cortex. *Philosophical transactions of the Royal society of London*. series B-biological sciences, **351**: (1346), 1413-1420.

Bierman, D.J. (2002) New developments in presentiment research on the nature of time. J. Fernandes & N.L.Santos (Eds). Proceedings of the second international symposium Frontiers of Science, Consciencias (Porto, Oct. 26-28, 2002)1, pp 89-124.CTEC, ISSN: 1645-6564

Bierman, D. J. & Radin, D. I. (1997). Anomalous anticipatory response on randomized future conditions. *Perceptual and Motor Skills*, 84, 689-690

Bierman, D. J. & Radin, D. I. (1998). Conscious and anomalous non-conscious emotional processes: A reversal of the arrow of time? *Toward a Science of Consciousness, Tucson III*. MIT Press, 1999, 367-386

Bierman, D. J. & Scholte, H. S. (2002). Anomalous anticipatory brain activation preceding exposure of emotional and neutral pictures. Paper presented at Toward a Science of Consciousness, Tucson IV

Bierman, D. J., Destrebecqz, A., Cleeremans, A. (2005).Intuitive Decision Making in Complex Situations: Somatic Markers in an Artificial Grammar Learning Task. pp. 297-305(9) *Cognitive, Affective, & Behavioral Neuroscience*, 5- 3, pp. 297-305(9)

Bechara, A., Tranel, D., Damasio, H., & Damasio, A. R. (1996). Failure to respond to anticipated future outcomes following damage to prefrontal cortex. *Cerebral cortex, Vol. 6 No. 2,* 215-225.

Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science, 275,* 1293-1295.

Brunia, C.H.M. (1999). Neural aspects of anticipatory behavior. *Acta Psychologica*, 101, 213-242.

Brunia, C.H.M., van Boxtel, G.J.M. (2001). Wait and see. *International Journal of Psychophysiology, 43*, 59-75.

Damasio, A.R. (1996). The Somatic Marker Hypothesis and the Possible Functions of the Prefrontal Cortex. *Philosophical transactions of the Royal society of London*. series B-biological sciences, **351**: (1346), 1413-1420.

Donkers, FCL & Boxtel, GJM Van (2005) Mediofrontal negativities to acverted Gains and losses in the Slot-Machine Task. *Journal of Psychophysiology*, **19** (4)

Donkers, FCL, Nieuwenhuis, S. & Boxtel, GJM van (2005) Mediofrontal negativities in the absence of responding.(2006). *Cognitive Brain Research*, In press.

Gratton, G., Coles, M.G.H., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology*, **55**, 468-484.

Deecke, L. (1987). Bereitschaftspotential as an indicator of movement preparation in supplementary motor area and motor cortex. In G. Bock (Ed.), Motor areas of the cerebral cortex : CIBA Symposium 132. London: Wiley.

Don NS, McDonough BE, Warren CA. (1998). Event-related brain potential (ERP) indicators of unconscious psi: A replication using subjects unselected for psi. *Journal of Parapsychology*, 62, 127–145.

Hartwell, J. W. (1978). Contingent negative variation as an index of precognitive information. *European Journal of Parapsychology*, 83-102.

Hartwell, J. W. (1978). An extension to the CNV study and an evaluation. *European Journal of Parapsychology*, xx-xxx.

Jasper, H. H. (1958). The ten-twenty electrode system of the International Federation, *Electroencephalography and Clinical Neurophysiology*, 10, 370-375.

Levin, J. & Kennedy, J. (1975). The relationship of slow cortical potentials to psi information in man. *Journal of Parapsychology*, *39*, 25-26.

May, E. C., Paulinyi, T., & Vassy, Z. (2005). Anomalous anticipatory skin conductance response to acoustic stimuli: Experimental results and speculation about a mechanism. *Journal of Alternative and Complementary Medicine, 11*, 695-702.

McCraty, R, Atkinson, M. & Bradley, R.T. (2004a). Electrophysiological evidence of intuition: Part 1. The Surprising role of the heart. *Journal of Alternative and Complementary Medicine, 10*, 133–143

McCraty, R, Atkinson, M. & Bradley, R.T. (2004b). Electrophysiological evidence of intuition: Part 2. A system-wide process? *Journal of Alternative and Complementary Medicine, 10*, 325–336

McDonough, B. E., Don, N. S., & Warren, C. A. (2002). Differential event-related potentials to targets and decoys in a guessing task. *Journal of Scientific Exploration, 16*, 187-206.

Morris, M.S., Thorne, K.S. , and Yurtsever, U. (1988).Wormholes, Time Machines, and the Weak Energy Condition, *Phys*. *Rev*. *Lett*. **61**, 1446–1449

Price, H. (1996). Time's arrow and Archimedes' point: New directions for the hysics of Time. Oxford University Press, ISBN 0-19-510095-6.

Radin, D. I. (1997). Unconscious perception of future emotions: An experiment in presentiment. *Journal of Scientific Exploration*, *11*, 163–180.

Radin, D. I. (2004). Electrodermal presentiments of future emotions. *Journal of Scientific Exploration. 18*, 253-274.

Rosenthal, R (2002). Covert communication in classrooms, clinics, courtrooms, and cubicles. *American Psychologist, 57*, 839-849.

Spottiswoode S. J. P. & May E. C. (2003). Skin conductance prestimulus response: Analyses, artifacts and a pilot study. *Journal of Scientific Exploration, 17*, 617–641.

Smith, M. (1998) THESIS

Tegmark, M. (2003). Parallel universes. In eds. J.D. Barrow, P.C.W. Davies & C. Harper (Eds.), *Science and Ultimate Reality*, Cambridge University Press.

Trillenberga, P., Verlegera, R., Wascherc, E., Wauschkuhna, B. & Wessela, K. (2000). CNV and temporal uncertainty with "ageing" and "non-ageing" S1— S2 intervals. *Clinical Neurophysiology, 111*, 1216-1226.

van Boxtel, G. J. M. & Böcker, K. B. E. (2004). Cortical measures of anticipation. *Journal of Psychophysiology, 18*, 61–76.

Walter, W. G., Cooper, R., Aldridge, V. J., McCallum, W. C., & Winter, A. L. (1964). Contingent negative variation: An electric sign of sensorimotor association and expectancy in the human brain. *Nature, 203*, 380–384.

Warren, C. A., McDonough, B. W., & Don, N. S. (1992). Event-related brain potential changes in a psi task. *Journal of Parapsychology*, *56,* 1-30.

Appendix A
THE GAMBLING BRAIN - Instructie

In dit experiment meten we de fysiologische reacties van mensen die met de fruitmachine spelen.

U start met een saldo van zeven munten. Deze worden door de proefleider voorgeschoten uit uw beloning voor uw medewerking. U betaalt steeds een munt voor een spel. Bij winst ontvangt u zeven munten. Drie gelijke vruchten betekent winst.

Het spelen met de fruitmachine is geheel op toeval gebaseerd. Dat wil zeggen dat niemand weet wat de uitkomst is, ook wij niet.

Het experiment begint met een demo (oefentrial) ter introductie. Hierna volgt een korte 'cooldown' periode waarin u zich kunt ontspannen. Daarna speelt u in totaal 128 trials. U kunt de fruitmachine steeds zelf starten door op een knop van het toetsenbord te klikken.

Als u nog vragen heeft, wilt u die dan nu aan de proefleider stellen?

Succes!