Pre-stimuli reaction of heart rate frequencies: retrocausality and learning

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Abstract

The experimental design used in the experiment described in this paper allows to distinguish anticipatory effects due to learning from anticipatory effects due to retrocausality:

- Differences in heart rate frequencies observed in phase 1, in association with unpredictable random selections operated by the computer in phase 3 can be attributed only to a retrocausal effect, as a consequence of the fact that future selections are unpredictable.
- Differences in heart rate frequencies observed in phase 1, in association with the choice operated by the subject in phase 2, can be interpreted as learning effects.

The fourth experiment uses the same sequence of colours as the first experiment, but in the third phase one colour has a 35% chance of being extracted (lucky colour), one has a 15% chance of being extracted (unlucky colour) and the last two colours have a 25% chance of being extracted (neutral colours). The task given to the subjects is to guess the highest number of colours selected by the computer (target). Subjects are not informed about the fact that colours have a different chance of being extracted.

Experimental hypotheses

Hypotheses of this experiment are the following:

1. *Retrocausal hypothesis:* statistical significant differences in heart rate measured in phase 1 are expected in association with targets (colours extracted by the computer, according to a random procedure, in phase 3) and non targets (colours not extracted by the computer in phase 3). These differences will be interpreted as retrocausal effects, considering the fact that the information associated with the colours (target or non target) is totally unpredictable during the measurement of heart rates in phase 1.
2. *Learning hypothesis:* according to the works of Damasio and Bechara (1994) a learning effect is expected in the form of heart rate differences measured in phase 1 in association with the choice (lucky and unlucky) operated by the subject in phase 2; these differences should increase during the conduct of the experiment.
3. *Interaction between retrocausal and learning effect:* the retrocausal effect and the learning effect are both assessed through heart rates; the first tests operated during the development of the software used for this experiment showed that the two effects interacted in the form of an inhibition of the retrocausal effect by the learning effect.

The hypothesis of a possible interaction emerged during the development of the software developed for the conduct of the experiment. Subjects who were involved in previous experiments described (spontaneously) a “butterfly” feeling in the stomach in association with stimuli in phase 1 which would be selected by the computer in phase 3, similar to what Damasio described as a somatic marker; in the tests carried out before starting this new experimental design this feeling, this somatic marker, was not reported and the retrocausal effect showed with less strength. This new element suggested the possibility of an interaction between the retrocausal and learning effect.

The experimental design

The same design of the first experiment has been used. The only change is the different extraction probability for each colour in phase 3: one colour has a 35% chance to be extracted and is therefore the lucky colour, another colour has a 15% chance to be extracted and it is therefore the unlucky colour, the last two colours have a 25% chance to be extracted and are therefore neutral colours.

Phase 1 *Presentation of stimuli and measurement of heart rate*				**Phase 2** *Choice*	**Phase 3** *Random selection*
Blue	Green	Red	Yellow	Blue/Green/Red/Yellow	Red
Non target	***Non target***	***Target***	***Non target***		***Target***
4 seconds HR01 HR02 HR03 HR04	*4 seconds* HR01 HR02 HR03 HR04	*4 seconds* HR01 HR02 HR03 HR04	*4 seconds* HR01 HR02 HR03 HR04		***Feedback***

Tab. 1 – Phases of an experimental trial:

1. *colours are presented on full screen for exactly 4 seconds and the heart rate is measured each second;*
2. *the experimental subject chooses one of the colours trying to guess the colour which will be chosen by the computer;*
3. *the computer selects, using a random algorithm, one of the 4 colours (target) and shows it in full screen (feedback).*

From a software perspective the different chance of extraction was obtained extracting a number from 1 to 100. When the number was:

- between 1 and 35 the lucky colour was selected;
- between 36 and 50 the unlucky colour was selected;
- between 51 and 75 the first neutral colour was selected;
- between 76 and 100 the last neutral colour was selected.

The same number can be extracted again, making each extraction totally independent from the preceding one. This algorithm leads to the extraction of lucky, unlucky and neutral colours in a proportion which does not coincide exactly with their probability of extraction. For example in the

3,000 trials of this experiment (30 subjects, 100 trials per subject) the lucky colour was selected 36.15% times, the unlucky colour 14.13% and the neutral colours 24.86%.

Carrying out of the experiment

The experiment was conducted in the period March/April 2009 by a student of Professor Enrico Di Pace. The sample was of 30 subjects. The instructions given to the student of Professor Di Pace were the following:

1. inform the subject about the total duration of the experiment (around 40 minutes);
2. choose a quite room, where the subject could be left alone for all the length of the experiment;
3. start the recording of the heart rate frequency only after it has stabilized. Initially, heart rate frequency is altered because of the movements that the subject made in order to apply the heart rate measuring device. Generally speaking the stabilization of the heart rate parameter requires less than a minute from when the subject sits in front of the computer for the duration of the experiment;
4. inform the subject about the task: try to guess the highest number of colours selected by the computer;
5. begin the experiment only after starting to record the heart rate frequency;
6. follow the subject for the first trial, in order to check that he has understood the task;
7. leave the subject alone in the room where the experiment is carried out.

At the end of each experiment the student forwarded the following 2 files, by e-mail, to the experimenter:

1. the file with heart rate frequencies, produced by the software Training Monitor 2.2.0 of SUUNTO. In this file heart rate measurements are associated with the time of the measurement;
2. the file produced by the software developed in Delphi Pascal for the execution of the experiment. This file contains the exact time of presentation of stimuli (in milliseconds), exactly synchronized with the beginning of the second, the choice operated by the subject and the selection operated by the computer, associated with the characteristics of the stimuli.

As soon as the files were received, a control data analysis was performed, in order to give a feedback to the student carrying out the experiment and in order to assess if the retrocausal effect was visible (table 2).

Example of feed-back table									
Subject n. 21					Subject n. 7				
	Blue	Green	Red	Yellow		Blue	Green	Red	Yellow
HR 1:	-0.671	2.200	-0.840	-1.103	HR 1:	0.276	-0.775	0.040	0.378
HR 2:	-0.772	2.399	-0.556	-1.471	HR 2:	0.231	-0.750	0.133	0.298
HR 3:	-0.950	2.467	-0.056	-1.766	HR 3:	0.210	-0.862	0.173	0.414
HR 4:	-1.353	2.310	1.080	-2.054	HR 4:	0.150	-0.913	0.187	0.560
HR 5:	-1.928	2.204	1.894	-1.892	HR 5:	0.117	-0.850	0.187	0.545
HR 6:	-1.954	1.897	2.474	-1.993	HR 6:	0.048	-0.875	0.227	0.640
HR 7:	-1.982	1.535	2.752	-1.755	HR 7:	-0.067	-0.688	0.320	0.491
HR 8:	-2.015	1.543	2.733	-1.704	HR 8:	-0.077	-0.763	0.373	0.524
HR 9:	-1.831	1.397	2.665	-1.704	HR 9:	-0.129	-0.712	0.427	0.482
HR 10:	-1.770	1.508	2.407	-1.691	HR 10:	-0.109	-0.700	0.467	0.375
HR 11:	-1.482	1.468	1.981	-1.641	HR 11:	-0.174	-0.625	0.467	0.402
HR 12:	-1.458	1.853	1.404	-1.637	HR 12:	-0.249	-0.650	0.600	0.378
HR 13:	-1.572	2.154	1.199	-1.679	HR 13:	-0.259	-0.625	0.573	0.402
HR 14:	-1.544	2.079	1.260	-1.676	HR 14:	-0.296	-0.525	0.573	0.348
HR 15:	-1.452	1.994	1.226	-1.661	HR 15:	-0.283	-0.513	0.507	0.405
HR 16:	-1.311	1.727	1.255	-1.541	HR 16:	-0.220	-0.525	0.413	0.438
General total: 83.764					General total: 0.000				

Tab. 2 – Table of heart rate mean values differences in phase 1 according to the choice operated by the computer in phase 3. Each line, indicated with HR (Heart Rate), corresponds to one of the 16 heart rate frequencies measured in phase 1, each experiment is formed by 100 trials and for each subject 100 measurements are therefore available for HR 1, HR 2, and so on. It is therefore possible to calculate the mean value when the blue, green, red and yellow colours are target and non target, for each HR. Low values in the difference between these mean values indicate the absence of the retrocausal effect, while high values indicate the presence of the retrocausal effect. In these two examples high values are observed for subject 21 and low values are observed for subject 7. As a cut off point the value of 1.5 was chosen, which according to random distributions should be observed in less than 1% of the differences.

The feedback was given in the form of a table which briefly showed which were the effects observed for each subject. In table 2 an example is shown for subject n. 21 and subject n. 7. These feedback tables consist of 16 lines, one for each of the 16 heart rate frequencies measured in phase 1 of the experiment. Phase 1 is repeated 100 times. It is therefore possible to calculate 16 mean values for each colour when it is target and for each colour when it is non target. The differences in these mean value provide a feedback telling if the retrocausal effect was visible and how strong it was. In the feedback table only the values of the differences between mean values when the colour is target and when the

colour is non target are shown. For example, for subject n. 21, in the first line (HR 1), it is possible to read that the mean value of the heart rate frequencies in phase 1, when the target is blue (when the computer selects the blue colour in phase 3) compared to when the blue is not a target is lower by 0,671 heart beats. The second line is relative to the second heart rate frequency measured during phase 1 and its value for the blue colour, when target, is -0,772 heart beats per minute

The retrocausal effect is observed as differences between the mean values of heart rate frequencies measured in phase 1 in association with the colour selected by the computer in phase 3. In table 2 only values over 1.5 are considered, since these values usually are reached with probabilities inferior to 0.01 ($p<0.01$). The greater the difference between mean values (both positive and negative), the greater is the retrocausal effect. At the bottom of the table is a total value of difference, calculated considering the absolute values (without negative signs) above the value 1.5. In this way, causal fluctuation of data are removed from the general total. Table 2 shows a general total of 83,764, for subject n. 21 and a general total equal to zero for subject n. 7.

The feedback table was sent to the student conducting the experiments in order to control situations which could reduce the retrocausal effect. In the first 7 subjects the effect was practically null: 4 subjects showed a general total equal to zero and 4 inferior to 15. The experiment was being conducted on an old laptop computer with a low brightness of the display. This problem had been noted and discussed at the beginning of the experiment and, because of the lack of effect in the first 7 subjects, it was decided to change computer with a new laptop with brighter colours. Once this change was made, a sudden increase in the values of the effect in the feedback tables was observed. On a total of 23 subjects, who conducted the experiment using the new computer, 16 showed general values of the effect over 15, 3 lower than 15 and 5 equal to zero. The number of subjects who did not show an effect changed from 57% with the old computer to 21% with the new computer.

In the last block of 23 subjects, analyzing the conditions associated with the 5 subjects who scored a general total equal to zero, low attention and noises seemed to have reduced the retrocausal effect.

The importance of a luminous display, of bright and brilliant colours and the absence of situations which could reduce the level of attention of the subject are conclusions which have been achieved in a

non systematic way, just for the purpose of optimizing the results of the experiment. These observations could constitute the basis for future experiments aimed at specifying in a more precise form the conditions which need to be satisfied in order to observe the retrocausal effect.

Effect: direction and addition

When the general total of table 2 is calculated, adding the real values (with the sign) and not the absolute value (without the sign), the total tends to zero. A similar situation was observed in the first experiment: when the comparison between target and non target is performed. Considering all the heart rate frequencies, no significant differences are observed, whereas when the comparison is performed within each colour differences become strong and statistically significant. It was also noted, that subjects show strong and statistically significant effects, but in opposite directions. In the sample of the first experiment the group in which heart rate frequencies increase when the blue colour is target was predominant. In this fourth experiment the group in which heart rate frequencies decrease is predominant.

The fact that the direction of the effects can be opposite and that when added together effects of single subjects subtract from effects observed in other subjects, leads to the impossibility of using correctly any statistical technique which adds effects together. Techniques such as t of Student and ANOVA are therefore not suitable for an analysis of this kind of data.

In neuropsychology and cognitive psychology effects are not additive, since they are not directional. In the experiments discussed in this work the direction of the effect is considered to depend on individual factors, for example subjects can react differently to colours according to the emotions which they associate with each colour. Non directional effects cannot be added, and as a consequence it is not legitimate to use parametric techniques. The problem can be summarized saying that when addition or subtraction are used effects need to be directional. In order to analyze correctly the data produced by these experiments it becomes therefore necessary to use techniques which do not require addition and subtraction of data. Techniques of this type are all those which are based on the production of frequency distributions. For this reason, in this last experiment, data analysis will be carried out using

non parametric statistical techniques, based on the analysis of frequency distributions. Statistical significance will be calculated using the Chi Square (χ^2) and exact test of Fisher.

When the effect is not directional, the use of ANOVA and t of Students lead to Type II errors in which the hypothesis H_1 is refused when it is true. Extreme values in the data set can also lead to Type I errors: accepting H_1 when the hypothesis is not true. Data analysis performed using frequency distributions (Chi Square) reduces this risk, as a consequence of the fact that all the values in the classes have the same weight, a fact which prevents extreme values from producing accidental statistical significances. The use of Chi Square reduces in this way the risk of Type I and II errors and, because it is a non parametric technique, it does not require difficult conditions such as homoscedasticity, Gaussian distribution of data and population, quantitative data and additive effects.

Data set

In order to study the retrocausal effect, statistical data analyses have been carried out on feedback tables of which an example is in table 2. Feedback tables have been calculated for each subject. Each value of a feedback table is associated with a colour, a position of the HR in the trial, the number of the subject and the group of the trial. Trials were divided into 3 groups: the first 33 trials (starting from the second trial) the central 33 trials and the last 33 trials[1].

In order to study the learning effect, the analyses have been conducted studying how the differences of the mean values of the heart rates are distributed in association with the choice operated by the subject (in phase 2). It was decided to name these tables "choice tables". Choice tables were calculated for each subject, for each group of trial (first 33 trials, central 33 trials and last 33 trials) and are relative to each of the 16 HR measured in phase 1. The difference of the mean HR values is calculated in association with the choice (lucky, unlucky and neutral) operated by the subject in phase 2.

In table 3 it is possible to see an example of a "choice table". This example is relative to subject n. 20

and shows how differences in the mean values of HR increase when the first 33 trials are considered and when the last 33 trials are considered.

Looking at the choice tables of different subjects it is possible to note totally different configurations and it becomes clear that data is non additive.

Differences in heart rate mean values measured in phase 1 in association with the choice operated by the subject in phase 2							
Subject 20 – first 33 trials				Subject 20 – last 33 trials			
Choice:	Neutral	Lucky	Unlucky	Choice:	Neutral	Lucky	Unlucky
HR 1:	-1.857	1.597	0.800	HR 1:	-0.202	3.143	-1.591
HR 2:	-1.790	1.472	0.845	HR 2:	1.136	2.507	-2.727
HR 3:	-1.070	0.722	0.675	HR 3:	1.283	2.300	-2.773
HR 4:	-0.412	0.167	0.380	HR 4:	1.577	2.121	-3.000
HR 5:	-0.055	0.181	-0.120	HR 5:	1.375	1.729	-2.545
HR 6:	0.283	0.306	-0.715	HR 6:	1.515	0.907	-2.227
HR 7:	0.577	0.056	-0.845	HR 7:	1.768	0.414	-2.227
HR 8:	0.706	0.194	-1.170	HR 8:	1.783	-0.479	-1.727
HR 9:	0.044	1.139	-1.290	HR 9:	1.669	-0.807	-1.409
HR 10:	-0.673	1.194	-0.375	HR 10:	1.915	-1.443	-1.318
HR 11:	-1.033	0.958	0.370	HR 11:	2.353	-2.136	-1.409
HR 12:	-0.912	0.500	0.700	HR 12:	2.599	-3.243	-1.045
HR 13:	-0.790	0.042	1.030	HR 13:	3.206	-3.714	-1.455
HR 14:	-0.614	-0.139	0.985	HR 14:	3.801	-4.871	-1.455
HR 15:	-0.070	-0.403	0.530	HR 15:	3.423	-4.921	-1.000
HR 16:	0.713	-0.736	-0.175	HR 16:	2.941	-4.143	-0.909
General total:	5.244			General total:	128.018		

Tab. 3 – Example of a "choice table". Differences between mean values of heart rate (HR) values measured in phase 1 associated with the choice operated by the subject in phase 2. In this table the 16 HR lines indicate the 16 HR measured in phase 1. Each session is made of 100 trials, there are therefore 100 HR1, HR2, HR3,… measurements for each subject. It is therefore possible, for each subject to calculate the differences of the mean values according to the choice that the subject operates in phase 2: neutral, lucky and unlucky. Low values tell that no learning effect is observed, high values tell that an effect is observed. In this example the same subject is compared at the beginning of the experiment (first 33 trials) and at the end (last 33 trials).

[1] The first trial was removed from data analyses because it was conducted with the presence of the experimenter. Consequently, data analyses have been conducted on the remaining 99 trials: from the 2nd to the 100th trial.

The retrocausal effect

It is important to say that having divided the feedback tables in 3 groups (first 33 trials, central 33 trials and last 33 trials), the value 1.5 of the difference between mean values does not correspond anymore to the statistical significance of 1% ($p<0.01$), because mean values are calculated on too small a number of trials (33). For this reason it was not possible to use the "theoretical" value 1% as a value of expected frequencies for the calculation of the Chi Square. In order to have a value of expected frequencies it was decided, therefore, to obtained it in an "empirical" way, producing the analogous of feedback tables using *non correlated targets* (NCT): targets which are not correlated with the selection operated by the computer in phase 3. Experimenting with NCT it was decided to opt for NCT which were produced using loops in which, for example, the first target was blue, the second green, the third red and the fourth yellow and repeating this sequence for all the 100 trials. This choice was made according to the following considerations:

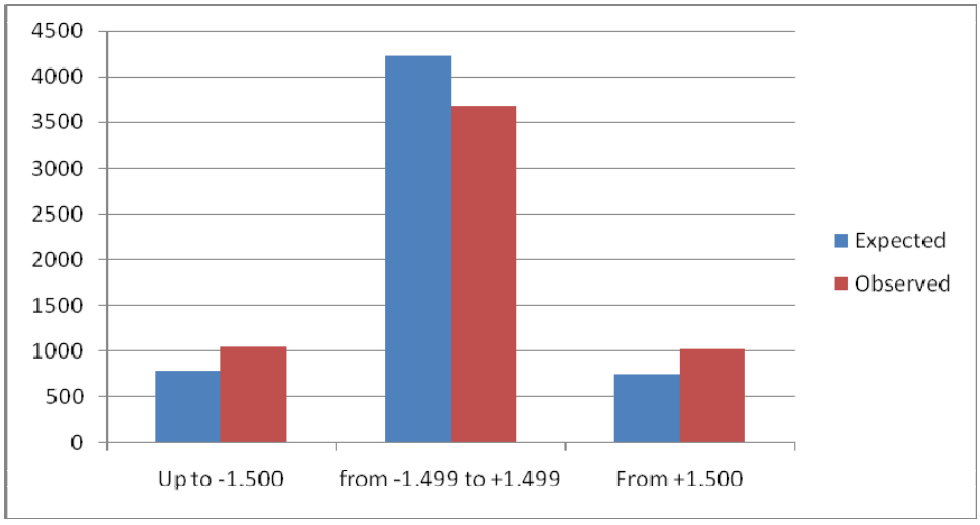
- The use of non correlated targets generated randomly (and not with a loop, as was done in this analysis), leads to frequency distributions which vary and which require that the experimenter makes a subjective choice among different possible distributions. The experimenter could, at this stage, orient the results choosing the distribution which is more convenient in order to obtain statistically significant results. This is avoided choosing a loop, which is not correlated, and which does not require the experimenter to operate a choice.
- The random selection of targets operated by the computer in phase 3 is not correlated (by definition) with the sequence of colours in phase 1. Consequently choosing the sequence of colours in phase 1 (as target colours) will not be correlated with the targets selected by the computer in phase 3 of the experiment, and would therefore be suitable for the calculation of expected frequencies.
- Using a loop each colour would be selected exactly 25% of the times, which is the percentage expected in the absence of an effect.
- As was discussed in chapter 5, the computer always uses the same random sequence (and for this reason it is named *pseudorandom*). In the experiments this sequence was turned into a random sequence interrogating the inner clock of the computer using unpredictable intervals thanks to the

reaction times of subjects in phase 2. As a consequence, using the random sequence of the computer in order to generate an uncorrelated sequence which was produced using the same random sequence, can result in a *bias* represented by a potential correlation (even though only theoretical) with the sequence produced by the computer during the execution of the experiment.

Using the loop of 4 colours, in order to generate NCT, table 4 is obtained.

Frequencies	***Differences of the mean values***			***Total***
	Up to -1.500	**-1.499 to +1.499**	**+1.500 and over**	
Observed	1053 (17.83%)	3680 (63.89%)	1027 (18.28%)	5760 (100%)
Expected	781 (13.56%)	4225 (73.35%)	754 (13.09%)	5760 (100%)

Tab. 4 – Observed and expected frequencies in the distribution of mean differences of HR, measured in phase 1 in association with the selection operated by the computer in phase 3 (see table 2). Chi Square = 263.86. Values of Chi Square (df 2) more than 13.81 correspond to p<0.001



Tab. 5 – Observed and expected frequencies in the distribution of mean differences of HR measurements in phase 1 in association with the choice of the computer operated in phase 3 (see table 2). Chi Square = 263.86 (p<0.001 from Chi Square values of 13.81 – gf 2)

Graph in table 5 shows the observed and expected frequencies of table 4. In the first group, on the left, differences up to -1.5 are associated with an observed frequency of 17.83% and expected frequency of 13.56%; in the central class (from -1.499 to +1.499) the observed frequency is 63.89% compared to an expected frequency of 73.35%; in the last class, on the right, the observed frequency is 18.28%, the

expected frequency is 13.09%.

The difference between observed and expected frequencies is equal to a Chi Square of 263.86 which, compared to 13.81 for a statistical significance of $p<0.001$, results to be extremely significant. It was not possible to use the exact test of Fisher as this test can be applied only on 2x2 tables.

How the retrocausal effect is distributed on colours

The fact that the retrocausal effect emerged on some colours and not others, and that it changed in a random way from one experiment to the other, was among the unexplained results of the previous experiments. In order to test the idea that all this confusion could be a consequence of the statistical techniques used in the first 3 experiments, in this last experiment the Chi Square technique is used. Chi Square shows the retrocausal effect on all the colours. The reason why on some colours the retrocausal effect was not observed is explained by the fact that in some colours (for example the yellow and red colour in the first experiment) the effect in the form of positive differences and the effect in the form of negative differences was balanced. Consequently, in a general analysis, opposite effects were simply cancelling each other out and annulling the result.

Table 6 allows to assess if the differences of the retrocausal effect among colours is statistically significant (compared to non correlated targets NCT) and if the effect is unbalanced. For example for the blue colour it is possible to observe 14% of differences over +1.5 compared to 13.09% expected according to the technique of the non correlated targets (NCT).

Differences	**Colours**				**Total**	**N.C.T.**
	Blue	**Green**	**Red**	**Yellow**		
From + 1.500	14.0%	22.0%	19.6%	15.7%	17.8%	13.09%
-1.499 to +1.499	60.7%	64.9%	64.6%	65.3%	63.9%	73.35%
Up to -1.500	25.3%	13.1%	15.8%	19.0%	18.3%	13.56%
	100% (n=1,440)	100% (n=1,440)	100% (n=1,440)	100% (n=1,440)	100% (n=5,760)	100.00%

Tab. 6 – Distribution of the differences of HR mean values (phase 1) associated with the selection operated by the computer (phase 3).

In table 7 the distribution of the blue colour is compared with the expected distribution (NCT). This

table allows to calculate the retrocausal effect on the blue colour. The Chi Square value of table 7 is 176.41 equivalent to $p<1/10^{27}$, where $/10^{27}$ indicates that before the number one 27 zeros need to be inserted. For tables with 2 degrees of freedom Chi Square values with a probability of 1/1000 start from 13.81.

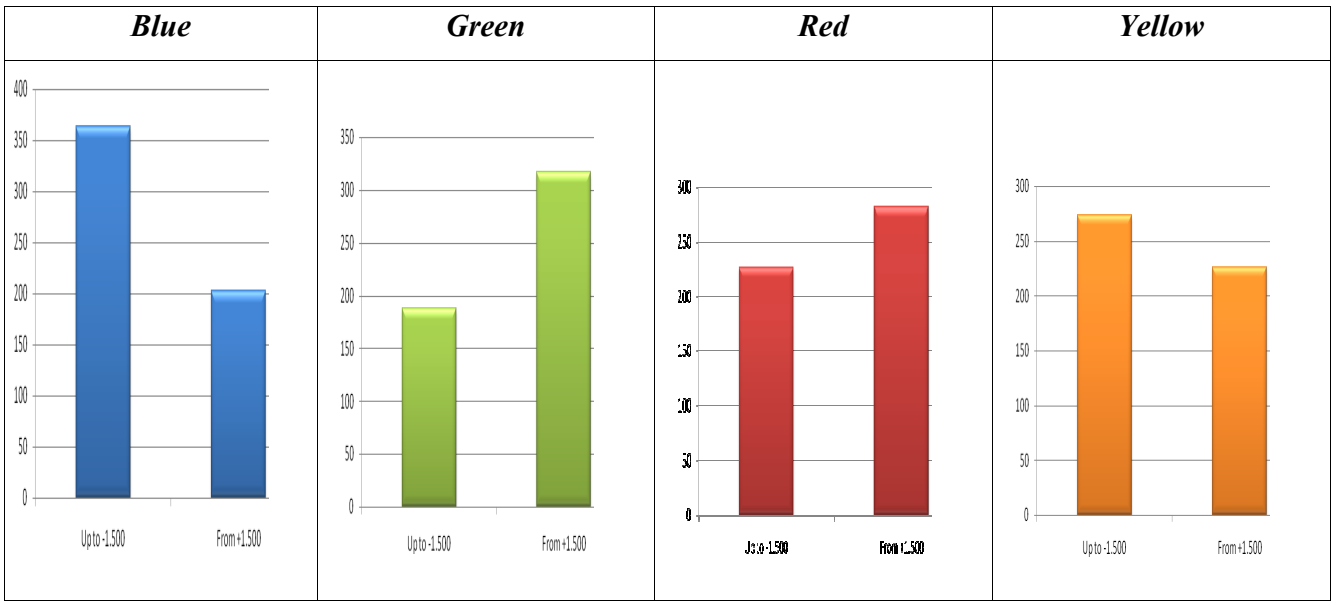
Frequencies	***Differences for the blue colour***			***Total***
	Up to -1,500	**-1.499 to +1.499**	**From 1.500**	
Observed	364 (25.3%)	874 (60.7%)	202 (14.0%)	1440 (100%)
Expected	196 (13.6%)	1056 (73.3%)	188 (13.1%)	1440 (100%)

Tab. 7 – Observed and expected frequencies in the distribution of differences in the HR means associated with the selection of the blue colour in phase 3 (see table 2). Chi Square value = 176.41. Values of Chi Square (df 2) over 13.81 correspond to p<0.001. Chi Square of 176,41 is equivalent to an estimated value of $p<1/10^{27}$*, where* $/10^{27}$ *indicates that before the number one 27 zeros have to be inserted.*

On the green colour the retrocausal effect is associated with a Chi Square value of 102.7.

Frequencies	***Differences for the green colour***			***Total***
	Up to -1,500	**-1,499 to +1,499**	**From 1.500**	
Observed	188 (13.1%)	935 (64.9%)	317(22.0%)	1440 (100%)
Expected	196 (13.6%)	1056 (73.3%)	188 (13.1%)	1440 (100%)

Tab. 8 – Observed and expected frequencies in the distribution of differences in the HR means associated with the selection of the green colour in phase 3 (see table 2). Chi Square value = 102.7. Values of Chi Square (df 2) over 13.81 correspond to p<0.001.



Tab. 9 – Comparison of positive differences of HR and negative differences. Whilst on the blue colour the effect prevalently takes the form of an increase in HR, on the green colour it takes the form of a decrease in the HR. For red and yellow the effect is distributed in a balanced way between subjects who show an increase in HR and subjects who show a decrease in HR, becoming therefore invisible to the t of Student and ANOVA.

Table 9 shows that for the blue and green colours the retrocausal effect is unbalanced, in more subjects the HR decreases when the target is blue, in more subjects it increases when the target is green. This unbalanced distribution of the positive and negative side of the effect permits to see the effect when using t of Student and ANOVA, but in a less significant way than when using Chi Square. Comparing the data of the first experiment, the unbalanced effects on the blue and green colours are exactly opposite. In the case of the red and yellow colours, the negative side and positive side of the effect are balanced and become therefore invisible to t of Student and ANOVA as they cancel each other out. The prevalence of one side of the effect is totally accidental and this fact explains why the effect on colours showed in a random way in the first 3 experiments.

In table 10 and 11 the observed and expected frequencies are compared for the red and yellow colours and show retrocausal effects with Chi Square 60.82 for the red colour and 56.67 for the yellow colour. Statistical significance or 1/1000 starts from Chi Square values of 13.81.

Frequencies	*Differences for the red colour*			*Total*
	Up to -1.500	**-1.499 to +1.499**	**From 1.500**	
Observed	282 (15.8%)	931 (64.6%)	227(19.6%)	1440 (100%)
Expected	196 (13.6%)	1056 (73.3%)	188 (13.1%)	1440 (100%)

Tab. 10 – Observed and expected frequencies in the distribution of differences in the HR means associated with the selection of the red colour in phase 3 (see table 2). Chi Square value = 60.62. Values of Chi Square (df 2) over 13.81 correspond to p<0.001.

Frequencies	*Differences for the yellow colour*			*Total*
	Up to -1.500	**-1.499 to +1.499**	**From 1.500**	
Observed	274 (19.0%)	940 (65.3%)	226 (15.7%)	1440 (100%)
Expected	196 (13.6%)	1056 (73.3%)	188 (13.1%)	1440 (100%)

Tab. 11 – Observed and expected frequencies in the distribution of differences in the HR means associated with the selection of the yellow colour in phase 3 (see table 2). Chi Square value = 56.67. Values of Chi Square (df 2) over 13.81 correspond to p<0.001.

Going back to the general table (table 6) it is possible to read in the column relative to the blue colour that 25.3% of the differences happen as a negative effect, whereas for the green colour it is 13.1%, for the red colour 15.8% and for the yellow colour 18.3%. The non correlated target gives an expected value of 13.56%. In order to use Fisher's exact test the table is transformed in the 2x2 formats (example in table 12) where only one cell is compared with all the rest. For example, in table 12 the class "up to -1.500" for the blue colour is compared with the rest of the data.

Differences	**Blue**	**Other colours**	**Total**
Up to -1.500	364 (25.3%)	689 (15.9%)	1053 (18.3%)
Other	1076 (74.7%)	3631 (84.1%)	4707 (81.7%)
Total	1440 (100%)	4320 (100%)	5760 (100%)

Tab. 12 – The negative mean differences of HR for the blue colour are compared with all the other data using this 2x2 table. The use of 2x2 tables allows the use of Fisher's exact test. For this table the Chi Square value is 62.91 and the exact probability calculated with Fisher's exact test is $p=0,40/10^{14}$.

The difference between observed and expected frequencies for the blue colour corresponds to a Chi Square of 62.91 which, according to the exact test of Fisher is equal to a probability of $p=0,4/10^{14}$, that is to say a probability of error of p=0.000000000000004. It is important to note that in this way the statistical significance of the effect has been calculated without using the non correlate targets (NCT), but using only the total of the 2x2 tables. As it has already been said, this does not mean that the effect

is unbalanced on the blue, but it means that in the composition of the sample there was a greater number of subjects which presented the effect on the blue colour as a decrease in heart rate values when the blue was target. It was already noted that in the first experiment the effect emerged in the opposite direction.

When the effect is calculated using the non correlated target distributions the effect appears on all the colours and with strong values. For example, on the blue colour it appeared with $p<1/10^{27}$. Using the totals of the 2x2 table, in order to estimate the expected distributions, the Chi Square value diminishes to $p=0,4/10^{14}$ as a consequence of the fact that only one side of the effect was considered. Using the technique of 2x2 tables the effect observed for the green colour is equal to p=0.00000055.

When using 2x2 tables Chi Square reaches 5% statistical significance with values of 3.84 or greater: 1% significance with values equal or greater than 6.64, and 1/1000 significance with values equal or greater than 10.83.

Learning effect

According to the learning hypothesis, the choice of the subject is preceded by the activation of neurophysiological parameters of the autonomic nervous system (Damasio, 1994) such as skin conductance and heart rate frequencies. In this experiment it is expected to see the activation of the heart rate frequency in the last trials of the experiment, as a consequence of the fact that as this is a learning effect it requires a certain number of trials.

Differences	**Colour chosen by the subject**			**Total**	**N.C.T.**
	Neutral	**Lucky**	**Unlucky**		
From + 1.500	14.0%	16.6%	17.2%	16.0%	13.1%
- 1,499 to +1,499	73.5%	66.0%	66.0%	68.5%	73.3%
Up to -1,500	12.5%	17.4%	16.8%	15.5%	13.6%
	100% (n=1,440)	100% (n=1,440)	100% (n=1,440)	100% (n=4,320)	100.0%

Tab. 13 – Distribution of HR differences (phase 1) in association with the colour chosen by the subject in phase 2. This table was calculate considering all the subjects and all the trials.

In this section data analysis is performed on choice tables (see table 3), which are those tables which link differences observed in the heart rate means measured in phase 1 with the choice performed by the subject in phase 2.

Table 13 shows the distribution of the differences of the choice tables divided into neutral, lucky and unlucky colours. The class "from +1.5" indicates positive differences, whereas the class "up to -1.5" indicates negative differences, and the intermediate class indicates the absence of differences. Data is expressed in the form of column percentages.

Before the choice of neutral colours the observed frequencies coincide exactly with the expected ones (73.5% compared to 73.3 expected according to non correlated targets: NCT), whereas for the lucky and unlucky colours it is possible to observe a difference between observed frequencies and expected ones. This difference is associated with a Chi Square of 39.15 ($p<1/10^9$) which shows the existence of a learning effect.

The subject can choose among four colours of which two are perfectly random and are therefore named "neutral colours", one is lucky and one is unlucky. At the beginning of the experiment the participants are informed that the selection of colours is perfectly random. During the execution of the experiment the subject should learn, according to the hypothesis, the different probabilities of extraction and this would show in the form of a different activation of heart rate frequencies in phase 1 which precede the choice operated by the subject in phase 2.

Differences (*absolute values*)	**Trial**			**Total**	**N.C.T.**
	2-34	**35-67**	**68-100**		
Up to 1.499	69.4%	73.8%	62.3%	68.5%	73.3%
From 1,500	30.6%	26.2%	37.7%	31.5%	26.7%
	100% (n=1,440)	100% (n=1,440)	100% (n=1,440)	100% (n=4,320)	100.0%

Tab. 14 – Distribution of mean differences of HR measured in phase 1 according to the choice operated by the subject in phase 2, divided for group of trials.

The computer selects which are the lucky, unlucky and neutral colours at the beginning of the experiment, using a random procedure. No one during the execution of the experiment knows which

are the lucky and unlucky colours, only at the end of the experiment this information is saved in the data file and can be known. The hypothesis is that the effect should increase while the experiment progresses and that it should be particularly strong in the last trials.

Table 14 shows that already in the first 33 trials (compared with the NTC distribution) Chi Square is 11,53, just over 1/1000 of statistical significance. In the middle 33 trials distribution coincides with the expected NTC distribution and therefore no effect is observed. In the last 33 trials the distribution differs significantly from the expected one. Chi Square is 89,77 which corresponds to $p<1/10^{22}$. These results show that especially in the last part of the experiment the learning effect results extremely significant.

The difference of HR over 1.5 are 30.6% in the first 33 trials, they drop down to 26.2% and go back up to 37.7% in the last trials. In the case of no effect the expected value is 26,7%. The effect can be seen using both the NCT criteria and the totals of the 2x2 table. In this last case the difference between observed and expected frequencies results in a Chi Square value of 44.01 ($p<0.23/10^{9}$, 1 df, p=0.00000000023). In other words, in whichever way the analysis is accomplished (using expected frequencies NCT or table totals) the effect shows in a very strong way in the last group of trials, as was expected by the hypothesis.

Table 15 is a copy of table 13, but it is relative only to the last 33 trials of the experiment. It is possible to observe that in this last table the effect before the lucky and unlucky colours increases. For example in the case of lucky colours HR was 17.4% in table 13 and in table 15 is 23.1%, whereas for the unlucky colour the increase of HR went from 17.2% to 24%.

Differences	**Colour chosen by the subject**			**Total**	**N.C.T.**
	Neutral	**Lucky**	**Unlucky**		
From + 1.500	15.8%	19.2%	24.0%	19.6%	13.1%
- 1.499 to +1.499	68.4%	57.7%	60.8%	62.3%	73.3%
Up to -1.500	15.8%	23.1%	15.2%	18.1%	13.6%
	100% (n=480)	100% (n=480)	100% (n=480)	100% (n=1.440)	100,0%

Tab. 15 – Distribution of the differences among mean HR values measured in phase 1 associated with the choice performed by the subject (phase 2). Table calculated on the last group of trials, for all the subjects.

Effects are unbalanced and HR before the choice of the lucky colour diminishes whereas before the choice of the unlucky colour it increases. This unbalanced effect is coherent with the effect which was observed by Damasio (1994).

It is important to note that the effect does not show in the same direction in all the subjects and it is therefore non additive.

Interaction between retrocausal and learning effects

In this section data analysis is operated again on feedback tables, relative to the retrocausal effect. Table 16 is divided in group of trials: first 33 trials, central 33 trials, last 33 trials.

In the first 33 trials 59.6% of the differences were below the 1.5 cut-off point, compared to 63.9% expected according to the total of the table and 73.3% according to the NCT criteria. On the other side 40.4% were above the 1.5 cut off point compared to 36.1% expected according to the totals of the table and 26.7% using the NCT criteria. In the intermediate 33 trials the observed effect is 29.2% compared to 26.7 expected by NCT. In the last 33 trials the effect is 38.8% compared to 26.7% expected according to NCT.

Differences (*absolute values*)	**Trial**			**Total**	**N.C.T.**
	2-34	**35-67**	**68-100**		
Up to 1.499	59.6%	70.8%	61.2%	63.9%	73,3%
From 1.500	40.4%	29.2%	38.8%	36.1%	26,7%
	100% (n=1,920)	100% (n=1,920)	100% (n=1,920)	100% (n=5,760)	100,0%

Tab. 16 – Distribution of mean value HR differences in phase 1 associated with the target selected by the computer in phase 3

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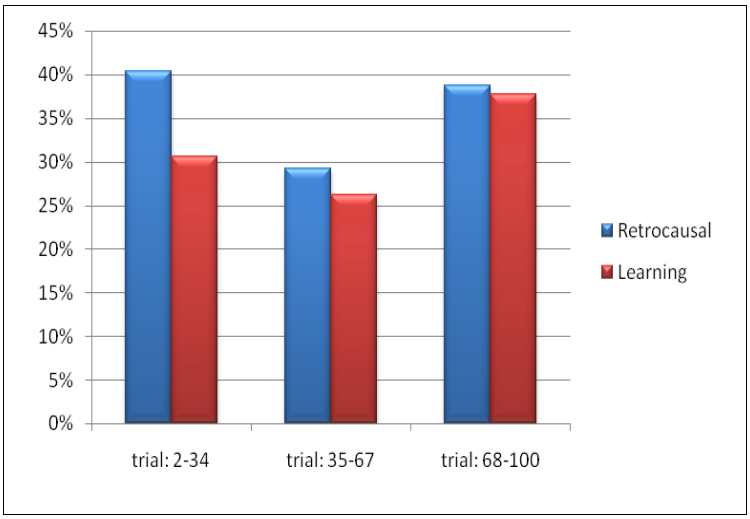
The effect results to be strong and significant in the first 33 trials and in the last 33 trials. It is interesting to note that the effect shows in the first 33 trials, as was expected by the retrocausal hypothesis. The effect can be assessed both with the NCT criteria and the totals of the tables. Using this last criteria, which results to be the most conservative one, in the first 33 trials Chi Square values is

53.55 ($p<0.76/10^{13}$, 1 df, p=0.000000000000076). In the middle trials the retrocausal effect practically disappears (according to NCT), but in the last 33 trials it turns out again to be strongly significant with a Chi Square of a 39.31 ($p=0.95/10^{10}$, 1 df, p=0.000000000095).



Tab. 17 – Interaction between retrocausal and learning effect. Statistical significance of 1% starts at frequency values of 29%

In the table relative to the retrocausal effect it is possible to see a strong effect in the first 33 trials, while in the table relative to the learning effect it is possible to see a limited effect, just statistically significant. Then, in the middle trials the effect disappears both in the case of the learning and retrocausal effect. At the end of the experiment, in the last 33 trials, the effect again becomes strongly significant both in the case of retrocausal effect and learning effect (as can be seen in table 17). The increase in the last 33 trials coincides with $p=0,95/10^{10}$ for the retrocausal effect and $p<1/10^{22}$ for the learning effect.

This trend suggests that in the first 33 trials the retrocausal effect is strong and the learning effect starts emerging. Conflicting together both effects become incoherent and loose their statistical significance in the middle 33 trials. The decrease of the retrocausal effect in the central part of the experiment had not been observed in the other experiments and can, therefore, be attributed to the new element which has been introduced, which is the learning effect. In the last 33 trials a strong rise in both the effects is observed. This trend suggests an interaction between the learning and retrocausal effect which probably leads to the loss of the effect in the central part of the experiment.

Table 18 is relative to the effects shown by the subject with the highest values of general difference (see table 2). In this example the retrocausal effect is extremely strong from the beginning of the experiment (73% compared to 26% expected), but it drastically drops down in the central part of the experiment and then climbs back up again.

Differences (*absolute values*)	**Trial**			**Total**	**N.C.T.**
	2-34	**35-67**	**68-100**		
Up to 1.499	26.6%	67.2%	29.7%	44.0%	73.3%
From 1.500	73.4%	32.8%	70.3%	56.0%	26.7%
	100% (n=64)	100% (n=64)	100% (n=64)	100% (n=192)	100.0%

Tab. 17 – Distribution of mean differences of HR measured in phase 1 in association with the target chosen by the computer in phase 3, divided by trials. This table considers only the data of the subject with the highest general total (see table 2).

The learning effect which is observed in the form of HR differences is not translated into an improvement in the guesses of the subject. When the subject discovers the existence of a lucky colour he/she could start choosing always this colour, increasing in this way the guesses from 25% (random) to 35% of the lucky colour. This increase was not observed, on the contrary in the first 33 trial the target was guessed correctly 24.75% times, in the middle trials 24.65% and in the last trials 25.47%. This slight increase is not statistically significant and it is therefore possible to assimilate it in the other values. It is therefore possible to state that in all the 3 parts in which the data analysis of the experiment has been divided subjects guessed randomly: 25% of the times. This data shows that even if the learning effect is clearly and strongly seen in HR differences, it is not translated in a behavioural or cognitive form.

Summary of the results

Statistical analysis in this chapter is quite detailed, for this reason results are here described immediately together with the conclusions.

Statistical data analysis shows:

1. A strong retrocausal effect on the blue colour $p<1/10^{27}$, green colour $p<1/10^{12}$, red colour $p<1/10^{13}$ and yellow colour $p<1/10^{11}$.
2. An unbalanced retrocausal effect on the colour blue (p=0.0000000000000040) and green (p=0.00000055).
3. From the first 33 trials, the retrocausal effect was observed, as expected by the hypothesis.

4. A learning effect associated with heart rate frequencies (p=0.00000000023). The effect was observed before the choice of a lucky and a unlucky colour (choice operated by the subject in phase 2). It is important to note that this effect emerges with strength in the last block of trials of the experiment, as was expected by the hypothesis, according to which a learning effect requires time to show.
5. An interaction between the two effects in the central part of the experiment in which the learning effect inhibits the retrocausal effect (p=0.000000000000076).

It is interesting to note that whilst a strong learning effect is observed in association with heart rate frequencies, this effect is not translated into more advantageous guesses. In all the blocks, subjects guess 25% as expected by the random distribution. Therefore the strong learning effect which is observed with heart rate frequencies is not translated into a cognitive learning.