Pre-stimuli heart rate differences: replica and controls

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Abstract

Experiments on pre-stimuli heart rate differences were replicated 3 times adding each time new controls on the heart rate device, on the experimental design and on the statistical data analyses.
All the experiments have confirmed the anticipatory reaction of heart rate, and have shown new characteristics of the effect, for example it is stronger on stimuli closer to the feedback, and it is totally absent when the computer does not show the feedback even though the choice is performed; this last control has been repeated in different conditions and leads to the exclusion of causes which could precede the effect.

1. Pre-stimuli heart rate responses: Tressoldi's experiments

In the article "*Heart Rate Differences between Targets and Nontargets in Intuitive Tasks*", Tressoldi (2005) describes two experiments, the first exploratory and the second confirmatory which show that the heart rate increases in advance of the presentation of stimuli (p=0.015 in the first experiment, p=0.001 in the second experiment).

Experiment 1

The first experiment involved 12 subjects, 5 males and 7 females with an average age of 25.5 years (range between 24 and 45 years), mainly university students. These subjects were asked to participate in a computerized trial which was based on the ability of guessing. The participants were asked to sit on a comfortable chair in front of a computer monitor; on their left hand was applied a device connected to an apparatus which detected the heart rate. All the subjects had been previously informed of the progression of events, and that the sequence of the pictures which would be shown was random. Their task was to guess which picture would be selected by the computer as a target. Each trial consisted of 3 phases:

1. in the presentation phase 4 pictures (landscapes, animals, monuments) were shown for about 10 seconds, and heart rate data was collected;
2. in the choice phase the simultaneous presentation of all four pictures followed. At this point the subject had to guess the target picture.
3. As soon as the choice of the subject was made the computer performed its choice, using a random algorithm, and selected one of the four pictures and showed it on the monitor.

Data acquisition and the correct functioning of the heart rate measuring apparatus was monitored by a research assistant with his or her back to the participant. Owing to the automation of the target selection, the assistant could not suggest anything to the subject. The experiment ended after 20 trials.

The results of this first experiment show a statistically significant difference between the heart rate measured, during the presentation phase, in association with target and non targets images:

- *Target* pictures are those which are selected (using a random procedure) by the computer after the expression of the choice of the subject.
- *Non target* pictured are those which are not selected by the computer.

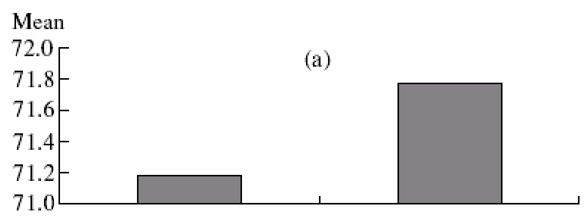
Before interpreting the results, the authors wanted to repeat the experiment on 12 other subjects, in order to exclude that the results of this first experiment could be a consequence of statistical artifacts.

Experiment 2

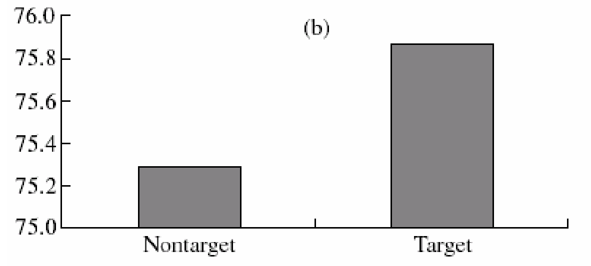
The second experiment involved 12 subjects, 5 males and 7 females, average age 25.3 (range 23-48 years). Also this second experiment, identical to the first one, shows a statistically significant difference in the heart rate when target and non target pictures are chosen.

Discussion of the results

Table 1 shows the heart rate frequencies measured in the two different experiments when observing target and non targets pictures.



p=0.015



p=0.001

Table 1 – results obtained by Tressoldi

The results obtained in the second experiment confirm the heart rate differences between target and non target pictures, which had been observed in the first experiment. The probability that the observed results may be a consequence of statistical artifacts, even if always present, may be considered low because of the concordant findings of the exploratory and the confirmatory experiments, and the use of the bootstrap procedure which forms new groups of 12 subjects, combining 6 subjects from the first experiment with 6 subjects from the second experiment, and which has always produced statistically significant results.

Tressoldi concluded that with this simple procedure it has been possible to see a slight, but significant, anticipatory change in the heart rate, depending on the nature of stimuli (target or non target), even though the choice performed by the subjects was totally random. In both the experiments, the number of guessed targets was equal to the quota expected by pure chance: 5 targets every 20 trials. Even though the sample is limited (altogether 24 subjects), 20 trials were carried out for each subject, enabling to underline even small differences between targets and non targets.

2. Replica of Tressoldi experiments - preparation of the experiments

The first attempts to replicate Tressoldi's experiments started in the month of November 2007. The initial obstacle was that of the heart rate measuring device. Producers and distributors of laboratory devices have been contacted, but all the products used built-in software which did not satisfy the synchronization requirements of the experiment. Furthermore the producers of these devices did not agree to provide the software keys which would have allowed the development of personalized software and the direct acquisition of heart rate data from the serial port. The laboratory devices which have been assessed presented always these limits: proprietary software which did not allow to access directly the device. In order to try to overcome this limit a laboratory in North Italy sent some devices, but in all cases the impossibility to establish a satisfactory synchronization between the device and the images which were presented on the PC monitor was assessed.

Professor Tressoldi was contacted and he confirmed the same difficulty. In his department in Padua (Italy) the problem was solved by a technician who himself build the heart rate devices. This solution was not possible in the department of psychology in the University of Rome.

In December 2008 the assessment was extended to devices used outside the experimental laboratories, in the field of sports training. Most devices showed the following limits:

1. the heart rate measurement is stored in a wrist watch, using in this way a different

clock from the one used to conduct the experiment;

2. the information is stored without any compensation of the delay due to the measurement;
3. some devices showed errors in the measure.

After a long evaluation, the “home training” device produced by SUUNTO (www.suunto.com), was chosen. This system includes a thorax belt for measuring heart rate parameters, and a USB interface (PC-POD) which receives these measurements by radio, using digital coded signals (which eliminate any possibility of interference) directly on the PC on which the experiment is carried out, using in this way the same clock of the experiment.

Tab. 2 - SUUNTO Heart rate monitor consisting of a thorax belt and a USB radio receiver

The SUUNTO heart monitor device measures the heart frequency every second and saves this information in a file associated with the exact time (year, month, day, hour, minute and second). The measurement is relative to the average value during the second and is saved compensating the delay due to the time which is necessary to perform the measurement and to process the information. The heart rate date, saved in the file, is therefore perfectly synchronized with the measurement performed. The heart rate information is saved as an integer number, without any decimal values.

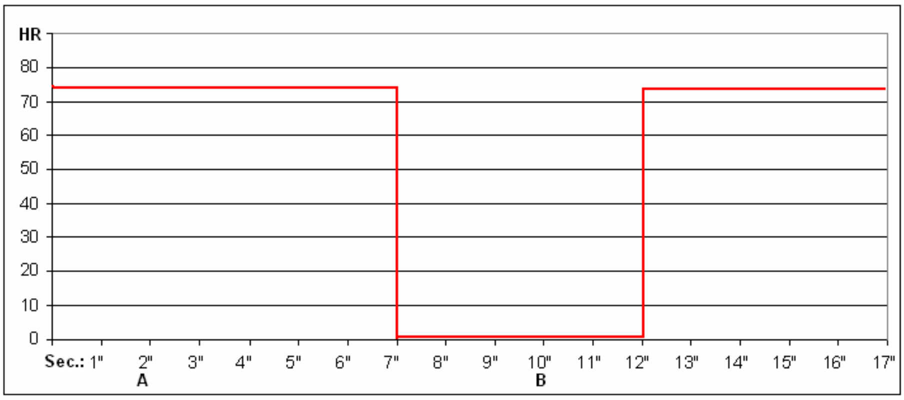
The SUUNTO “home training” device has been developed in order to monitor sports training activities and can be used in the most extreme conditions, for example underwater. It does not require the use of gel in order to conduct the signal and its use is extremely simple.

Consequently it does not require the presence of an assistant in the same room in which the experiment is carried out. The only limit was observed in cold climates; the impossibility to measure the heart rate parameter was observed in some subjects. These subjects were excluded from the sample.

- Behavior of the SUUNTO heart rate device

Before starting the experiments the synchronization of the SUUNTO heart rate device with the clock of the PC was assessed. The heart rate information is shown in "real time" on the PC monitor and it is also saved in a file:

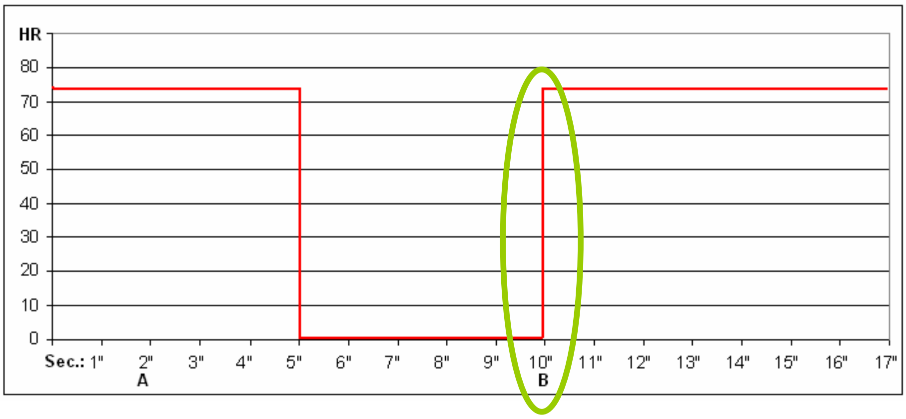
1. *In real time on the PC monitor*. In this modality it was observed that (tab. 3):
   A. When the signal is deactivated (moving the device away from the chest of the subject, point A) the measurement disappears after 5 seconds;
   B. When the signal is reactivated (moving the device back on the chest of the subject, point B) the measurement reappears after 2 seconds.



Tab. 3 – Behavior of SUUNTO heart rate measurements on the PC monitor

2. *Data saved in the file.* In this modality it was observed that (tab. 4):
   A. When the signal is deactivated (moving the device away from the chest of the subject, point A) the last measurement is kept for 3 seconds;

B. When the signal is reactivated (moving the device back on the chest of the subject, point B) ***the measurement reappears immediately***.



Tab. 4 – Behavior of SUUNTO heart rate measurements saved in the data file

This control shows that the delay in the measurements shown in "real time" on the PC monitor is approximately of 2 seconds, while in the data file the delay is compensated and the measurement is associated to the exact time (point B of table 4, marked in green).

In the data file the measurement of the heart rate is associated with the time of the clock of the computer (year, month, day, hour, minute and second). A second control carried out during the statistical analysis of the results showed that the measurement is relative to the second shown by the clock, therefore a measurement associated with 14.13'.25" has been calculated starting at 14.13'.25".000 and ending at 14.13'.25".999. During the data analysis a series of controls were performed shifting the measurements forwards or backwards of one or more seconds. It was observed that desynchronizing the measurement by only one second, in the experiments in which stimuli were presented for only 2 seconds, cancelled all statistical significant results. In other words, the perfect synchronization of the heart rate measurements with the presentation of the stimuli on the PC monitor is fundamental for the observation of the effect.

- Choice of stimuli

The trial devised by Tressoldi is divided into 3 phases:

1. stimuli are shown individually on the PC monitor and heart rate is measured;
2. stimuli are shown together on the PC monitor and the subject tries to guess which one will be selected by the computer;
3. the computer selects one of the 4 stimuli (target stimulus), using a random procedure, and shows it on the PC monitor full screen (feedback).

The first experiment was conducted using software developed in Visual Basic 2005. The following experiments used software developed in Delphi Pascal which allowed a better control of the computer hardware and a more precise synchronization of the presentation of the images.

The hypothesis of the experiment is that in the event of anticipatory effects heart rate measurements in phase 1 (the presentation phase) are significantly different between target images (those which will be chosen by the computer in phase 3) and non target images (those which will not be chosen by the computer).

The first experiments used stimuli made of black bars placed horizontally, vertically and diagonally on a white background. Data analysis did not show any significant difference between targets and non targets.

The hypothesis was therefore analyzed in more depth and it was noticed that the central hypothesis of the "*syntropy model*" is that anticipation should be mediated by emotions and, therefore, in order to see differences between target and non target stimuli, images should arise emotions. Following this indication it was decided to use 4 elementary colors: blue, green, red and yellow. Using these colors, a strong difference in the heart frequencies between target and non target stimuli was observed. The difference was observed within the same color, while considering all the colors together differences were not observed. It was therefore decided to conduct the experiments using these 4 elementary colors as stimuli.

In the first experiments in phase 1, stimuli were presented for 4 seconds each. Heart rate was measured each second. In the second experiments, in phase 1, the duration of stimuli presentation was reduced to 2 seconds each. This allowed to perform further controls on the behavior of the heart rate measurements and the synchronization with the presentation of stimuli.

Phase 1				**Phase 2**	**Phase 3**
Presentation of stimuli and measurement of heart rate				*Choice*	*Random selection*
Image 1	Image 2	Image 3	Image 4		
Non target	***Non target***	***Target***	***Non target***		***Target***
4 seconds	*4 seconds*	*4 seconds*	*4 seconds*		***Feedback***

Tab. 5 – Phases of an experimental trial:

1. *colors 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 colors trying to guess the color which will be chosen by the computer;*
3. *the computer selects, using a random algorithm, one of the 4 colors (target) and shows it in full screen (feedback).*

It is important to note that during the experiment two software are active:

1. produced by SUUNTO for the processing of the information arriving from the heart rate thorax belt. This program associates each heart rate frequency to the date and second of the measurement. This data is stored in a file in a directory created by the SUUNTO software.
2. produced using Delphi Pascal for the presentation of stimuli and the conduction of the experiment. Stimuli are presented exactly at the turn of the second, with the precision of milliseconds, obtaining in this way a perfect synchronization between the data stored by the SUUNTO software and stimuli presented by the computer. This last program

saves data in a different directory from the one used by the SUUNTO program. Each event is associated with the exact moment of its happening (year, month, day, hour, minute, second and millisecond).

Only at the end of the experiment the two files are merged together using the time information during which the stimulus was presented and the heart rate measured. In the outcome file information relative to the nature of the stimulus (target and non target) is added according to the choice operated by the computer.

- Random choices and unpredictability

In order to test anticipatory effects the fundamental condition is that the choice operated by the computer in phase 3 is unpredictable.

In a random sequence each term is totally independent from the previous and following terms, no rule links different parts of the sequence. This condition is known as unpredictability of random sequences and it is referred to as "lack of memory": the process of random selection does not recall any information about the values which were selected previously and cannot be used for the prediction of the values which will be extracted in the future.

Random sequences imply the following qualities:

1. *Unpredictability*. The knowledge of any portion of the random sequence does not provide useful information in order to predict the outcome of any other element of the sequence. In other words, the knowledge of the first k values does not provide any element in order to predict the value k+1: this property is called unpredictability.
2. *Equiprobability*. A sequence is random if in each position each value has the same probability to be extracted. In the case of a dice, each side has the same probability to be selected. Similarly, equal probability is expected when using a coin: during each tossing heads and tails have the same probability to show. Equiprobability implies independent

sequences as it requires that the outcome of each selection is independent from any previous selection. A consequence of equiprobability are flat frequency distributions as each term, in time, will show a similar number of selections as the other terms.

3. *Irregularity*. Unpredictability requires random sequence to be irregular and not repetitive.
4. *Absence of order.* In random sequences no type of structure or order can be detected.

The basic difference among *causal* and *random* can be traced back to the fact that *causal* events can be predicted, whereas *random* events cannot be predicted. As a consequence a *random* sequence can be defined as a sequence that no cognitive process will ever be able to predict.

- Pseudorandom and random

Computer languages usually use the word *random* to identify the instruction which starts the algorithm for random selections of numbers. In this paper the Delphi-Pascal programming language will be used as an example. Delphi-Pascal has a predefined random sequence (2^{32} numbers) which can be assessed through a pointer which can be defined by the user or by the value of the built-in clock. Delphi-Pascal uses the following instructions:

- *Randomize* reads the value of the built-in clock and uses this value as the pointer to the predefined random sequence;
- *Random* reads the value of the predefined sequence using the pointer selected by the randomize instruction.

The user can also define a personalized pointer. This option is generally used in those software which encrypt information. Utilizing the same pointer the extraction of random numbers from the predefined random sequence will always be the same.

It is now important to understand why the random sequences produced by a computer are named pseudorandom.

In order to obtain different random sequences the *randomize* procedure is used; this procedure reads the built-in clock of the computer in order to extract an unpredictable pointer. The problem arises when the *randomize* procedures are recalled in a loop. As a consequence of the fact that each loop requires always the same processing time the new value extracted from the built-in clock will be determined by the previous extraction. In other words the extractions, even if performed using a predefined random sequence, are all determined by the first value which was extracted: the first value determines the second value, and so on, and the condition of independency between the extraction of different terms is not met.

Usually the fact that the sequences generated by computers are pseudorandom is considered of secondary importance. However, in experiments which want to test anticipation, and which are based on the assumption of unpredictability, a pseudo-random sequence would inevitably be considered an artifact in the experimental design.

Luckily the solution to this problem is incredibly simple. The problem arises from the fact that the duration of the loops is always the same. In order to overcome this problem, obtaining in this way pure random extraction, it is necessary to use loops which are based on unpredictable periods of time.

This condition can be easily met when an external, unpredictable factor, is inserted in the loop and modifies its execution time. In the experiments conducted in this study, in which the subject is asked to press a button corresponding to the color that he/she thinks the computer will select, the reaction time of the subject is always unpredictable. In this way, the unpredictable reaction time of the subject, makes the loop time become unpredictable, and the value extracted from the built-in clock of the computer becomes independent from the other values previously extracted. In this way the independence among different selections is restored and the sequence becomes totally unpredictable: perfectly random.

For this reason, in all the experiments which have been conducted in this study, the subject was asked to operate a selection; the only real reason for this request was that of restoring the independence of the terms in the random selection operated by the computer.

3. Results of the experiments

In this chapter 3 experiments are described:

1. The first experiment used always the same sequence of colors: blue, green, red and yellow. The subject was asked to try to guess the color that the computer would have chosen. The hypothesis was that in presence of anticipation, in the phase 1 a significant difference in the heart rate during the presentation of target and non target stimuli would emerge. This first experiment involved 24 subjects and results have been extremely significant from a statistical point of view.
2. In order to exclude that the difference in the heart rate measurements among targets and non targets could depend upon causes which precede the choice performed by the computer, in the second experiment it was tested if the difference remained when the computer operated the choice, but did not show the feedback. Results show that when the feedback is shown differences are strong and statistically significant, but when the feedback is not shown differences disappear. This result leads to exclude any possible cause antecedent to the choice performed by the computer in the differences observed between targets and non targets.
3. In the third experiment it was observed that:
    a. Colors behave in a different way according to their position. These results lead to the hypothesis that the effect might propagate in the form of a wave with opposite peaks.
    b. The effect results stronger when closer to the feedback of the computer.
    c. When stimuli with numbers, and not with colors, are used (in this experiments the numbers from 1 to 4 were used) the effect is stronger in the last position.
    d. When the feedback is not shown the effect disappear.

3.1 Experiment no. 1

Each trial of the experiment is divided in 3 phases.

1. *Presentation phase:* 4 images are presented one after the other on the screen of the computer. The first one is blue, the second one is green, the third one is red and the fourth is yellow. Each image (color) is shown for exactly 4 seconds. The subject is asked to look at the images, and during the presentation the heart frequency is measured at fixed intervals of 1 second. For each image 4 measurements of the heart frequency are saved: one for each second. The presentation of the image is perfectly synchronized with the heart rate measurement. When necessary the synchronization is re-established showing a white image before the presentation of the color. It is important to note that the SUUNTO heart frequency device does not require any type of supervision. Subjects were alone while conducting the experiment; the experimenter waits outside the laboratory or the place in which the subject is undergoing the experiment.
2. *Choice phase:* at the end of the presentation of the 4 colors, an image with 4 color bars is shown (blue, green, red and yellow) in order to allow the subject to choose (using the mouse) the color which he thinks the computer will select. In other words, the subject is asked to guess the color which the computer will select.

Phase 1 *Presentation of stimuli and measurement of heart rate*				**Phase 2** *Choice*	**Phase 3** *Random Selection*
Image 1	Image 2	Image 3	Image 4		
Non target	***Non target***	***Target***	***Non target***		***Target***
4 seconds	*4 seconds*	*4 seconds*	*4 seconds*		***Feedback***

Tab. 6 – Phases of an experimental trial

3. *Random selection of the target and feedback:* as soon as the subject chooses a color the computer selects the target color, using a random process, and shows the selected color full-screen on the computer (*Feedback*).

The experiment consists of 20 trials and requires approximately 7 minutes. Each subject was asked to repeat the experiment 3 times.

- The sample

The experiment was conducted on a sample of 24 subjects, with ages ranging from 15 to 75. A total of 14 females and 10 males was present in this sample. Each subject performed the experiment 3 times, for a total time of slightly more than 20 minutes. Heart rate frequency was measured 960 times for each subject, producing a sample of heart rate frequencies which allows to calculate statistical significances also within each subject.

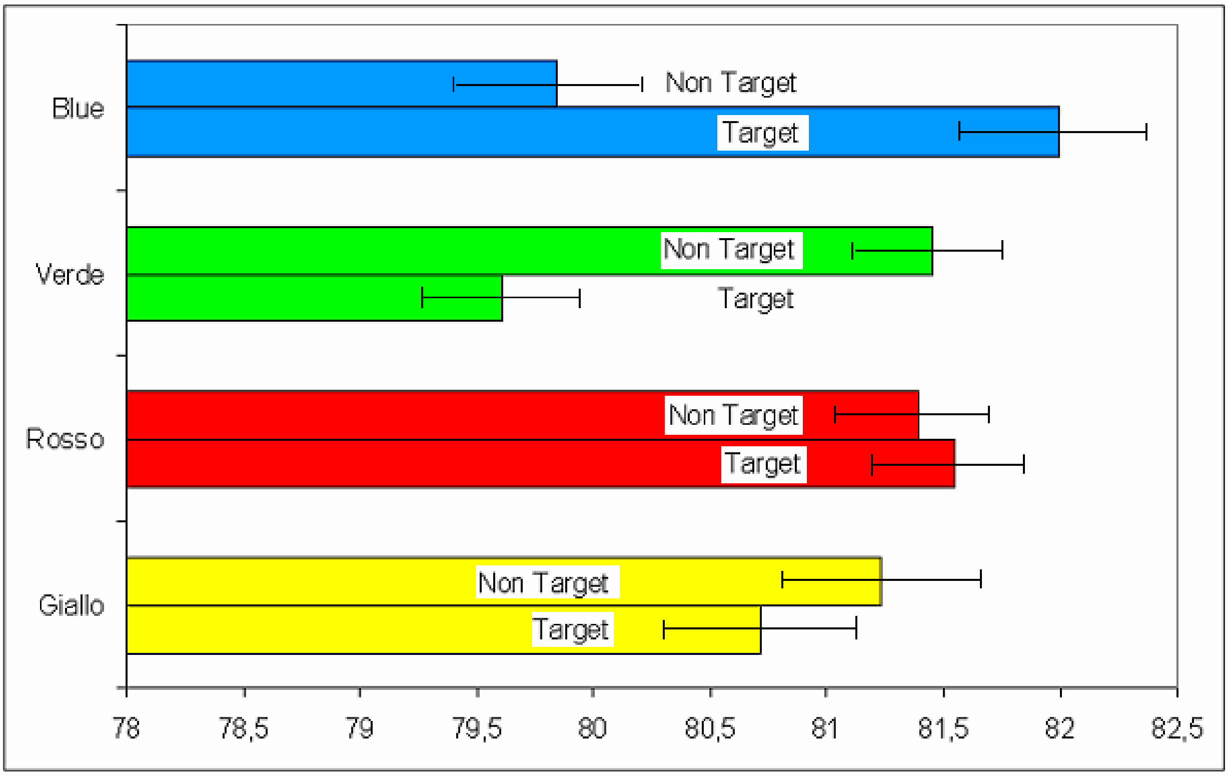
- Results

Target is the color selected and shown by the computer after the subject performs the guess.

The hypothesis is that in phase 1, in presence of anticipation, differences should be observed between heart rates measured during the presentation of target colors (colors selected by the computer in phase 3) and non target colors (colors which have not been chosen by the computer in phase 3).

Taking into account all the heart rate frequencies no significant difference is observed between target and non target images; the target images obtain an average value of the heart rate frequency of 80.94 and the non target images of 80.97. But, when the analysis is conducted within each color, strong differences of the heart rate are observed between targets and non targets for the blue color (target 81.99 and non target 79.84) and the green color (target 79.60 and non target 81.45). These differences correspond to a t of Student value of 10.74 for the blue color, and 8.81 for the green color.

A t Student value of 3.291 is statistically significant with $p<0.001$, meaning that there is less than 1 probability in 1,000 to be wrong when stating that the difference is not a product of chance. A t of Student of 8,81 (obtained in our experiment comparing the target and non target images of the green color) tells that the probability of being wrong is practically equal to zero; it is therefore possible to state, with nearly absolute certainty, that there is a difference between target and non target images, which is not a consequence of chance.



Tab. 7 – Mean heart rate frequency divided by color and target

A second analysis was performed using the Chi Square test. Statistical significance was calculated comparing the number of measurements which were over or under the baseline of the color. Also in this case a strong statistical significance was observed with Chi Square values over 30; $p<0.001$ significance is reached with Chi Square values of 10.8.

3.2 Experiment no. 2

During the discussion of these results a professor from the faculty of physics, in Rome, suggested that the effects observed could be caused by the emotions and expectations of the subject which interact with the electronics of the computer, determining the selection of the color. If this counter explanation is correct, the effect in phase 1 should be observed also when the computer operates the choice of the target but does not show the selected color on the monitor as a feedback.

The second experiment was therefore designed in order to control if the effect observed in phase 1 can be the consequence of causes which precede the choice operated by the computer.

This second experiment differs from the previous one for two elements:

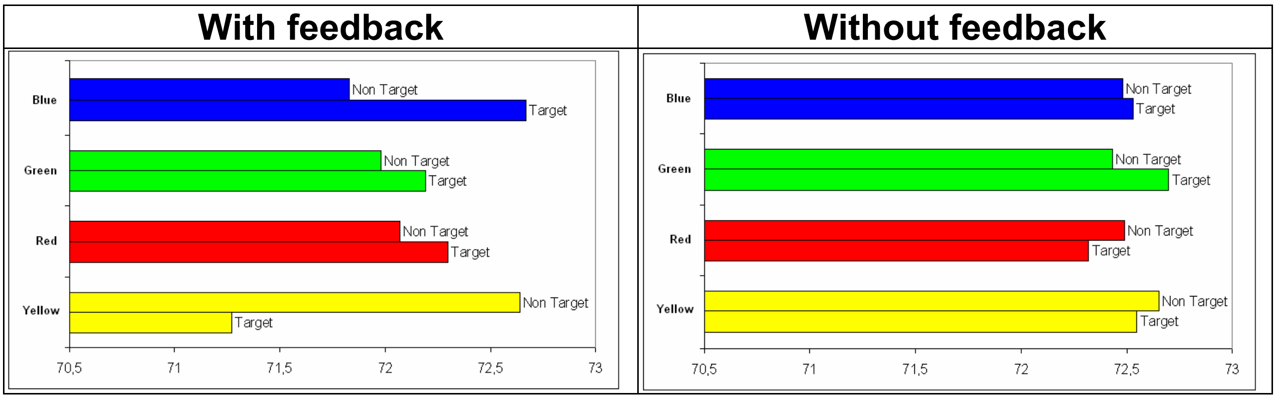
1. the computer chooses in a totally random way if the feedback will be shown or not.
2. The presentation of stimuli in phase 1 was reduced from 4 seconds to 2 seconds. This condition allowed to increase the number of heart rate measurements which could be used in the statistical data analysis and reduce the length of the experiment.

The succession of the colors remains the same: blue, green, red and yellow.

The experiment was aimed to:

- Verify again the effect in phase 1.
- Verify if the effect in phase 1 persists when the feedback is not shown. More precisely when the computer selects the color (phase 3), but instead of showing the selected color a gray full screen is shown.

The experiment consists of 100 trials per subject, of which slightly less than 1 out of 5 were without feedback. The sample consisted of 8 subjects. Trials without feedback are chosen randomly by the computer. On a total of 800 trials 151 were without feedback. On a total of 3,200 heart rate measurements (8 subjects x 100 trials x 4 stimuli) 604 were without feedback and 2,596 with feedback. Even though the presentation time was reduced from 4 to 2 seconds the effect emerged with strong statistical differences within the blue and the yellow colors when the feedback was shown (trials with feedback).



Tab. 8 – average heart rate values

On the other hand, the effect is totally absent when the computer, after performing the choice of the target color, does not show it on the monitor (trials without feedback).

It is interesting to note that in the first experiment the effect was strong on the blue and green color, while in this second experiment the effect on the green color is absent but it is present on the yellow color. This modulation of the effect suggests that it might depend on the sequence of the colors and the length of the presentation of each stimulus.

In this experiment, as in the previous one, a slight tendency towards guessing correctly the outcome was noticed (26% compared to 25% which was expected). This difference is not statistically significant, but it is interesting to note that while in the first 50 trials 25,08% of the guesses were correct, in the last 50 trials this percentage increases to 26,95%. This increase suggests the existence of a learning process (Tab. 9).

	First 50 trials	Last 50 trials	Total
Guessed	25,08%	26,95%	26,04%
Not guessed	74,92%	73,05%	73,96%
Total	100,00% (315)	100,00% (334)	100,00% (649)

Tab. 9 – Outcome of the guessing task in trials with feedback

If this learning effect is confirmed, in future experiments, it would support the hypothesis that subjects can learn to listen to their emotional signals and use them in order to favor positive outcomes. From a cognitive point of view learning to guess correctly should be simply impossible in an experiment, like this one, in which the selection performed by the computer is totally unpredictable.

3.3 Experiment no. 3

The third experiment was more complex. The aim was to:

1) Replicate the anticipatory effects found in the previous experiments.
2) Replicate the absence of anticipation when the feedback is not shown.
3) Study how the effect changes in different positions of the sequence.
4) Study how the effect changes when the position of the colors is changed.

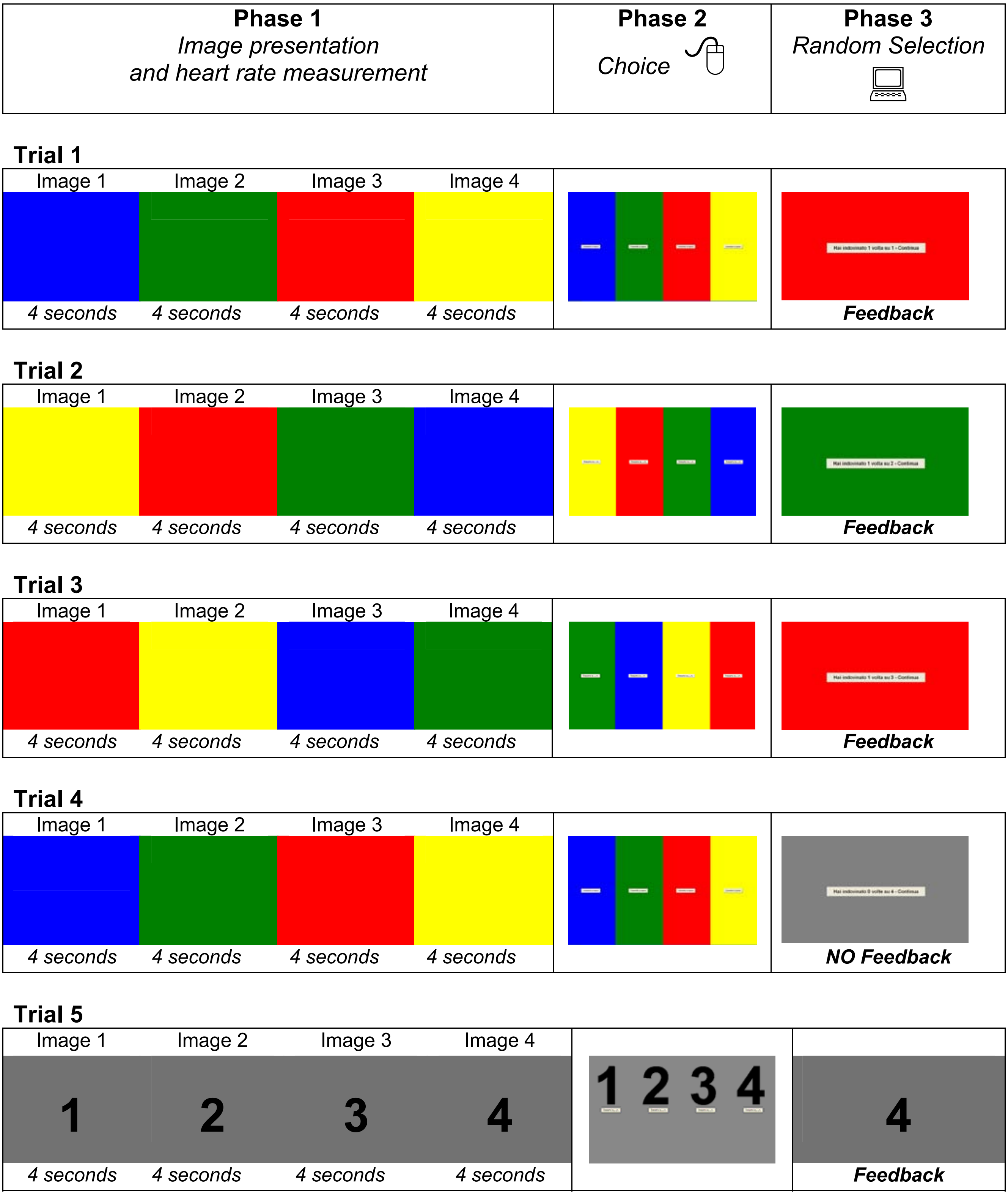
- Experimental trials

The experiment was based on 5 different trials, each one with a different sequence of colors and stimuli (table 10):

1. in phase 1 of the first trial the sequence is blue, green, red and yellow and each color is presented for 4 seconds; in phase 2 the computer shows all the colors together and waits

for the choice operated by the subject; in phase 3 the computer randomly selects the target color and shows it full screen. A button is shown with the percentage of times the subject has guessed correctly; the subject has to press the button in order to start a new trial.

2. in phase 1 of the second trial the sequence is yellow, red, green and blue and each color is presented for 4 seconds; in phase 2 the computer shows all the colors together and waits for the choice operated by the subject; in phase 3 the computer randomly selects the target color and shows it full screen. A button is shown with the percentage of times the subject has guessed correctly; the subject has to press the button in order to start a new trial.
3. in phase 1 of the third trial the sequence is green, blue, yellow and red and each color is presented for 4 seconds; in phase 2 the computer shows all the colors together and waits for the choice operated by the subject; in phase 3 the computer randomly selects the target color and shows it full screen. A button is shown with the percentage of times the subject has guessed correctly; the subject has to press the button in order to start a new trial.
4. in phase 1 of the first trial the sequence is blue, green, red and yellow and each color is presented for 4 seconds; in phase 2 the computer shows all the colors together and waits for the choice operated by the subject; in phase 3 the computer randomly selects the target color but does not show the selected color (***no feedback***). A button is shown with the percentage of times the subject has guessed correctly; the subject has to press the button in order to start a new trial.
5. in phase 1 of the fifth trial the sequence is no. 1, no. 2, no. 3 and no. 4 and each number is presented for 4 seconds; in phase 2 the computer shows all the numbers together and waits for the choice operated by the subject; in phase 3 the computer randomly selects the target number and shows it full screen. A button is shown with the percentage of times the subject has guessed correctly; the subject has to press the button in order to start a new trial.



Tab. 10 – Trial used in the third experiment

This sequence of 5 trials was repeated for 20 times, reaching a total of 100 trials for each subject, for a total length of the experiment of slightly more than 45 minutes.

Heart rate is measured throughout all the experiments every second.

It is important to remember that the choice operated by the computer is perfectly random (and not pseudorandom) as the interaction with the built-in clock depends on the moment in which the subject performs the choice of the stimulus.

- Results

The sample was of 23 subjects, 14 females and 8 males, ranging from 16 to 61 years of age. The data analysis was carried out twice, once considering the second heart rate measured during the stimulus presentation, and the second time considering the third heart rate (4 heart rates were measured for each stimulus). In both data analyses 400 heart rate measurements were taken into account for each subject. As a whole the total number of cases (n) was 400 x 23 = 9,200. The difference among the heart rates was studied using the t of Student test. This test reaches statistical significance of:

- 5% - with values equal or exceeding 1.96;
- 1% - with values equal or exceeding 2.576;
- 1/1000 – with values equal or exceeding 3.291.

- Results for the first 3 trials (colors with feedback)

Table 11 shows a strong statistical significance for targets placed in the last position, just before the feedback. Heart rate measurements go from an average of 78.78, observed for non targets, to 80.37, observed for targets.

Statistical significant differences between targets and non targets using the t of Student (first 3 trials)	
1°	-
2°	-
3°	-
4°	6,445

Tab. 11 – In the last position a statistically significant difference of $p<0,001$ (t of student 6,445) was observed

As noticed in the previous two experiments the effect tends to counterbalance on different colors; in some colors and positions an increases in the measurement of the heart rate is observed, in other colors and positions a decrease is observed. The effect observed in table 11 is also observed in the 5th trial, in which numbers were presented instead of colors.

- Results of the first 4 trials (colors)

Table 12 shows that the effect on colors changes according to their position in the sequence. It is important to remember that while in the first 3 trials the computer shows the feedback, in the fourth trial the feedback is not shown. In this last trial no statistically significant differences were observed between target and non target colors. This result confirms the fact that when the feedback is not shown (in phase 3) the effect (in phase 1) disappears.

	Trial with colors			
	1	2	3	4
Blue	-	4,746	-3,455	-
Green	-	-	2,839	-
Red	-6,649	-	-	-
Yellow	5,623	-3,894	-	-

Tab. 12 – Differences among targets and non targets measured with t of Student

The absence of the effect in the fourth trial leads to the exclusion of causes which could be previous to the effect. The hypothesis of an anticipatory effect seems to be confirmed.

- Fifth trial (numbers)

The fifth trial shows a strong effect (t of Student -5.7) only on targets associated to the last position (number 4). This result supports the hypothesis that the effect is stronger when the stimulus is closer to the feedback.

- Considerations

The probability of choosing a target is always the same, and each stimulus should at the end show a frequency distribution similar to the others. In this experiment, as was also done in the other two experiments, it was checked if the distribution of the targets is flat. In this experiment the blue was chosen as a target 547 times, green 591, red 563 and yellow 599. This distribution meets the expectations of a random sequence.

Differences emerged among the data which was collected in the experiments conducted in the laboratory of the Department of Psychology in Rome and experiments conducted at home. Statistical significance is stronger in the data collected at home, and subjects in the experiments conducted in the laboratory of the Department of Psychology showed a tendency to guess less correctly. While at home subjects guessed on an average correctly more than 26%, in the laboratory of Psychology the percentage dropped to 23%. This data seems to confirm the hypothesis that emotionally resonant environments can favor the propagation of signals based on emotions and therefore reinforce anticipatory effects.

In this experiment other controls were added in order to check possible artifacts. For example at the end of the experiment, other selections of targets were added to the data file. No statistically significant result was observed among these “invented” targets and non targets. This test showed that statistically significant differences do not emerge, in this experiment, as a consequence of pure chance.

4. Conclusions: time symmetry, supercausality and retrocausality

Changes of paradigm often coincided with counterintuitive discoveries:

- It was intuitive to imagine Earth to be flat, but counterintuitive to imagine it round;
- It was intuitive to imagine the Sun orbiting around the Earth, but counterintuitive to imagine the Earth orbiting around the Sun.

Nowadays it is intuitive to imagine time which flows from the past to the future, but counterintuitive to imagine that past, present and future coexist!

Einstein's relativity started a new description of reality which is symmetrical in respect of time: on one side energy and waves which propagate from the past to the future, on the other side energy and waves which propagate backwards in time from the future to the past, and which we experiment as *attractors*. Einstein used the term *Übercausalität* (supercausality) to refer to this new model of causality.

The formula $E = mc^2$, usually attributed to Albert Einstein, was first published by Oliver Heaviside in 1890, improved by Henri Poincaré (1900) and Olinto De Pretto (1903), and became famous with Einstein's special relativity (1905), where it was integrated with the momentum in the energy/momentum/mass equation:

$$E^2 = c^2 p^2 + m^2 c^4$$

In this equation energy (E) is the sum of the momentum (p) and in the mass (m) multiplied by the speed of light (c). It is important to note that this equation is a second order equation which requires the use a square root in order to obtain the value of E, the energy of the object. Square roots always yield two solutions, one positive and one negative. For example the number 4 can be the result of $+2^2$ or -2^2. For this reason when the square root of a number is calculated the result is always dual: negative and positive. As a consequence of this fact the outcome of the energy/momentum/mass equation is always dual: one positive ($+E$) and one negative ($-E$).

It is important to note that according to special relativity:

- The positive solution ($+E$) describes energy which propagates in the familiar direction, from the past to the future;
- The negative solution ($-E$) describes energy which propagates backwards in time, from the future to the past.

The negative solution was considered to be impossible, unphysical, an absurd mathematical solution, as it was considered impossible that causes could be placed in the future and act backwards in time. This contradictory solution was solved saying that when the momentum (p) is equal to zero, in all those systems which share the same momentum with the observer, $c^2 p^2 = 0$ and the energy/momentum/mass equation simplifies to $E^2 = m^2 c^4$ which under square root becomes $E = mc^2$ (Einstein's famous equation). But it is important to note that also in this case this equation should keep track of the dual solution: one negative $-E = -mc^2$ and one positive $+E = +mc^2$.

In 1924 Wolfgang Pauli (Nobel prize 1945 in physics), studying the spin associated to the electrons, discovered a momentum (p) which can never be equal to zero, and which is a basic element of matter. Even an object which is perfectly still has a momentum which derives from the spin of electrons. As a consequence of this discovery the energy/momentum/mass equation could not be simplified, at least in the sub-atomic world.

In 1926 Klein and Gordon united the energy/momentum/mass relation (special relativity) with Schrödinger's wave equation (quantum mechanics) obtaining the following equation:

$$E\psi = \sqrt{p^2 + m^2}\psi$$

The solution of Klein and Gordon's equation depends on a square root which always leads to a dual solution: one positive ($+E\Psi$), in which waves propagate from the past to the future, and one negative ($-E\Psi$), according to which waves propagate backward in time, from the future to the past.

In 1928 Paul Dirac tried to remove the unwanted negative solution, which propagates backwards in time, by applying the energy/momentum/mass equation to the study of relativistic electrons. With great disappointment he was faced again with the dual solution: positive electrons and negative electrons (the anti-particle of the electron).

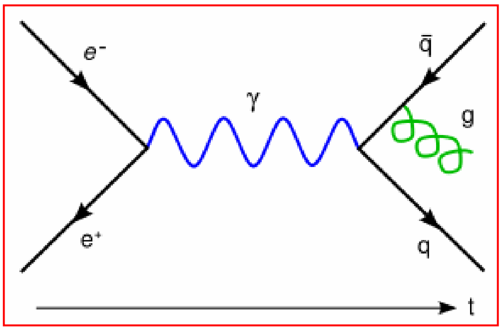
The anti-particle of the electron, which was first named neg-electron by Dirac, was experimentally observed by Carl Anderson in 1932 and named *positron*. In this way Anderson become the first person to demonstrate the existence of the negative solution, which propagates backward in time: not only a strange mathematical solution, but an essential part of reality. From Dirac's equation a universe constituted by matter, which moves forward in time, and antimatter, which moves backward in time, emerges.

Roger Penrose in his book "The Road to Reality" (Penrose, 2005) underlines that usually physicists tend to reject as "unphysical" any solution which contradicts classical causality, according to which causes always precede effects. Any solution which makes it possible to send a signal backward in time is usually rejected. Even if Penrose chooses to reject the negative solution of the energy equation, he states that this refusal is a consequence of a subjective choice, towards which other physicists have different opinions.

Penrose dedicates nearly 200 pages of his book to the paradox of the negative solution. According to Penrose it is important that the value of E is always positive because negative values of E lead to catastrophic instabilities in the Standard Model of sub-atomic physics. Unfortunately in relativistic particles both solutions of the equation need to be considered as a possibility, even a non physical negative energy has to be considered as a possibility. This does not happen in non relativistic particles. In this last case, the quantity is always defined as positive, and the embarrassing negative solution does not appear. Penrose adds that the relativistic version of Schrödinger's equation does not offer a procedure in order to exclude the negative solution. In the case of a single particle this does not lead to any real problem, however when particles interact, the wave function cannot yield only the positive solution. This creates a conflict with the law of classical causation. In order to remove the embarrassing negative solution Dirac suggested in 1931 an hypothesis which Penrose describes simply as crazy. Dirac used Pauli's principle, according to which two electrons cannot share the same state, in order to suggest that all the states of negative energy are occupied, forbidding in this way any interaction between the positive and negative states of matter. This ocean of negative energy which occupies all positive states is called *Dirac sea*. On this assumption is based the Standard Model of physics.

Even if classical physics rejects the negative solution of energy and the possibility of retrocausality, several respected scientists have worked and are working on this possibility.

A classical example are Feynman's diagrams of electron-positron annihilation. According to which electrons are not destroyed by the contact with positrons, but the release of energy is caused by the fact that electrons change direction in time, becoming positrons. When Feynman's diagrams are interpreted they imply necessarily the existence of retrocausality (Feynman, 1949).



John Archibald Wheeler and Richard Feynman suggested to use the solution of the "anticipated waves", waves which move backward in time, in order to solve Maxwell equations. Feynman has also used the concept of retrocausality in order to produce a model of the positrons which reinterprets Dirac's hypothesis on the sea of negative energy which occupies all possible states. In this model, electrons which move backward in time would acquire positive charges (Wheeler 1945).

Yoichiro Nambu (Nobel 2008 in physics) has applied Feynman's model to the processes of annihilation of particle-antiparticle couples, arriving at the conclusion that it is not a process of annihilation or creation of couples of particles and antiparticles, but simply a change of time direction of particles, from the past to the future or from the future to the past (Nambu 1950).

Costa de Beauregard used the concept of retrocausality in order to explain entanglement (de Beauregard, 1977) and in June 2006 the American Association for the Advancement of Science organized a conference on retrocausality at the University of San Diego in California.

As it is possible to see, the idea that time is unitary and that the arrow of time can be inverted is quite a recent one. The concept of retrocausality can be considered a direct consequence of special relativity.

Until the XIX century, time was considered to be irreversible, a sequence of absolute moments. In 1954 the philosopher Michael Dummet showed that there is no philosophical contradiction in the idea that effects can precede causes (Dummet, 1954). More recently, Jan Faye of the University of Copenhagen argued that even if it will not be possible to organize time travel at the macroscopic level, this fact does not exclude that retrocausality can act at other levels (Faye, 1994), and Jeanne Peijnenburg uses the concept of retrocausality in order to describe and redefine the cognitive processes of perception (Peijnenburg, 1999).

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