Use of training with BCI (Brain Computer Interface) in the management of impulsivity.

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***Abstract*—Impulsivity represents one of the risk factors strongly related to dependent behavior in subjects with a diagnosis of substance dependence. The risk appetite, in particular, represents a construct connected with other components such as jumping to conclusion and risk taking.**

There are several forms of treatment used with subjects who have problems related to impulsivity. A good part of these is aimed at subjects with ADHD (Attention Deficit Hyperactivity Disorder), in the form of training or exercises implemented on software. This work aims to evaluate the use of training for concentration, attention and meditation on reducing risk appetite. The experimental design, of a pre-post type, involves assessing the risk appetite before and after training, to be carried out in six sessions over two weeks. The comparison between the experimental group and the control groups showed significant efficacy in reducing the levels of impulsivity in subjects with addiction.

This work represents a pilot study on the possible use of meditation, concentration, and training exercises and demonstrates how these can be considered as excellent forms of training for the reduction of impulsiveness and risk appetite, showing their feasibility in the contexts of intervention and cure for addictions.

Keywords—impulsivity; BCI (Brain Computer Interface); training; risk taking; substance dependence

I. Introduction

Although the construct of impulsivity is not unitary, but composed of several dimensions such as orientation to the present, decrease in the ability to postpone gratification, behavioral disinhibition, risk taking, search for sensations, intolerance to boredom, sensitivity to rewards, hedonism and lack of programming [1], it represents a risk factor for addiction and in particular for substance addiction [2, 3].

One of the models that particularly explains the relationship between impulsivity and addiction is the *discounting model*. This experimental paradigm analyzes the sensitivity of the subjects to a reward, or rather the sensitivity that they show in the choice between two types of rewards: one immediately available and one obtainable only later but with greater value. The "reward effects" provided immediately by the substance, such as inebriation and euphoria, are preferred, in case of conduct of use of substances, to long-term psychophysical well-being. Experimental evidence confirms this hypothesis especially for subjects with heroin and cocaine addiction [3]. In this case, decision-making processes also come into play, i.e. the ability to make the most advantageous choice among the possible ones, which represents a neuro-behavioral dimension related to impulsive behavior and consequently also to the conditions of dependence [4, 5, 6]. Subjects diagnosed with addiction show a lack in the decision-making capacity that increases their risk appetite, a dimension which is also strongly correlated to impulsivity. Research conducted to analyze risk appetite in individuals diagnosed with substance addiction has indeed shown that patients with cocaine, opioid and alcohol addiction have different results from controls in tasks that analyze risk appetite such as the Iowa Gambling task and the Balloon Analogue Risk task, which use a dynamic similar to gambling [7, 8, 9]. These studies also highlighted how high levels of impulsivity would lead addicted subjects to exhibit cognitive biases such as the "jumping to conclusions ", that is, making decisions in a hurry, jumping to conclusions based on scarce evidence [10, 11]

Drug addiction shares the impulsive traits with different psychiatric disorders such as: schizophrenia, impulse control disorders, obsessive-compulsive disorder, antisocial and borderline personality disorders and, not least, attention deficit hyperactivity disorder (ADHD) [12]. Since impulsivity is a typical trait of ADHD as well as substance abuse conditions, the risk of developing substance abuse behavior in adulthood is high in these patients [13]. In the treatment of ADHD, appropriate trainings, which exploit technology to obtain the brainwave feedback of the subject engaged in an exercise, are sometimes used with proven efficacy. Neurofeedback is one of the techniques that has shown efficacy in reducing impulsivity and increasing attentional abilities in subjects with ADHD [14, 15, 16], even if efficacy has not been proved for the hyperactivity component. [17].

Another type of condition useful for reducing impulsiveness in ADHD is meditation, mainly used by means of the Mindfullness or the Transcendental Meditation approach. Several studies have shown that relaxation and meditation techniques result in significant reductions in impulsivity levels in boys with ADHD [18]. The Transcendental Meditation technique, if practiced consistently and for long periods of time, also represents an effective non-pharmacological aid for the treatment of ADHD [19], with evident results also linked to the reduction of the level of anxiety and stress and the improvement of symptoms of inattention and impulsiveness. Even in contexts of care and support for drug addicts - such as community and health care - meditation and relaxation are used to a large extent and are considered as important components in the treatment of addictions [20, 21].

This work is intended as an exploratory study aimed at investigating the possible influence of a training that consists of attention, concentration and meditation exercises, on the risk-taking tendency and impulsiveness in subjects with a diagnosis of substance dependence. As for meditation, two macro categories of meditative exercises can be considered: concentration exercises and relaxation exercises. The concentration exercise involves focusing attention on a single datum or stimulus, while relaxation techniques aim to reduce the activity of mental processes, experiencing a state of inner calm and a sense of peace [22, 23].

Obviously, the brain wave patterns that characterize the two states are opposite: a state of concentration will be associated with brain waves between 12 and 30 hertz (Beta waves), while waves between 8 and 12 hertz (alpha waves) will be associated with a state of relaxation.

The training used in this work involves the use of a BCI (Brain Computer Interface) device with the help of the Mindset of the Neurosky company (www.neurosky.com) which allows the user to duly monitor the change of his mental state.

II. Hardware, software, and measures

Hardware BCI (Brain Computer Interface): Mindwave Headset Neurosky.

The Mindwave Neurosky Headset is a brain wave reading device (EEG) that transfers the acquired signals via Bluetooth to an external device, such as a computer to which it is connected, by creating a communication interface. The device looks like a light plastic helmet with two sensors: a single dry electrode placed on FP1 (according to the international 10-20 system) to detect the EEG signal, placed on the user's forehead, and another reference sensor which is instead placed into the subject's right ear.

Balloon Analogue Risk Task

The Balloon Analogue Risk Task (BART) [23] is a computerized measurement of risk-taking behavior. The test is based on the discounting model which investigates sensitivity to rewards. The subject is presented the task by displaying several balloons in sequence. First the ball is totally deflated. The participant is offered the opportunity to earn money by inflating the ball by pressing a special button. The button works like a pump and with each click the balloon gets bigger, making the subject gain a fixed sum. Each click increases the amount you can earn but also the risk for the ball to explode. At any time, the user has the option of making a choice between continuing to inflate the balloon of another unit or collecting the amount so far won. If the participant decides to stop and get the money, a new balloon will appear to be inflated and the amount earned will be added to the total of the rewards. If, on the other hand, the subject decides to inflate the balloon further and it bursts, the next balloon will be displayed, but the total amount will remain unchanged. Participants are not informed of the ball's breaking point.

At the end of the performance, the subject will have a total score given by the average number of inflates relating to unexploded balloons, an index that grows with increasing risk appetite [24]. In the original version of the task, each click allows the subject to gain 0.5 cents and 90 balls are presented to the subject in sequence (number then reduced in other versions, to make the test shorter). The balls are presented in random order and are of three different types according to the number of clicks necessary to burst the ball. For type number one, the range of possible inflation ranges from a minimum of 1 to a maximum of 8, There is therefore a breakpoint between 1 and 8. The probability that a balloon can explode at the first click is therefore 1 / 8. If the ball does not explode at the first click, the probability is reduced to 1/7 and so on. Type number two has a range from 1 to 32clicks, while type three, from 1 to 128. According to this, the mid-explosion point of a 1/128 balloon will therefore be of 64 clicks.

The reliability of this test in determining risk appetite has been proved in several studies and with it also reliability in retest [25, 26].

III. Attention, concentration and relaxation exercises

The software used to monitor concentration and relaxation levels during training are the Brain-Wave Visualizer and Schulte freeware applications that can be downloaded online for Neurosky Mindwave headset (www.neurosky.com). These allow users to be trained to voluntarily produce a concentration condition. A subject is placed in front of a computer monitor to which the neurosky BCI headset is connected. The graphic representation of a wooden barrel is displayed in the center of the screen, below the barrel there is a level bar that indicates in real time the concentration level of the subject. When the subject focuses on the barrel and the brain wave pattern shows an activation relative to a state of concentration, the barrel, according to the intensity of the signal, begins to burn more or less intensely, until it explodes if the concentration is kept long enough. The screen will indicate the best time obtained by the subject in burning a barrel, the total recording time and the total number of burnt barrels.

The second exercise is Schulte (Cusoft), a tool designed to train the level of attention. The test consists of a visual searching task on a 5x5 matrix of numbers arranged randomly, above the matrix is displayed the bar showing the current level of attention. By means of the computer mouse the subject will have to click in sequence the numbers from 1 to 25. The BCI headset measures the level of attention on a scale from 1 to 100. The software eventually returns the total score by taking into account errors and duration.

Exercises for relaxation

The training and monitoring exercise of the meditative relaxation condition is also part of the Brain-Wave Visualizer software. In this case, the user will see a sphere displayed in the center of the screen; if the subject develops a brain wave pattern attributable to a relaxation condition, it will levitate. In this case the level band indicates relaxation in the condition of meditation, and the sphere rises (being able to reach any height) more or less quickly according to the signal strength. The screen shows the values in meters of the altitude reached by the sphere during registration, the maximum height reached during the registration period and the flight time, i.e. the duration that the sphere spends flying.

IV. METHODOLOGY AND EXPERIMENTAL PROCEDURE

The total duration of the research was two weeks and the experimental design was a pre-post type, with administration of the BART test before starting the training and at the end of the two weeks of training. All subjects signed their consent to the processing of data for research purposes.

40 subjects took part in the research, half of whom were diagnosed with addiction.

1) Experimental group: addiction + training. Subjects with diagnosis of addiction, subjected to training.

2) Control group: addiction + no training. Subjects with diagnosis of addiction, not subjected to training.

3) Control group: no addiction + training. Subjects who do not have an addiction diagnosis and subjected to training.

4) Control group: no addiction + no training. Subjects who do not have an addiction diagnosis and have not undergone training.

The two control groups that did not carry out any training, did not carry out any particular research-related activity in the following two weeks, while each one of the the subjects tested with the training took part in six sessions, over two weeks, three times a week, alternating specific training for concentration and one specific for relaxation. The training sessions took place in a normally lit room, with the only precaution of ensuring maximum silence throughout the session.

The table below shows the distribution of subjects based on socio-demographic variables.

TABLE I. SOCIO-DEMOGRAPHIC VARIABLES DISTRIBUTION

Variable	*Level of variable*	*Control: no dependence + training*	*Control: no dependence + no training*	*Experimental group*	*Control: dependence + training*
Sex	Male	6	6	10	4
	Female	4	4		6
Age	Male	35	23.7	38.4	41
	Female	37	33		44
First substance	Cocaine			6	2
	Alcohol			4	8
Age of first drug use				18.4	22.6
Age of scolarity		12.4	13	8	9.4

Training

The subject was made to sit at a desk and made to wear the BCI headset following the instructions provided by the experimenter. The electrode was placed in the center of the forehead in contact with the skin, ensuring a comfortable position of the equipment on the head, so as not to bother while performing the exercises. While the device was connecting, the subject was invited to get the most comfortable position. At this point, the connection of the equipment and the actual operation were tested, by means of the indicators of the level of concentration, attention and relaxation. Clarifications were provided to the subject on the functioning of the device and a few minutes were granted to become familiar with the level bars indicating the two states of consciousness. When the subject was ready, the administration of the exercises began.

After starting the Brain Wave Visualizer software and selecting the relaxation exercise, the subject is in front of the monitor which shows the sphere, the indicator of current relaxation level and the total height of the sphere at the beginning and when it is at its greatest height, current flight time and best flight time. When the subject is ready, recording starts. The time during which the subject must try to levitate the sphere and keep it in flight as much as possible, is 5 minutes. At the end of the five minutes, the height reached by the sphere and the time spent flying are recorded. At this point the training ends and the subject is asked for some feedback on the exercise.

After starting the Schulte software, the correct operation of the device is checked by means of the bar indicating the level of concentration going up and down. Once the exercise has started, the subject must complete the sequence of numbers from 1 to 25 in the shortest time. At the end of the task, the useful data are recorded: score, peak of attention during the exercise, errors and average level of attention.

Once Brain Wave Visualizer has been started and the concentration exercise has been selected, the user is in front of the screen showing the wooden barrel, the bar of the current concentration level and the totalizers of the current time and best time in which the subject manages to burn the displayed barrel. The task is to detonate the largest number of barrels within five minutes. At the end the number of detonated barrels are shown as well as the best time taken to detonate a barrel.

V. DATA ANALASYS

The table below concerns a series of Student *t* tests for independent samples for each of the four experimental conditions, based on the indicative value of the propensity to take risk calculated with the BART test, i.e. the *average of "clicks" performed by a subject by the unexploded balloons* for each type of balloon. As already mentioned, the three types of balloons that differ by different explosion probability are reported: type 1 balloons with 1/8 initial explosion probability, type 2 balloons with 1/32 explosion probability and type three with initial explosion probability of 1/128.

TABLE II. MEANS, T TEST AND DEGREE FREE FOR THE FOURTH EXPERIMENTAL CONDITIONS IN THE BART TEST

	Table column subhead	*Mean T0*	*Mean T1*	*t (df)*
Control: no dependence + training	Type 1 pump	97	72.2	5.10 (9)**
	Type 2 pump	147.4	118.4	1.97 (9)
	Type 3 pump	282	357.7	-1.39 (9)
Control: no dependence + no training	Type 1 pump	75.8	70	1.33 (9)
	Type 2 pump	97.2	80.6	1.96 (9)
	Type 3 pump	371	394.4	-.22 (9)
Experimental group	Type 1 pump	110.4	100.6	4.46 (9)**

	Table column subhead	Mean T0	Mean T1	t (df)
	Type 2 pump	169.8	151.6	3.17 (9)*
	Type 3 pump	498.8	514	-.09 (9)
Control: dependence + no training	Type 1 pump	90	93	-.98 (9)
	Type 2 pump	122.2	143.8	-1.94 (9)
	Type 3 pump	454.8	599.8	-1.09 (9)

** Significance <.001

* Significance <.01

In the experimental group we can see a decrease in the average number of clicks for the first two types of balloons but not for the third one. In the control group (no addiction + training), however, there is a reduction in the average value of pumping, therefore a reduction in the propensity to take risk, only for the balls of the first type.

As for the training tasks, a series of t Student tests were carried out for independent samples for the concentration tasks, recording for each session: the time spent to solve (as per the matrix of numbers) and the number of barrels detonated in five minutes (as per the Brain Wave Visualizer task). For the relaxation task, instead, the maximum height reached by the sphere (indicating the intensity of relaxation achieved) and the permanence of the sphere in flight have been recorded for five minutes (indicating the ability to maintain constant a sufficiently high level of concentration) (see table III).

TABLE III. MEANS, T TEST AND DEGREE FREE FOR THE TWO EXPERIMENTAL CONDITIONS IN THE SCHULTE, BOTTLE AND MEDITATION EXERCICES

	Table column subhead	Mean T0	Mean T1	t (df)
Experimental group	Schulte: time	96.8	74.4	2.86 (9)*
	Bottle number	3.2	9.4	-12.6 (9)**
	Meditation: height	8.7	8.4	.07 (9)
	Meditation: time	25.9	102.4	-4.56 (9)**
Control: no dependence + training	Schulte: time	39	30.6	-.43 (9)
	Bottle number	10.6	13.2	-6.5 (9)**
	Meditation: height	23.7	28.2	-1.90 (9)
	Meditation: time	159.9	277.2	-5.12 (9)**

** Significance <.001

* Significance <.01

As far as the concentration tasks are concerned, we can see that the experimental subjects showed an improvement towards a decrease in the time required for solving the task and the number of barrels detonated.

As per the concentration tasks, a significance is shown in the improvement for the time of flight of the sphere in flight but not for the height reached in both groups.

VI. DISCUSSION

The results of the analysis on the comparison between the means of the control group and experimental group between the first and second administration of BART, show the validity of the training for the management of impulsivity and risk taking in dependent subjects. This is also proved by the results obtained in concentration and meditation tasks. The lack of significance relating to the third type balloon in the BART test could be justified by a possible "length" or "fatigue" effect of this type of balloon.

This work therefore shows that the use of training is effective and certainly useful as a therapeutic and treatment tool associated with other types of interventions already present in community and / or outpatient settings for the treatment of addictions. The use of innovative technological tools, such as the BCI, has the advantage of increasing motivation for treatment and opening new perspectives for intervention in the experimentation and use of new technologies in the context of treatment for addictions.

The use of new technologies for psychological care and well-being is constantly increasing, as are apps for smartphones and serious games [26]. The results obtained in this experimental trial can open the way to the structuring of specific programs and software, which leverage the mechanisms of attention and meditation. In particular, in the field of serious games, it could be useful to structure challenge-type games in which, for each challenge or objective to be achieved, it could be useful to insert mechanisms of concentration and attention, which, once achieved, would allow to switch to schemes gameplay and subsequent challenges.

Results support this perspective, which should, in the future, be better assessed with experiments on the validity and effectiveness of attention, concentration and meditation training, overcoming the limits of the sample size and the variability of the types of addiction, experimenting the training also with subjects with gambling addiction or new addictions.

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