Title: Dynamics of the general factor of personality: a predictor mathematical tool of alcohol misuse

Short title: A dynamical model to predict alcohol misuse

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Abstract

There are few studies developed about the General Factor of Personality (GFP) dynamics. This paper uses a dynamical mathematical model, the response model, to predict the short-term effects of a dose of alcohol on GFP and reports the results of an alcohol intake experiment. The GFP dynamical mechanism of change is based on the Unique Trait Personality Theory (UTPT). This theory proposes the existence of GFP which occupies the apex of the hierarchy of personality. An experiment with 37 volunteers was performed. All the participants completed The Five-Adjective Scale of the General Factor of Personality (GFP-FAS) in trait-format (GFP-T) and state-format (GFP-S) before alcohol consumption. The participants in the experimental group (28) received 26.51 g. of alcohol and a slight food, while the participants in the control group (9) just received the food. Every participant filled the GFP-S each 7 minutes. The results show that GFP is modified by a single dose of alcohol: both the high scores of GFP-T and the high scores of GFP-S explain the most part of the alcohol impact. Moreover, they prove that the response model calibration to the GFP-S scores reproduces the biphasic GFP dynamics as a consequence of an alcohol dose intake described by the literature. In fact, the results also demonstrate that the response model provides the UTPT prediction: the high scores of GFP-T predict a stronger stimulant-like effect and a stronger inhibitor effect. Thus, the response model is a useful mathematical tool to predict those individuals inclined to the alcohol misuse.

Keywords: ordinary differential equation, integro-differential equation, dynamical stimulus-response model, multiple linear regression analysis, biphasic alcohol effects, alcohol misuse.

1. Introduction

It is well-known the social importance of alcohol consumption in the Western Society. The common consumption of alcohol in "suitable" doses is culturally accepted, despite the relationship of this consumption with personality disorders [1, 2]. However, the answers to what a suitable dose is or what a misuse is, depend on the individual personality. The capability of alcohol to induce stimulant effects and positive mood is thought to play a role in alcohol's abuse

liability [3, 4]. Thus, the problem addressed in this paper is how to know if an individual has a predisposition to the alcohol misuse. Particularly, this paper is an attempt to deepen into understanding of alcohol impact on an individual's personality using two mathematical approaches:

1. Multiple linear regression analysis.
2. A dynamical stimulus-response model, called briefly as response model.

The multiple linear regression analysis provides a first statistical evidence of the alcohol misuse. Subsequently, the response model provides the dynamical pattern of the personality response to an alcohol intake dose. It has two differentiated parts: (a) the stimulus, which is modeled by two coupled ordinary differential equations that have an analytical solution; (b) the dynamical response, which can also be modeled with two coupled ordinary differential equations, containing the analytical solution of the stimulus. However, the dynamical response has an equivalent version given by an integro-differential equation, which describes better the basic underlying psychological processes of the alcohol effects on personality. Both equivalent versions of the dynamical response are presented in this paper.

The response model has been developed in the context of the Unique Trait Personality Theory (UTPT), and it is used in the paper as a tool to predict the alcohol misuse. The UTPT [5, 6] is a system personality theory developed in the last years, which claims for a unique trait, later substituted by the equivalent concept of General Factor of Personality (GFP), to understand the overall human personality. A fundamental part of the paper to pursuit this objective is the performed experimental design with 37 participants. It has been set up to better understand the relationship between alcohol and personality in order to detect in advance those individuals inclined to alcohol misuse.

About the GFP concept, two approaches have recently emphasized the importance of GFP as an emergent field in personality theory. On the one hand, an approach to GFP deals with "the single general factor hypothesis", within the five-factor model, or other personality models. In this approach GFP occupies the apex of the hierarchy of personality factors [7-18].

On the other hand, the General Factor of Personality Questionnaire (GFPQ) proposed in [6] is presented as a questionnaire constructed specifically to assess GFP in the context of the UTPT. The UTPT can be summarized in three postulates that are developed in the following paragraphs.

The existence of GFP and the possibility of being measured is the first postulate of the UTPT. This theory proposes a hierarchical model where the highest level corresponds to GFP, which extends from an impulsiveness-and-aggressiveness pole (approach tendency) to an anxiety-and-introversion pole (avoidance tendency). This continuum represents a wide personality dimension named as extraversion [5, 6, 19, 20]. In this case, extraversion has a broader meaning than that generally implied in current personality research.

Another way to measure the GFP is the Five-Adjective Scale of the General Factor of Personality (GFP-FAS), whose validity and relationship with the GFPQ to measure the GFP has been proven [21, 22]. This scale has a trait-format (GFP-T) (how extraverted is an individual in general) and a state-format (GFP-S) (how extraverted is an individual in a concrete situation). Thus, the suitable way to measure the GFP dynamical response to a stimulus such as a stimulant drug is determining the time evolution of the GFP-S.

The existence of a biological base of the GFP is the second postulate of the UTPT. The UTPT considers extraversion (in its previously referred broader meaning) to be the psychological indicator of a physiological substrate of GFP: the general activation of the stress system (the activation level, for short). In this sense, this paper considers extraversion and activation level, respectively to be the equivalent psychological and physiological levels of description of GFP. Simultaneously, the activation level arises from the biological bases of GFP. These biological bases have been studied by assessing the dynamical response of the immediate-early gen DRD3 in blood when the stimuli are either methylphenidate or a self-regulation therapy [23], by assessing the dynamical response of the immediate-early gen c-fos [24], and by assessing the neurotransmitter glutamate in blood when the stimulus is methylphenidate [25]. The relationship between these three levels of description is unknown, and it takes part of a more general problem of science: the body-mind problem [26]. In fact, the work [26] attempts to deepen in the research of a relationship between extraversion and its biological bases, from a dynamical response invariance hypothesis.

The third postulate of the UTPT asserts that GFP has a dynamic nature, i.e., the GFP short term response as a consequence of a determined stimulus can be described by a dynamical stimulus-response model [19, 24, 26, 27, 28]. The UTPT allows as well a better understanding of the mutual influence between personality and the effect of stimulant drugs: the GFP-T measures the stable GFP while the GFP-S measures the situational personality as a consequence of the drug stimulus.

In fact, the UTPT predicts that the dynamical GFP response (identified by the time evolution of the GFP-S scores) has a typical inverted-U pattern [5, 6, 19, 20]. The inverted-U pattern was already identified by Solomon and Corbit [29], Grossberg [30] and Amigó [5], as the typical personality response to a stimulant drug. Moreover, these works report that, in the presence of a stimulus, the inverted-U is a consequence of a balance between three effects: a homeostatic control, an excitation effect and a delayed inhibitor effect. In fact, the balance of these effects provides as well the individual responses to a stimulant drug, which can be different to the inverted-U pattern.

Additionally, those individuals with higher GFP-T scores have higher excitation and inhibitor effects (measured by the time evolution of the GFP-S scores). Oppositely, the individuals with lower GFP-T scores have lower excitation and inhibitor effects (also measured by the time evolution of the GFP-S scores). Note that, although alcohol is considered a depressant drug, its acute effects reproduce generally an inverted-U, referred in the literature about alcohol as biphasic effect, similar to a stimulant drug, such as literature demonstrates (see below).

The third postulate of the UTPT supports as well a long term dynamics for GFP. Caselles et al. [20] present a long time term response model to evaluate personality as a consequence of a drug stimulus (cocaine).

About the acute effect of alcohol and its relationship with personality, there are evidences that alcohol produces both stimulant-like and sedative-like effects [32, 33], despite the alcohol is considered as a depressant substance of the Central Nervous System [33]. In fact, the Differentiator Model [34] supports that, as a consequence of alcohol intake, the individuals with a high risk of alcohol misuse experiment intensively the stimulant-like effect (or positive mood) in the first phase of the blood alcohol curve (BAC).

Two scales have been designed to assess the biphasic effect of alcohol: (a) the Biphasic Alcohol Effects Scale (BAES) [31] is a 14-item scale consisting of adjectives that describe the stimulant-like and sedative-like effects of alcohol, and (b) a brief version of the BAES, the B-BAES [35, 36], provided by a 6-item scale (energized, excited, up, sedated, slow thoughts, sluggish). In fact, the use of the scale provided in [31] has proved that alcohol consumption produces stimulant-like effects and increase the physical activity level (movements and expressions) [37]. In addition, low alcohol doses produce growths in the positive mood [32]. Those individuals that experiment stimulant-like effects after an alcohol dose also report about greater euphoria and liking levels, compared with those individuals that experiment mostly sedative-like effects [38-41].

The Psychomotor Stimulant Theory of Addiction [42] asserts that the shared pattern of all misuse drugs included alcohol is their capacity to produce psychomotor activation. From this theory, the biological mechanisms that underlie the psychomotor activation are similar to those effects of positive reinforcing of the misuse drugs.

Some individual conditions can influence on the alcohol acute effect. For instance, it has been proved that the alcohol biphasic response is different for light and heavy drinkers [43]. On the one hand, the light drinkers did not show a biphasic response and, on the other, the heavy drinkers felt strongly the alcohol euphoria and positive effects and felt lighter the alcohol sedative-like effects. In addition, it has been proved that social drinkers report greater stimulant-like subjective effects to alcohol than lighter drinkers [44].

Furthermore, there are evidences about the relationship between sensation-seeking and alcohol misuse and its problem consequences [45]. The role of sensation-seeking on the alcohol acute effects has also been studied. For instance, Ray et al. [46] reported that the high sensation-seekers increase more the stimulant-like effects such as “vigor” and reduce more the sedative-like effects than the low sensation-seekers. In addition, Fillmore et al. [47] found that the high sensation-seekers had a higher sensitivity to the subjective reinforcing alcohol effects and a higher damaged inhibitory control than the low sensation-seekers; the corresponding measures were done with cognitive tasks of information processing. These studies support the results of other researches, which assert that high sensation-seekers are more sensitive to the alcohol reinforcing effects, and they can become more sensitive to its effects than when experimenting tolerance to those effects. For instance, the priming alcohol dose can increase the euphoria sensation such as “liking” and “wanting to drink more”, as well as the repeated consumption and the alcohol seeking [48-51].

The proposals of the present study are to know:

(a) If the GFP-FAS, both in its trait version (GFP-T) and in its state version (GFP-S), is a good statistical predictor of the alcohol misuse.

(b) How the response model can reproduce the biphasic GFP dynamics as a consequence of an alcohol intake dose.

(c) How good the response model is as a mathematical tool to also predict the alcohol misuse.

To reach the aims of these proposals, two tools have been used: the response model and the Five-Adjective Scale of the General Factor of Personality (GFP-FAS), already validated [21, 22]. In addition, these aims will help to deepen in the relationship between personality (GFP) and the alcohol acute effects from a dynamical approach.

The dynamical GFP response to an alcohol dose intake is provided by the response model cited above. The response model is an integro-differential equation that has three fundamental terms to describe this dynamical response, which was already identified by Solomon and Corbit [29], Grossberg [30] and Amigó [5], as the typical personality response to a stimulant drug: the homeostatic control, the excitation effect and the delayed inhibitor effect. The numerical solutions of this equation for both the consumer group and for every individual consumer, observing that the solutions reproduce the corresponding experimental outcomes, make non-trivial the paper contribution.

Besides, the approach here presented is different to that presented in [52]. In that work, the alcohol misuse is studied as an epidemic model, where the *stimulus variable* plus the *stable personality variable* (GFP-FAS in its state version or GFP-S) (see Section 4) is substituted by an *information variable*. In other words, the alcohol misuse has an external cause to individuals in [52], given by the *information variable*, while in the response model the alcohol misuse has an internal cause at individuals, given by the *stimulus variable* plus the *stable personality variable*.

More details are provided in the paper sections. In Section 2 the experimental design is presented. Its results are analyzed in Section 3, where the statistical results provide that the GFP-T and the GFP-S are good predictors of the alcohol misuse. In Section 4 our response model is presented and explained. Section 5 deals with the calibration of the response model from the data obtained with the experimental design. The use of the response model as a mathematical tool to predict the alcohol misuse is developed in Section 6. The conclusions of the work are presented in Section 7, together with the paper discussion and criticisms.

2. The experimental design

Participants

Fifty volunteers presented to participate in the experiment, all of them from Valencia (Spain). Some selection rules were applied on them to be accepted as participants in the experiment:

(a) Do not have incompatible medication with alcohol.
(b) Come accompanied to the experiment.
(c) Do not work the day of the experiment.
(d) Do not be abstemious.
(e) Do not be alcoholic.
(f) For the control group: have had bad experiences with alcohol.

These selection rules provided thirty seven participants, divided into two groups: the experimental group (28 alcohol consumers) and the control group (9 non consumers). From them there were 10 males (27%) and 27 females (73%). The mean age was 32.84 (SD=11) with ages ranging between 20 and 55 years. The mean weight was 64.18 kg with weights ranging between 50 and 94 kg.

Instruments

The Five-Adjective Scale of the General Factor of Personality (GFP-FAS) [21, 22] was used to measure the GFP. The 5 adjectives are: adventurous, daring, enthusiastic, merry and

bored. The GFP-FAS is related with the Big Five traits and it can integrate all basic traits of personality [22]. Concretely, the GFP-FAS is related positively with Extraversion, Agreeableness and Openness, and negatively with Neuroticism and Conscientiousness.

In the context of the experimental design two versions of the GFP-FAS were used: the trait-format version (GFP-T) ("How are you in general in your life?") and the state-format version (GFP-S) ("Are you like this at this moment?" or "do you feel so at this moment?"). All participants filled out the state-format version form each seven minutes to obtain a situational measure of the GFP.

Dose of alcohol: 26.51 g.

Procedure

The procedure begins requesting all the participants to refrain from consuming alcohol since the afternoon prior to the experiment. They had to assist with an empty stomach at ten o'clock in the morning. Once they were all together in the room where the experiment had to take place, they filled in the two forms corresponding to the two lists of adjectives of the GFP-FAS in its trait and state formats. Next, the 28 consumers group had two glasses of red wine with a total amount of 26.51 g of alcohol (280 ml of red wine with a concentration of 12% alcohol). This consumption was accompanied by a slight piece of bread (50 g) with cured ham (20 g). The 9 controls group only had the food. Subsequently, in order to observe the corresponding dynamical response, the participants filled, for 126 minutes, a form with the GFP-FAS state version list of adjectives each 7 minutes, until a total of 18 registers. This method permits a short-term (126 minutes) variation register of the individual's personality. Note that the referred adjectives in the state format represent situational aspects of personality.

The placebo effect has not been considered in this study design because the purpose of this study was not to distinguish the effect of alcohol from the effect of other variables (such as, for instance, suggestion, type of instructions, hour of the day, or mood). The interest of the experiment centers on the study of the short-term dynamic change of personality, which is measured from a list of adjectives and produced by ingesting a substance, such as alcohol.

3. Statistical results

The statistical results are presented and analyzed in this section. The first objective of this analysis is to compare both groups: the experimental group (EG) and the control group (CG). The groups are compared by using the General Factor of Personality-Trait (GFP-T) and the General Factor of Personality-State (GFP-S) variables, as well as the variable representing the averages of the scores obtained from the 18 GFP-S time registers (M18). The M18 variable has been chosen as representative of the alcohol dose impact. The reason is that methods such as the repeated measure tests and the temporal series analysis are not suitable for a statistical approach due to: (a) the measures are not independent, they are related by a causal dynamics; (b) the amount of measures is not enough to set up a method of temporal series; in fact, the response model is used to deepen into the nature of this impact.

The statistical method used for the purpose above mentioned is the non-parametric MannWhitney-U test to obtain the mean differences between the GFP-T, the GFP-S and the M18 variables. The results are shown in Table 1.

Please insert Table 1, about here

From Table 1 it can be observed that there are no significant differences between the personality variables of the EG and the CG. However, the M18 variable after the alcohol intake is significantly higher in the EG cases than in the CG cases (that did not have the alcohol dose).

Focusing on the beginning of the relationships between the GFP-T and GFP-S variables and the M18 variable after the alcohol intake, Table 2 presents the corresponding correlation matrix.

Please insert Table 2, about here

From Table 2 it can be observed that the GFP-T correlates significantly and positively with the GFP-S. In addition, both variables are related with a greater score after the alcohol intake.

Table 3 presents the results of a linear multiple regression analysis, with M18 as dependent variable and GFP-T, GFP-S, weight, age and gender as independent ones.

Please insert Table 3, about here

Note that, in Table 3 the GFP-T variable is the predictor of the M18 variable after the alcohol intake. When the GFP-T variable is removed from the regression equation the corresponding results are presented in Table 4.

Please insert Table 4, about here

Although the use of the M18 variable to assess the alcohol dose impact has been justified above, the M18 variable is only an additive variable. Therefore, there is no possibility to study the dynamics of the alcohol dose impact with the M18 variable.

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The conclusion of this section is that the GFP-T and the GFP-S are good statistical predictors of the alcohol misuse, answering positively to the paper proposal (a) of Section 1.

4. The response model

A stimulus-response model (briefly, the *response model* for the particular one here presented) is a mathematical tool used to compute the short term dynamics of the GFP as a result of a stimulus produced by a single dose intake of a drug, as a generalization of the model provided in [19]. Particularly, the next section demonstrates that the response model is also capable to compute the short term dynamics of the GFP as a result of a single dose intake of alcohol. Now, let us present the response model in the following paragraphs, particularized for a single dose of alcohol.

The stimulus of the response model provides the evolution of the alcohol amount in organism after being consumed by an individual. It is given by two coupled ordinary differential equations:

$$\left.\begin{array}{c} \frac{dm(t)}{dt} = -\alpha \cdot m(t) \\ m(0) = M \end{array}\right\} \tag{1}$$

$$\left.\begin{array}{c} \frac{ds(t)}{dt} = \alpha \cdot m(t) - \beta \cdot s(t) \\ s(0) = s_0 \end{array}\right\} \tag{2}$$

In (1) $m(t)$ is the non-assimilated alcohol amount, M is the initial amount of alcohol of a single dose and α is the alcohol assimilation rate. In (2) $s(t)$ represents the stimulus, i.e., the amount in organism of the alcohol non-consumed by cells, s_0 is the amount of alcohol present in organism before the dose intake, and β is the alcohol metabolizing rate. The analytical solution of the stimulus as a function of time t is obtained by integrating the system (1) - (2):

$$s(t) = \begin{cases} \frac{\alpha \cdot M}{\beta - \alpha}\left(e^{-\alpha \cdot t} - e^{-\beta \cdot t}\right) : \ \alpha \neq \beta \\ \alpha \cdot M \cdot t \cdot e^{-\alpha \cdot t} : \ \alpha = \beta \end{cases} \tag{3}$$

Eq. 3 assumes that $s_0 = 0$ due to the experimental conditions explained in Section 2, which obligates the participants to the non-alcohol consumption since the afternoon prior to the experiment.

The dynamics of the GFP is given by the following two coupled ordinary differential equations:

$$\left.\begin{array}{c} \frac{dy(t)}{dt} = a(b - y(t)) + \frac{p}{b}s(t) - b \cdot q \cdot z(t) \\ y(0) = y_0 \end{array}\right\} \tag{4}$$

$$\left.\begin{array}{c} \frac{dz(t)}{dt} = -\frac{z(t)}{\tau} + s(t) \cdot y(t) \\ z(0) = 0 \end{array}\right\} \tag{5}$$

In Eqs. 4 and 5, $s(t)$ represents the stimulus given by Eq. 3; $y(t)$ represents the GFP dynamics; and b and $y0$ are respectively its tonic level and its initial value.

The dynamics of Eq. 4 is a balance of three terms, which provide the time derivative of the GFP: the homeostatic control ($a(b - y(t))$), i.e., the cause of the fast recovering of the tonic level b, the excitation effect ($\frac{p}{b}s(t)$), which tends to increase the GFP, and the inhibitor effect ($b \cdot q \cdot z(t)$), which tends to decrease the GFP and is the cause of a continuously delayed recovering, given by Eq. 5. Parameters a, p, q and τ are named respectively the homeostatic control power, the excitation effect power, the inhibitor effect power and the inhibitor effect delay. All the parameters of the model depend on the individual personality or individual biology and on the type of stimulus, alcohol for the present case. It is important to stress the correct interpretation of the tonic level b: its value is situational and depends on the individual and the kind of stimulus.

Eqs. 3, 4 and 5 define the response model. It reproduces the dynamic patterns forecasted in the works [5, 29, 30], and thus, it can be considered theoretically validated through the scientific literature about the subject [19].

In the present experiment, the dose unit is M=26.51 g of alcohol and the time unit is one minute. The most important variable is the GFP variable $y(t)$. In the work [19] the extraversion unit is the theoretical hedonic scale unit, which was also used in the works [29, 30] for the same variable to theoretically quantify the effect of a drug on an individual. Nevertheless, if a model like the one presented here has to be calibrated, the representative variable must be observable, that is, it can be reproduced in an experiment. Following this idea, in the present work the GFP variable has been measured by the Five-Adjective Scale of the General Factor of Personality (GFP-FAS) [21, 22], whose range of variation is [0, 25], i.e., a measure in the psychological level of description.

To better understand how to use the response model as a tool to predict the alcohol misuse, it must be rewritten in another way by integrating Eq. 5 and substituting it in Eq. 4:

$$\left.\begin{array}{c} \frac{dy(t)}{dt} = a(b - y(t)) + \frac{p}{b}s(t) - b \cdot q \cdot \int_0^t e^{\frac{x-t}{\tau}} \cdot s(x) \cdot y(x)\, dx \\ y(0) = y_0 \end{array}\right\} \quad (6)$$

Note that Eq. 6 is an integro-differential equation. Jointly to Eq. 3 represents an equivalent version of the response model. In Eq. 6 the inhibitor effect is proportional to the product of the stimulus and the GFP variable, $s(x) \cdot y(x)$, continuously delayed with the weight $e^{\frac{x-t}{\tau}}$. In other words, Eq. 6 can also be identified as a continuous-delay differential equation, which is a generalization of the equation presented in the work [19]:

$$\left.\begin{array}{c} \frac{dy(t)}{dt} = a(b - y(t)) + \frac{p}{b}s(t) - b \cdot q \cdot s(x - \tau) \cdot y(x - \tau) \\ y(0) = y_0 \end{array}\right\} \quad (7)$$

i.e., a discrete-delay differential equation (also known in the mathematical literature as difference-differential equation).

Both Eqs. 6 and 7 provide the dynamic patterns forecasted in [5, 29, 30], i.e., a dynamical pattern with a balance between two terms in which the stimulus is present ($s(t)>0$): an excitation effect (similar to the stimulant-like effect, for alcohol) and a delayed inhibitor effect (similar to the sedative-like effect, for alcohol). In addition, the homeostatic control, $a(b-y(t))$, is essential for the convergence of their solutions to a tonic level $b>0$.

Once the model is calibrated for an individual, the *excitation effect intensity* is represented by the individual excitation effect power value divided by the tonic level, p/b, and the *inhibitor effect intensity* is represented by the individual inhibitor effect power value multiplied by the tonic level, $b \cdot q$. Thus, both terms, p/b and $b \cdot q$, represent the corresponding individual intensities of the excitation effect and the delayed inhibitor effect demanded by the dynamic patterns forecasted in the works [5, 29, 30].

On the other hand, the assertion of the third UTPT postulate (see Section 1) must be taken into account: those individuals with higher GFP-T scores have higher excitation and inhibitor effects, and oppositely, the individuals with lower GFP-T have lower excitation and inhibitor effects. Therefore, the p/b and $b \cdot q$ terms are interpreted in the following way: the more inclination to the individual alcohol misuse (with higher GFP-T scores), the greater the individual excitation effect intensity value, p/b, and the greater the inhibitor effect intensity value, $b \cdot q$, must be held; and oppositely, the lesser inclination to the individual alcohol misuse (with lower GFP-T scores), the lower the individual excitation effect intensity value, p/b, and the lower the inhibitor effect intensity value, $b \cdot q$, must also be held.

In fact, it is demonstrated in Section 6 that, in the context of the experimental group, the more extraverts (those individuals with a greater GFP-T) have a greater excitation effect intensity value and a greater inhibitor effect intensity value, while the more introverts (those individuals with a lesser GFP-T) have a lesser excitation effect intensity value and a lesser inhibitor effect intensity value.

Note that the relationship exposed between the stable personality, measured by the GFP-T scores, and the dynamics consequence of an alcohol dose intake, is done by using the response model given by Eqs. 3 and 6, and not by Eqs. 3, 4 and 5. However, Eqs. 3 and 6 are much more complex to handle mathematically than Eqs. 3, 4 and 5, due to its integral term. Therefore, in practice, the response model given by Eqs. 3, 4 and 5 is used to obtain the numerical solutions of the response model.

5. Calibration of the response model

The aim of this section is to calibrate the response model, given by Eqs. 3, 4 and 5 (equivalent to Eqs. 3 and 6). The chosen way is to compare the experimental data obtained from the lists of the GFP-S scores provided by the experimental subjects with the theoretical values of the $y(t)$ model variable. The calibration method minimizes the difference between the quadratic sum (QS) and the determination coefficient (R^2) of both sets of data (experimental and theoretical ones), i.e., QS-R^2. It implies the simultaneous minimization of the quadratic sum (QS) and the maximization of the determination coefficient (R^2). This method has become more successful than just minimizing QS or just maximizing R^2. In fact, the method provides very high R^2 and random residuals.

Deepening in the calibration method details, note that to obtain the theoretical values of the model, first of all an arbitrary value belonging to a determined scale is assigned to each model parameter, and the theoretical values from Eqs. 3, 4 and 5 are computed. Subsequently the method generates random numbers for each model parameter obligated to vary inside the determined scale, choosing those values that make lesser QS-R^2. In each step of this model the theoretical values are computed numerically by solving the response model through Eqs. 3, 4 and 5 with the 4th order Runge-Kutta method. In addition, the optimization procedure follows a basic genetic algorithm which includes: (1) first random population generation, (2) ordering and selection, (3) random immigration, (4) random reproduction (with random mutation) up to completing population, (5) new ordering and selection, (6) checking the end condition: if yes then exit routine else go to (3). The end condition is: "no lesser QS-R^2 values are observed". The method has been developed in a C++ program [53], and their results have been plotted by using the last version of MATHEMATICA [54].

Observe in addition that in the method development the initial value of Eq. 4, y_0, is known because it is the GFP-S value before the alcohol intake. The amount of alcohol consumed for an individual of the experimental group is M=26.51 g. However, the response model is also fitted to the dynamical response given by the GFP-S values for the control group, in order to demonstrate the universality of the response model. The implicit hypothesis in this test is that this mathematical structure also reproduces the dynamical response to an atmosphere stimulus. The common initial condition, including food intake, with the alcohol consumers, can be considered as stimulant, plus a subsequent subjective process of boring, which can be considered as depressant. Note, however, that it is assumed that the mathematical structure of the stimulus is also represented by Eq. 3 to make this fitting. Thus, for the control group, the amount of alcohol must be also calibrated. The model parameters and their symbols, scales and starting values used in the above explained minimization method, are presented in Table 5 for both groups.

Please insert Table 5, about here

In Table 5 the scales and the initial values of M, τ, α, β, a, p and q model parameters have been chosen by previous simulations of the calibration method that provide similar values than the ones provided by the time averages of GFP-S of the experimental group. Obviously, the scale and the initial value of the b model parameter must keep varying inside the experimental scale of GFP-S scores.

The results of the calibration method are those corresponding to the experimental group (Case 0) and the control group (Control 0), represented by their GFP-S time averages. Besides, the results of the individual experimental cases (Case 1 to Case 28) and of the individual control cases (Control 1 to Control 9). On the one hand, Figures 1 to 5 provide:

1. The joint experimental GFP-S and theoretical (calibrated) dynamical responses to the alcohol intake (plus food consumption) at short time term (acute effect) for Cases 0 to 28.
2. The joint experimental GFP-S and theoretical (calibrated) dynamical responses to the boring stimulus (plus food consumption) at short time term (acute effect) for Controls 0 to 9.

In addition, Table 6 provides the corresponding fitting level by the determination coefficient (R^2) as well as the residuals' randomness by the p-value of the Anderson-Darling test. This test reports if the residuals distribute as a N(0,std), i.e., as a Normal distribution of zero mean and constant standard deviation (std), being std the standard deviation of the residuals. Observe that p-values greater than 0.05 must be obtained in favor of the Null Hypothesis (H_0: the residuals distribute as a N(0,std)) opposite the Alternative Hypothesis (H_1: the residuals do not distribute as a N(0,std)).

Please insert Table 6, about here

On the other hand, Table 7 presents the outcomes of the optimal model parameters (consequence of the calibration method described above) for Cases 0 to 28 and Controls 0 to 9.

Please insert Table 7, about here

Note that Figure 1 for Case 0, corresponding to the time averages of the experimental group, reproduces the biphasic pattern supported by the specialized literature cited in Section 1. In fact Table 6 shows for this case that the response model fits significantly the biphasic effect with a 0.97 determination coefficient (i.e., the GFP-S acute response to alcohol intake is explained in a 97% by the model). This determination coefficient value indicates a very low dispersion of results, given by the residuals, whose p-value Anderson-Darling test is 0.97, i.e., clearly random.

Please insert Figure 1, about here

Besides, the control group reports that the atmosphere stimulus (previous common food intake with the alcohol consumers plus a boring process) has a very small effect compared with the one of alcohol intake (see below). The joined results of both the experimental and the theoretical values (consequence of the minimization method described above) versus time for Control 0 (control group) are represented in Figure 1 for Control 0. The outcomes for the optimal model parameters (consequence of the calibration method described above) are presented in Table 7 for Control 0. Note that Figure 1 for Control 0 reproduces a first slight stimulant-like effect, followed by a strong sedative-like effect, using the time means of the control group GFP-S. Thus, the control group would also reproduce a biphasic pattern. However, the slight first stimulant-like effect can be interpreted as a consequence of the previous common food intake, while the subsequent strong sedative-like effect can be interpreted as a consequence of the boring subjective sensations of the control individuals. Thus, the very low stimulant-like effect must be stressed in order to value the most important contribution of the alcohol intake in the experimental group. Note in addition that the response model fits as well significantly this response with a 0.91 determination coefficient, but with more dispersion than for the experimental group. Thus, this determination coefficient indicates that the response model can also explain the combined effect on the GFP-S of two continuous stimuli: food consumption plus boring, with 91% significance. Observe that the level of dispersion is greater for the control group. It indicates that the effect of the only atmosphere stimulus presents greater inter-

individual differences than when the alcohol intake stimulus is added. However, again the residuals are clearly random due to the Anderson-Darling test p-value is 0.92 (Table 6 for Control 0).

Figures 1 to 4 reproduce the individual differences of Cases 1 to 28 of the experimental group. Table 7 reports the corresponding optimal values of the model parameters. From the observation of these figures a general conclusion can be obtained: the effect of the alcohol intake reproduces mostly the biphasic response (23 subjects of 28). However, there is a little group that presents either a boring response (Case 2 and Case 11) or a non-pattern response (Cases 13, 15 and 28). This variability of responses represents the individual differences of the response to a single alcohol intake.

Please insert Figure 2, about here
Please insert Figure 3, about here
Please insert Figure 4, about here

Besides, the response model fits with a low determination coefficient (plus a high dispersion) for those cases that represent a dominant boring response: R^2=0.31 for Case 2 and R^2=0.41 for Case 11. The determination coefficient is even lower for those cases that present no appreciable response: R^2=0.14 for Case 13, R^2=0.14 for Case 15 and R^2=0.19 for Case 28. The remaining 23 cases for which the responses have a clear biphasic response range with determination coefficients between R^2=0.38 and R^2=0.96. Case 5 must be stressed because its response has not the sedative-like effect, with R^2=0.95. In general, in the subgroup of the 23 cases that reproduce the biphasic effect, the phenomenon "the higher the R^2 the lower the dispersion" is observed. This fact can be much more appreciated in those cases where R^2 is greater than 0.75: Case 1 (R^2=0.88), Case 4 (R^2=0.80), Case 5 (R^2=0.96, without sedative-like effect), Case 6 (R^2=0.76), Case 8 (R^2=0.83), Case 9 (R^2=0.95), Case 12 (R^2=0.96), Case 16 (R^2=0.93), Case 17 (R^2=0.91), Case 19 (R^2=0.88), Case 21 (R^2=0.87), Case 22 (R^2=0.93), Case 23 (R^2=0.83), Case 25 (R^2=0.94) and Case 26 (R^2=0.78).

Note in addition, in Table 6, that the Anderson-Darling tests for the corresponding residuals provide significant p-values (significantly greater than 0.05) for the 28 consumer cases. These outcomes mean that the residuals always hold Normal distributions of zero averages and constant standard deviations, i.e., the dispersions are actually random.

Therefore, the results provided for the individual cases of the experimental group jointly with the time-means of this group point out the validation of the response model to reproduce the biphasic dynamical response as a consequence of an alcohol intake, at short time term.

Figures 4 and 5 reproduce the individual differences of Controls 1 to 9, belonging to the control group. Table 7 reports the corresponding optimal values of the model parameters. From the observation of these figures the general conclusion is that non-alcohol consumers reproduce a slight excitation effect followed for a stronger inhibitor one. The first excitation effect is explainable by the expectations created by the food consumption and by a passing on due to the group atmosphere created by the alcohol consumption of neighbors.

Please insert Figure 5, about here

Note again that the Anderson-Darling tests, in Table 6, for the corresponding residuals provide significant p-values (significantly greater than 0.05) for the 9 control non-alcohol consumer cases. Again these outcomes report that the residuals always hold Normal distributions of zero averages and constant standard deviations, i.e., the dispersions are actually random.

Therefore, the results provided for the individual cases of the control group, jointly with the corresponding time-means of this group, point out the validity of the response model to reproduce even the dynamical GFP-S response of an individual as a consequence of a subjective atmosphere stimulus (such as group food intake plus boring sensation), also at short time term, which demonstrates the potential universality of the response model.

The conclusion of this section is that the response model is capable to reproduce the biphasic GFP dynamics as a consequence of an alcohol intake dose, such as the proposal (b) of Section 1 asserts.

6. The response model and the alcohol misuse

This section is devoted to the use of the response model as a predictor of the alcohol misuse. To do this, the following items must be brought from the above parts of the paper:

1. Alcohol intake produces a biphasic response that literature supports. The biphasic response consists of a stimulant-like effect followed by a sedative-like effect.
2. The response model describes mathematically the two effects of a stimulus: the so-called excitation effect (or stimulant-like effect, for the alcohol intake) and the inhibitor effect (or sedative-like effect, for the alcohol intake).
3. The excitation effect power parameter p and the inhibitor effect power parameter q provide, respectively, the excitation and inhibitor effect intensities of a given stimulus on a given individual (represented by p/b and $q \cdot b$ in Eqs. 6 and 7), and thus, of the stimulant-like and sedative-like effects.

From these items developed along the paper, the objective of this section is to demonstrate that the greater the GFP-T scores, the greater the excitation effect and the inhibitor effect intensities, and vice versa, i.e., the lesser the GFP-T scores, the lesser the excitation effect and the inhibitor effect intensities, such as the UTPT predicts. Focused on the alcohol intake, this demonstration will imply that the more extraverted an individual is, the more inclined to the alcohol consumption will be, including its misuse.

To reach this demonstration in the context of the presented experimental design, the experimental group (EG) is divided into two subgroups, both with 12 individuals: the introverted group (IEG), or the consumers that have a GFP-T scores lesser than the median (17) and the extraverted group (EEG), or the consumers that have a GFP-T scores greater than the median, also considering their b, p and q values obtained from the model calibration in Section 5. Note that the four individuals with median 17 have been removed from this analysis to separate significantly both groups. The results are presented in Table 8.

Please insert Table 8, about here

At a starting point, a Mann-Whitney test is performed to reach the objective. The results are presented in Table 9.

Please insert Table 9, about here

Note that the results of the Mann-Whitney test confirm that the more introverted group (those with lesser GFP-T, below median) has a lesser value for p/b and $b \cdot q$ intensities, and thus, lesser stimulant-like and sedative-like effects, as a consequence of the alcohol intake. And, vice versa, the more extraverted group (those with greater GFP-T, above median) has a greater value for p/b and $b \cdot q$ intensities, and thus, greater stimulant-like and sedative-like effects, as a consequence of the alcohol intake. The consequence of this test with the experimental group is that the GFP-T scores, i.e., the GFP-FAS in its trait format, along with the response model, are good predictors of the alcohol misuse, such as the proposal (c) of Section 1 asserts.

7. Conclusion

This paper has analyzed the short time dynamics of the GFP as a consequence of a single intake dose of alcohol. It has been found that the effect produced by the alcohol consumption is greater for those individuals with a higher GFP score, both at trait level (GFP-T) and at state level (GFP-S), measured by their group averages.

In addition, it has been demonstrated that a single dose of alcohol produces a biphasic effect that can be reproduced by the response model. Moreover, the response model can also reproduce the dynamics of subjective atmosphere effects, such as the ones found in the control group: a brief and minor stimulating effect at the beginning followed by a prolonged sedative-like effect (inhibiting) at the remaining time of the experiment, due to the lack of activity of the subjects, since they had to spend their time with a very low level of stimulation. However, a future research should consider the responses to the alcohol consumption at long time term, where different doses and different frequency patterns must be considered, such as the one presented in the work [20], where the drug considered is cocaine.

Note that, once the response model is calibrated for the experimental group, there exists a close relationship between the stable personality, measured by the GFP-T scores, and the biphasic effect of alcohol. In fact, the extraverted individuals (those individuals with greater GFP-T scores), feel greater stimulant-like and sedative-like effects than the introverted individuals (those with lesser GFP-T scores).

However, it is well known that the acute effect of alcohol consumption can vary depending on the personal and/or atmosphere circumstances. The study [55] concluded that an alcohol dose does not improve the mood when the consumption is done in a previous pleasant atmosphere, but the mood and the happiness does improve if the previous atmosphere is unpleasant. Nevertheless, the consumption of alcohol accompanied with food consumption also produces biphasic effects in the mood, but the sedative-like effects can start before if only food is consumed.

Due to the experimental atmosphere was pleasant in the present study, it could be expected that the best predictor of the alcohol effect was the GFP-T more than the GFP-S. In fact, the multiple regression analysis has demonstrated this expectation: the GFP-T is the best predictor of the acute alcohol effect measured by the M18 variable along the 126 minutes of the

experiment. Thus, the GFP-S effect is also very relevant in the present study through the M18 variable. In addition, as it has been demonstrated, a higher activation level at the beginning of the experiment (due to the stimulant atmosphere conditions) is also a good predictor of the alcohol effect. These results are also coherent with the UTPT due to the individuals with a higher level of GFP-T are who present higher levels of GFP-S in stimulant atmosphere conditions.

The present study about alcohol intake, as a depressant of the Central Nervous System, provides a mathematical approach to study the dynamics of the relation between personality and alcohol consumption, which fills an important gap in studies about alcohol effects. In general, there are many studies that relate personality with the use or misuse of alcohol, even with the effect of single doses, but this study presents an original approach provided by a dynamical relationship between these variables. Note that it is not just a relational approach, but it is an approach supported by a basic theory, the Unique Trait Personality Theory (UTPT). And this theory has the quality that explains the underlying psycho-physiological processes of the General Factor of Personality (GFP): one of the more booming topics of the current Psychology.

CONFLICTS OF INTEREST

This work does not have any conflicts of interest.

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TABLES

TABLE 1 Results of the MannWhitney-U test to obtain the significant differences between the GFP-T, the GFP-S and the M18 variables for two groups

	Group	Rang average	*U*	Significance
GFP-T	Experimental	20,70	78.5	.093
	Control	13,62		
GFP-S	Experimental	18,36	108	.522
	Control	21		
M18	Experimental	22.13	38.5	.002
	Control	9.28		

TABLE 2 Correlation matrix. *The correlation is significant at the 0.05 level (2 queues)

	GFP-T	***GFP-S***
GFP-S	.43*	
M18	.47*	.41*

TABLE 3 Linear multiple regression analysis. M18 is the dependent variable, and GFP-T, GFP-S, weight, age and gender are the independent ones. The fitted R^2 is 0.198

	B	**Beta**	**t**	**Significance**
GFP-T	.54	.47	2.77	.010

TABLE 4 Linear multiple regression analysis. M18 is the dependent variable, and GFP-S, weight, age and gender are the independent ones. The fitted R^2 is 0.337

	B	**Beta**	**t**	**Significance**
GFP-S	.47	.69	3.80	.001
Weight	-.11	-.53	-2.93	.007

TABLE 5 Symbols, scales and starting values of the model parameters

Parameter symbol	**Name**	**Scale**	**Initial value**
M	Amount of alcohol (experimental group)	[26.51, 26.51]	26.51
M	Amount of alcohol (control group)	[0, 50]	25
τ	Inhibitor effect delay	[0, 1000]	60
α	Alcohol assimilation rate	[0.025, 0.046]	0.028
β	Alcohol metabolizing rate	[0.003, 0.023]	0.008
a	Homeostatic control power	[0, 10]	0.1
b	Tonic level	[0, 25]	12.5
p	Excitation effect power	[0, 100]	10
q	Inhibitor effect power	[0, 10]	0.001

TABLE 6 Determination coefficients R^2 and *p*-values obtained for Cases 0 to 28 and Controls 0 to 9

	Case 0	Control 0	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
R^2	0.97	0.91	0.88	0.31	0.38	0.80	0.96	0.76	0.69
p-value	0.97	0.92	0.88	0.99	0.77	0.81	0.17	0.64	0.83
	Case 8	**Case 9**	**Case 10**	**Case 11**	**Case 12**	**Case 13**	**Case 14**	**Case 15**	**Case 16**
R^2	0.83	0.95	0.53	0.41	0.96	0.14	0.69	0.14	0.93
P-value	0.91	0.84	0.98	0.32	0.86	0.90	0.52	0.44	0.98
	Case 17	**Case 18**	**Case 19**	**Case 20**	**Case 21**	**Case 22**	**Case 23**	**Case 24**	**Case 25**
R^2	0.91	0.64	0.88	0.47	0.87	0.93	0.83	0.64	0.94
P-value	0.86	0.95	0.99	0.23	0.86	0.97	0.67	0.74	0.85
	Case 26	**Case 27**	**Case 28**	**Control 1**	**Control 2**	**Control 3**	**Control 4**	**Control 5**	**Control 6**
R^2	0.78	0.42	0.19	0.30	0.30	0.71	0.90	0.91	0.67
P-value	0.52	0.48	0.66	0.18	0.76	0.81	0.35	0.90	0.87
	Control 7	**Control 8**	**Control 9**						
R^2	0.01	0.40	0.91						
P-value	0.23	0.99	0.93						

TABLE 7 Optimal values of the model parameters for Cases 0 to 28 and Controls 0 to 9

	Case 0	*Control 0*	*Case 1*	*Case 2*	*Case 3*	*Case 4*	*Case 5*	*Case 6*	*Case 7*
M	*26.51*	*1.0261*	*26.51*	*26.51*	*26.51*	*26.51*	*26.51*	*26.51*	*26.51*
τ	*2.4405*	*6.3705*	*0.0551*	*0.1075*	*0.1039*	*20.6352*	*1.3199*	*14.8255*	*0.0682*
α	*0.0426*	*0.03485*	*0.0363*	*0.0293*	*0.0256*	*0.0329*	*0.0265*	*0.0459*	*0.0268*
β	*0.0221*	*0.0174*	*0.0215*	*0.0199*	*0.0213*	*0.0038*	*0.0030*	*0.0136*	*0.0128*
a	2.9221	0.0077	0.0661	0.0668	0.0108	0.1030	0.2337	0.0000	0.3473
b	10.9280	22.6692	13.9678	20.3849	9.0549	17.8932	9.1928	6.4516	12.4832
p	27.0957	0.0000	0.5197	1.2868	0.0968	1.3489	1.7861	0.7564	1.2696
q	0.0015	0.00016	0.0000	0.0019	0.0000	0.0000	0.0000	0.0001	0.0003

	Case 8	**Case 9**	**Case 10**	**Case 11**	**Case 12**	**Case 13**	**Case 14**	**Case 15**	**Case 16**
M	26.51	26.51	26.51	26.51	26.51	26.51	26.51	26.51	26.51
τ	2.2038	936.553	0.1120	0.1545	141.2663	3.4422	4.2928	5.1965	897.216
α	0.0301	0.0250	0.0327	0.0251	0.0253	0.0459	0.0458	0.0312	0.0254
β	0.0218	0.0031	0.0224	0.0070	0.0030	0.0229	0.0228	0.0034	0.0030
a	0.2650	0.4021	7.5506	1.2598	0.0172	7.4902	1.8658	0.1697	0.1447
b	0.5052	17.1318	11.2099	17.4568	16.1827	14.4683	10.8517	13.2980	12.3093
p	0.2221	3.25928	52.9382	0.0072	0.5005	0.0000	35.9046	6.6503	3.0004
q	0.0009	0.0000	0.0000	0.0035	0.0000	0.0038	0.0025	0.0003	0.0000

	Case 17	**Case 18**	**Case 19**	**Case 20**	**Case 21**	**Case 22**	**Case 23**	**Case 24**	**Case 25**
M	26.51	26.51	26.51	26.51	26.51	26.51	26.51	26.51	26.51
τ	3.8758	10.0854	6.3883	7.8665	9.0528	3.8448	17.3334	33.7899	54.2456
α	0.0342	0.0365	0.0458	0.0459	0.0260	0.0432	0.0457	0.0286	0.0251
β	0.0145	0.0229	0.0226	0.0229	0.0030	0.0219	0.0228	0.0030	0.0030
a	0.1374	0.1662	2.5354	5.3488	0.0136	0.3061	0.3727	0.1022	0.8638
b	8.0813	11.3733	9.2194	9.0043	10.7994	9.5180	6.4080	12.5373	13.8999
p	2.2194	5.0588	55.3253	47.6736	0.7172	5.8388	4.6969	2.3656	10.8027
q	0.0004	0.0001	0.0025	0.0024	0.0000	0.0003	0.0003	0.0000	0.0000

	Case 26	**Case 27**	**Case 28**	**Control 1**	**Control 2**	**Control 3**	**Control 4**	**Control 5**	**Control 6**
M	26.51	26.51	26.51	19.2333	0.0498	0.3297	0.8212	0.0405	0.7499
τ	5.1981	2.7465	0.0690	0.5628	25.2572	0.8458	60.3497	239.380	17.9897
α	0.0459	0.0280	0.0439	0.0260	0.0411	0.0327	0.0252	0.0458	0.0459
β	0.0227	0.0226	0.0030	0.0158	0.0229	0.0162	0.0030	0.0126	0.0227
a	0.3387	1.0186	0.0000	0.2157	0.0449	0.0120	0.0169	0.0038	0.0576
b	4.7175	3.8028	19.0742	8.4465	16.5634	19.8458	13.0989	19.6029	17.7955
p	2.5612	12.9915	0.0100	24.7391	2.7564	1.1420	17.1592	2.7944	0.0000
q	0.0009	0.0072	0.0000	0.0454	0.0017	0.0030	0.0003	0.0003	0.0004

	Control 7	**Control 8**	**Control 9**
M	0.7499	1.7799	3.1515

τ	18.8109	8.3392	21.1891
α	0.4014	0.0459	0.0252
β	0.0250	0.0229	0.0030
a	0.0127	0.1364	0.0815
b	3.1536	16.0507	17.7421
p	11.1135	5.2976	8.1165
q	0.0000	0.0003	0.0001

TABLE 8 Introverted (IEG) and extroverted (EEG) groups extracted from the experimental group, classified by the *GFP-T* values, with the corresponding *p/b* excitation effect intensity values and the *b·q* inhibitor effect intensity values

	GFP-T	Cases	*p/b*	*q·b*
IEG	12	Case 12	0.030933	4.85E-05
	13	Case 6	0.117248	0.000658
	13	Case 26	0.542932	0.004392
	14	Case 1	0.037207	0
	14	Case 8	0.017795	0.011285
	14	Case 18	0.444795	0.001399
	15	Case 3	0.0107	0
	15	Case 7	0.10171	0.003882
	15	Case 9	0.190248	0.000308
	15	Case 16	0.243755	0.000123
	16	Case 5	0.194302	0.000257
	16	Case 21	0.066412	7.56E-05
EEG	18	Case 2	0.063129	0.039751
	18	Case 10	4.72245	0
	18	Case 11	0.000416	0.062338
	18	Case 20	5.294506	0.022016
	18	Case 23	0.732976	0.002243
	19	Case 27	3.416301	0.027597
	19	Case 28	0.000528	0
	20	Case 19	6.000926	0.023888
	20	Case 25	0.777177	0.000375
	21	Case 15	0.500103	0.004282
	22	Case 14	3.308653	0.027336
	23	Case 22	0.61345	0.003522

TABLE 9 Statistics (U) and p-values of the Mann-Whitney tests to compare the excitation effect intensity values (*p/b*) and the inhibitor effect intensity values (*b·q*) for extraverts and introverts. EEG: extraverted group; IEG: introverted group.

Intensities	Group	N	Average rang	U	Sig.
p/b	EEG	12	15.75	33	.024
	IEG	12	9.25		
b·q	EEG	12	15.58	35	.033
	IEG	12	9.42		