From the Big Five to the General Factor of Personality: a Dynamic Approach

Joan C. Micó[1], Salvador Amigó[2] and Antonio Caselles[2]

[1] *Universitat Politècnica de València (Spain)*
[2] *Universitat de València (Spain)*

Abstract. An integrating and dynamic model of personality that allows predicting the response of the basic factors of personality, such as the Big Five Factors (B5F) or the general factor of personality (GFP) to acute doses of drug is presented in this paper. Personality has a dynamic nature, i.e., as a consequence of a stimulus, the GFP dynamics as well as each one of the B5F of personality dynamics can be explained by the same model (a system of three coupled differential equations). From this invariance hypothesis, a partial differential equation, whose solution relates the GFP with each one of the B5F, is deduced. From this dynamic approach, a co-evolution of the GFP and each one of the B5F occurs, rather than an unconnected evolution, as a consequence of the same stimulus. The hypotheses and deductions are validated through an experimental design centered on the individual, where caffeine is the considered stimulus. Thus, as much from a theoretical point of view as from an applied one, the models here proposed open a new perspective in the understanding and study of personality like a global system that interacts intimately with the environment, being a clear bet for the high level inter-disciplinary research.

Received 30 August 2012; Revised 3 September 2013; Accepted 24 January 2014

Keywords: general factor of personality, big five, unique personality trait theory, dynamics of personality, caffeine.

General Systems Theory faces several challenges in the context of science development. One of them is to provide social and human sciences with an epistemological status similar to that of applied sciences (physics, chemistry, biology, economics, etc.). A way to deal with this challenge is to find validated mathematical dynamic models for magnitudes of social interest with the same predictive potential as the existing models used in applied sciences. In addition, such mathematical models should be expressed using the same universal language as in the applied sciences, i.e., in terms of differential/integral/finite-difference equations, which have proved to be so fruitful and successful in the positive sciences. This approach also permits to compare models and systems, as well as to classify them into categories, independently of their discipline, i.e., to build general systems. With respect to uncertainties, there are mathematical methods adequate to deal with uncertainties, data errors and personal estimations, producing results with its respective confidence intervals.

This article is a first attempt to face this challenge in the context of personality theory. Concretely, we discuss in this paper a dynamic mathematical approach to understand personality from the perspective of a general factor of personality (GFP) and its relationships with the Big Five Factors (B5F). On the one hand, we propose only one mathematical model to describe the dynamic pattern of response of the GFP and the B5F as a consequence of the same stimulant drug single dose. Let this model be named as the *response model*. In the application case performed in order to validate the *response model*, the stimulus is caffeine, considered as a stimulant drug. Acute doses of caffeine, at levels typically found in a cup of coffee, produce stimulant-like subjective effects (Childs & de Wit, 2006; Nehlig, 1999). On the other hand, assuming that each factor dynamics holds the *response model*, i.e., under the invariance of its dynamic pattern, the mathematical relation among these factors is obtained. Let this mathematical relation be named as the *bridge model*. In other words, both the GFP and the B5F co-evolve in time, as a consequence of the same stimulus, with values connected by the *bridge model*.

The General Factor of Personality and the Big Five Factors

The existence of a GFP is claimed by the Unique Personality Trait Theory (UPTT) (Amigó, 2005), which proposes a hierarchical approach where the highest level corresponds to the unique trait (the GFP), extended from an impulsivity and aggressively pole (approach tendency) to an anxiety and introversion pole (avoidance tendency). Following the UPTT, the brain activation level represents the biological base of the GFP.

Correspondence concerning this article should be addressed to Antonio Caselles. Departament de Matemàtica Aplicada. Universitat de València. Dr. Moliner, 50. 46100. Valencia (Spain). Fax: 34–963543922.
E-mail: Antonio.Caselles@uv.es

There are evidences of the existence of a GFP to describe the overall personality and its relationships with the B5F (Amigó, 2005; Amigó, Caselles, & Micó, 2008; Rushton & Irwing, 2008), as well as its biological base (Amigó, 2005; Amigó, Caselles, Micó, & García, 2009a; Micó, Amigó, & Caselles, 2012; Rushton, Bons, & Hur, 2008).

Actually, the structural model of personality that has attracted the most research interest has been the Big Five model (Digman, 1990; McCrae & Costa, 1987, 1997). The first proponents of this personality model obtained five robust and orthogonal factors, irreducible basic dimensions. However, there is evidence about these dimensions are strongly related (Becker, 1999; Digman, 1997; Eysenck, 1991, 1992; Wiggins & Trapnell, 1996).

Several authors found evidence for the existence of a single common factor underlying the Big Five (Figueredo et al, 2006; Musek, 2007; Rushton & Irwing, 2008; Rusthon et al., 2008; Saucier & Goldberg, 2003). For example, Musek (2007) confirmed the existence of a GFP (the Big One) characterized by high versus low Emotionality Stability, Conscientiousness, Agreeableness, Extraversion and Openness. He proposed a comprehensive theoretical model of personality structure with the Big One at the highest level of hierarchy. Rusthon et al. (2008) found the same relations pattern among the B5F and the GFP. Some different results were found by Amigó, Caselles, and Micó (2010), with a GFP positively related with Extraversion and Openness, but negatively related with Neuroticism (what is equivalent to positively related with Emotional Stability), Conscientiousness and Agreeableness.

On the other hand, there is really an only study known by the authors about the interaction between GFP, the B5F and the acute effect of drugs: the one of Corr and Kumari (2000). These authors observed some individual differences in the reaction to amphetamine in Psychoticism: d-amphetamine increased the energy arousal and the hedonic tone and reduced the tense arousal in normal individuals whereas the high Psychoticism individuals experienced the opposite pattern. Neither the Search of Newness nor Extraversion modified the effects of d-amphetamine. In addition, no studies about the evolution at very short term (laboratory experiment) of these factors of personality are known by the authors. Thus, an integrating and dynamic model of personality that allows predicting the response of the basic factors of personality (such as the B5F or the GFP) to acute doses of a drug does not exist. The UPTT (Amigó, 2005), offers a theoretical frame to investigate this integration proposal.

The UPTT asserts that the human activation level of the stress system is the responsible of the different responses to a stimulus. Lower tonic activation levels correspond with the impulsivity and aggressively pole (approach tendency), while higher tonic activation levels correspond with the anxiety and introversion pole (avoidance tendency). The activation level response to a stimulus is given by a certain time pattern that can be described mathematically by the *response model* (Amigó, Caselles, & Micó, 2008; Caselles, Micó, & Amigó, 2010) and explains personality dynamics as a consequence of the effect of a stimulant drug. Thus, the UPTT, which defends the existence of the GFP, is an important theoretical frame to develop a dynamic model of relations between the GFP and the B5F that allows understanding the dynamics of the global personality.

Summarizing, the UPTT and the referred studies present a structural model which is attempted to be represented mathematically here by the *response model* and by the *bridge model*. On the one hand, the *response model* provides the common dynamic pattern for the GFP and the B5F. On the other hand, the *bridge model* provides the dynamic interrelationship among the GFP and the B5F. Thus, this structural model, given by the pair of both models, has a dynamic nature, showing a co-evolution of all involved factors as a consequence of a same stimulus, rather than an unconnected evolution.

The Mathematical Models

The *response model* is founded on three basic theories that explain the time pattern of the effects of drugs and the differential reactivity to them, i.e., the opponent-process theory of acquired motivation of Solomon and Corbit (1974), the gated dipole theory of Grossberg (2000) and the UPTT of Amigó (2005). In the study of Amigó et al., (2008) the GFP dynamics, represented biologically by the brain activation level, is modeled holding the *response model* from the three basic theories above referred.

In addition, the *response model* has been used to describe the GFP dynamics under the effect of a single dose of caffeine (Caselles, Micó, & Amigó, 2011). Besides, the *response model* has also been used to describe the GFP dynamics and the *c-fos* dynamics (considered as a biological substrate for personality) under the effect of a single dose of methylphenidate (Micó et al., 2012). The substrate of personality has also been studied by the experimental evaluation of the glutamate in blood as a consequence of a single dose of methylphenidate (Amigó et al., 2009a; Micó, Caselles, Amigó, Cotolí, & Sanz, 2013) and, by the experimental evaluation of the DRD3 gene expression, as a consequence of a suggestion technique (Amigó, Caselles, & Micó, 2013).

On the other hand, the process to obtain the *response model* is based on the *General Modeling Methodology* established by Caselles (1994) within the General Systems Theory context that the same author developed. Caselles (1992a, 1993, 1995) proposes a modeling process which not only attempts to organize partial methods, but also attempts to include the ideas of Forrester (1961, 1970), the creator of *Systems Dynamics,* and the contributions of other authors. The General Modeling Methodology attempts to generalize the scientific method or the hypothetic-deductive method to be applied to model complex systems. Ten stages may be identified in this methodology, and natural feedback processes take place between them instead of them being linearly run.

The *response model* is constituted by three coupled differential equations, being the state variables the following ones: the *non-assimilated drug*, the *drug in blood* (which represents the stimulus), and the GFP. The derivative with respect to time of the GFP is the sum of three flows. Two of them are a consequence of the stimulus while the third flow appears with a finite and positive delay. The first flow, named as *homeostatic control*, is a mechanism of fast recovering of the tonic GFP. The second flow, named as excitation effect, increases the GFP as a consequence of the stimulus. The third flow is a slow control mechanism, named as *inhibitor effect,* which after the time delay (named as *inhibitor effect delay*), decreases the GFP. Thus, the equation corresponding to the GFP is a delay differential equation with finite delay and, therefore, it represents an "all or nothing" phenomenon.

Further simulations show that the model for the effect of a single dose of a stimulant drug can also be described without delay. Nevertheless, an addiction model needs that delay is considered, as Solomon and Corbit point out (1974). The model without delay can reproduce the same dynamic patterns above mentioned. Following the scientific principle of choosing the simplest model, we are going to work, in the context of this paper, with the model without delay, leaving for future research the question of if an addiction model would really need the mathematical consideration of a delay.

Thus, the *response model* that we propose in this paper is based on the model without delay that describes mathematically the dynamic pattern of both the GFP and the B5F, as a consequence of a stimulant drug intake. According to this assumption, the *bridge model* is deduced in this paper as a partial differential equation that relates any pair of factors and time. The solutions of the *bridge model* provide the co-evolution of all factors, as a consequence of a stimulant drug intake.

The Application Case

In order to validate both models, we start from an innovating and little used experimental approach.

In this approach, the experimental subjects fill in a list of 25 adjectives that correspond to the B5F (Brody & Ehrlichman, 1998), requesting to them that they respond so much considering such adjectives as traits ("Are you like that in general? ") or like states ("Are you like that or feel like that at this moment?").

Thus, a trait-format and state-format of this list of adjectives exists. This allows us simultaneously to have a version of personality in the trait level and a version of situational personality or in the state level, as much for the B5F as for the GFP. The version of "personality states" allows us to evaluate the personality at every moment and based on the effects of a certain stimulus like caffeine, of a similar manner to the scales of the mood-states or of the effects of situations elaborated specially for this purpose, such as the *Multiple Affect Adjective Check List* (MAACL, Zuckerman & Lubin, 1965) or the *Profile of Mood States* (POMS, McNair & Droppleman, 1971). The theoretical foundation of this proposal comes guaranteed by the existing hierarchical models of personality, specially the model of parameters of Pelechano (1973, 2000), that considers three levels of consolidation of the dimensions of personality, from the upper level of consolidation to the situational level or state level. Schutte, Malouff, Segrera, Wolf, and Rodgers (2003) elaborated a Big Five States Inventory starting from the hierarchical model of personality. Traits are conceptualized as higher-level and enduring characteristics, while states are lower level and less enduring characteristics (p. 592). A factor analysis showed an acceptable fitting between responses on measures of transitory states and the Big Five dimensions. The subjects had to answer: "Describe yourself as you see yourself at the present time not as you wish to be in the future or as you were in the past" (p. 594). They used an experimental manipulation, the positive mood induction procedure, to attempt to change the levels of the Big Five States. There was a significant increase in surgency, agreeableness and openness from pre- to post-induction.

Trait and state can be measured with the considered list of adjectives. This option has two advantages: 1) the isomorphism of the measures, which do not require different instruments for the evaluation of trait and state; 2) the possibility to study the dynamics of personality at short and at long term.

Both, *response* and *bridge* models, are validated in the application case, corresponding to an experimental design with twenty adult subjects that consumed coffee with an empty stomach. The instruments of this experiment are: the Big Five Personality Adjectives List (BFPAL) (Brody & Ehrlichman, 1998) and the Five-Adjective Scale of the General Factor of Personality (GFP-FAS, Amigó, Micó, & Caselles, 2009b).

The validation process has two parts. In the first part, the *response model* of each factor is fitted to experimental data with the minima squared method. Once the parameter values are obtained (see Tables 1 and 2), the method to assess the *response model* for each factor is to compute, both for the mean values and for each individual case, the determination coefficients between experimental and predicted data, observing that, in general the coefficients are enough high as to accept the *response model* (see Table 3). In the second part, considering the parameter values obtained in the first part, the same method is followed to assess the *bridge model* between pairs of factors, i.e., to evaluate the corresponding determination coefficients (see Table 4). In addition, a visual evaluation of both models is possible through the observation of the figures representing the experimental data together with the predicted data (see Figures 2 to 23), both for the mean data and for Case 1 (considered as one of the most representative cases).

The following sections of the article are organized as follows. Section 2 presents the *response model*, valid for all factors. In Section 3 the *bridge model* between each pair of factors and time is deduced from the assumptions set up in Section 2. Section 4 presents the experimental design of the application case. Section 5 presents the *response model* validation for the six factors (the GFP and the B5F), as well as the *bridge model* between each pair of factors and time. Section 6 is devoted to the comparison with alternative models and the theory limitations, as well as the separation of the actual results of the paper from the potential use of these results. Section 7 presents the conclusions of the study.

The Response Model

Following the hypothetico-deductive method, we start from a theoretical model that can explain the evolution of the GFP as a consequence of a stimulus and try to validate it through its contrast with real data. Amigó et al. (2008) presented a model that has enough the theoretical foundation to be worthy of being tested through an experiment with human subjects. Contributing to such validation is the work of Caselles et al. (2011). In order to make the paper self-contained, let us synthesize this model in this section as well as a modification of the same model (Micó, Amigó, & Caselles, 2008).

Let $y(t)$, b and y_0 be respectively the GFP, its tonic level and its initial value. Amigó et al. (2008) demonstrate that the delay differential equation that explains the evolution of the GFP as a consequence of a drug intake is:

$$\frac{dy(t)}{dt} = \begin{cases} a(b-y(t))+\frac{p}{b}s(t) : 0 \le t \le \tau \\ a(b-y(t))+\frac{p}{b}s(t)-b\cdot q\cdot s(t-\tau)\cdot y(t-\tau) : t > \tau \end{cases} \tag{1}$$
$$y(0) = y_0$$

Where,

t is time, a, p, q and τ are parameters to be explained later;

$s(t)$, represents the stimulus, i.e., the amount in blood of drug non consumed by cells;

$a(b-y(t))$ is the *homeostatic control*, i.e., the cause of the fast recovering of the tonic level b, being a the "power" of this control;

$p\cdot s(t)/b$ is the *excitation effect*, which tends to increase the GFP, being p the *excitation effect power*;

$b\cdot q\cdot s(t-\tau)\cdot y(t-\tau)$ is the *inhibitor effect*, which tends to decrease the GFP and is the cause of the its slow recovering, being q the *inhibitor effect power* and being τ the *inhibitor effect delay* time after which the inhibitor effect takes place (which means that an "all or nothing" effect occurs, similar to the electrochemical transmission in the neuron axon).

Being $c(t)$ the non-assimilated drug, i.e., the drug not yet in blood,

$s(t)$ and $c(t)$ are computed by two coupled differential equations:

$$\left.\begin{array}{c} \dfrac{dc(t)}{dt} = -\alpha \cdot c(t) \\ c(0) = M \end{array}\right\} \tag{2}$$

$$\left.\begin{array}{c} \dfrac{ds(t)}{dt} = \alpha \cdot c(t) - \beta \cdot s(t) \\ c(0) = s_0 \end{array}\right\} \tag{3}$$

Where,

M is the initial amount of drug of a single dose;

α is the drug assimilation rate;

s_0 is the amount of drug present in blood before the dose intake;

β is the drug distribution rate.

Equations (1), (2) and (3) define a *response model*. It reproduces the dynamic patterns forecasted by Solomon and Corbit (1974), Grossberg (2000) and Amigó (2005), and it can be considered theoretically validated through the scientific literature about the subject (Amigó et al., 2008).

The equation obtained by eliminating the delay in equation (1) is the following:

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

The *response model* on which we are going to found our deductions is the one formed by Equations (2), (3) and (4). This particular *response model* has been validated by Micó et al., (2008). The experimental design presented in this paper confirms that validation. A causal diagram of this model can be found in Figure 1 and, the paper
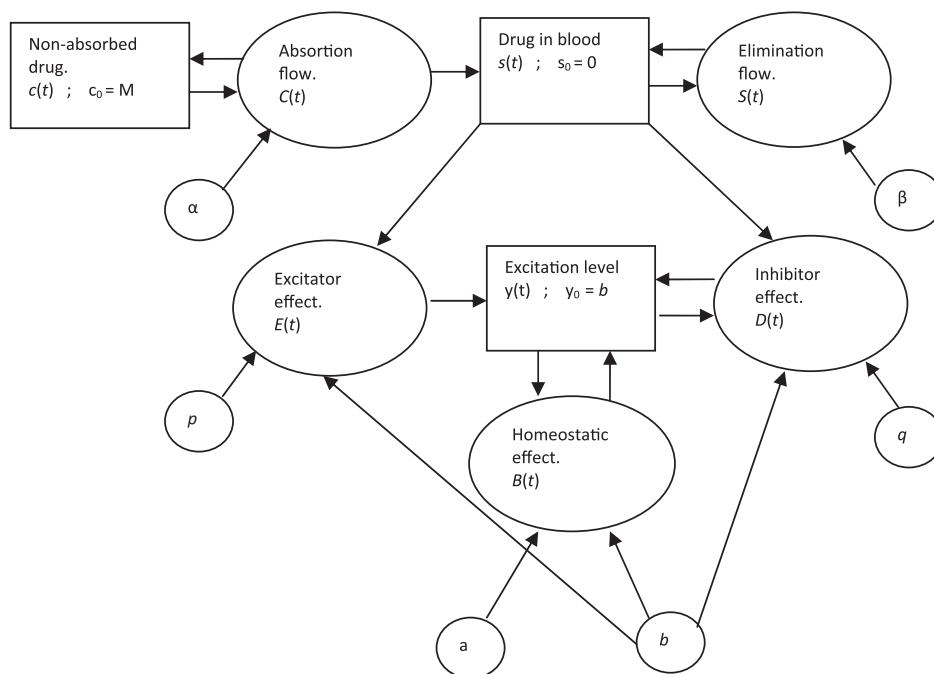
Figure 1. Causal diagram of the response model.

of Amigó et al., (2008) provides a hydrodynamic diagram that can help to better understand the model with delay from a qualitative approach.

The elimination of the delay in (1) to obtain (4) provides the possibility to obtain the bridge model as a partial differential equation without delays. This makes possible to handle analytically the bridge model (see the following section).

The Bridge Model

The aim of this section is to deduce theoretically a *bridge model* between each pair of the six considered factors (the GFP and the B5F). Each *bridge model* is constituted by a partial differential equation and a boundary condition. The solution of this pair of equations provides the co-evolution of the considered factors as a consequence of a single dose of a stimulant drug. In other words, given a value of an arbitrary factor *i*, and a value of the stimulus, *s(t)*, in a certain time instant *t*, the value of another but different factor *j* can be deduced. The validation of the hypothetical *response* and *bridge* models by its contrast with experimental data would confirm the common dynamics of all factors and their correlated evolution as a consequence of a single dose of a stimulant drug, what represents a progress towards a unified dynamic theory of personality.

Our hypothesis, in order to obtain the bridge model between each one of the B5F and the GFP, is that the dynamic response of each one of the B5F,

as a consequence of a single dose of a stimulant drug, is also provided by equation (4), that is:

$$\left. \begin{array}{c} \dfrac{dE_i(t)}{dt} = A_i\big(B_i - E_i(t)\big) + \dfrac{P_i}{B_i}s(t) - B_i \cdot Q_i \cdot s(t) \cdot E_i(t) \\[2mm] E_i(0) = E_i^{(0)} \end{array} \right\} \quad (5.i)$$

Where,

$1 \leq i \leq 5$, and each subscript value corresponds to each one of the B5F, in the following sort: $E_1 \equiv E$ (Extraversion), $E_2 \equiv R$ (Responsibility), $E_3 \equiv N$ (Neuroticism), $E_4 \equiv O$ (Openness to Experience), $E_5 \equiv A$ (Agreeableness);

$E_i^{(0)}$ is the corresponding initial value in $t = 0$;

A_i, B_i, P_i and Q_i, are the parameters equivalent to the corresponding ones in (4);

$s(t)$ is the stimulus function, i.e., is the same than in equation (4), and obtained through equations (2) and (3).

The assumptions (5.i) come from the visual observation of the scores of each factor plotted versus time. See Figures 2 to 7 for the mean values of the group and Figures 8 to 13 for Case 1. Such figures, where the dots represent the experimental data versus time, suggest a same dynamic pattern, common to all factors. The validation of this hypothesis is performed below, in Section 5.1.

The method followed to obtain the *bridge model* considers that (4) and (5.i) hold, and finds the equations that keep (4) and (5.i) invariant. Let the functions

that relate the B5F, (E_i), time, (t), and the GFP, (y), be the following:

$$E_i = E_i(t, y) \qquad (6.i)$$

From (6.i), deriving with respect to time, equations (7.i) are obtained:

$$\frac{dE_i}{dt} = \frac{\partial E_i}{\partial t} + \frac{\partial E_i}{\partial y}\frac{dy}{dt} \qquad (7.i)$$

Substituting (4) in (7.i) equations (8.i) are obtained:

$$\frac{\partial E_i}{\partial t} + \frac{\partial E_i}{\partial y}\left[a(b-y) + \frac{p}{b}s(t) - b\cdot q\cdot s(t)\cdot y\right]$$
$$= A_i(B_i - E_i) + \frac{P_i}{B_i}s(t) - B_i\cdot Q_i\cdot s(t)\cdot E_i \qquad (8.i)$$

Equations (8.i) are quasi-linear partial differential equations that, together with the boundary conditions stated below, define the *bridge model*. Observe that the use of Equation (1) instead of Equation (4) (without delay) would provide a partial differential equation similar to (8.i) but with different delays for dependent variables, $E_i(t,y)$, and for the independent variables, t and y. This equation would be impossible to handle analytically such as it is done in this section. However, it is obvious that a more general bridge model that can include the delays and can be analytically handled must be investigated.

Equations (8.i) can be solved through their characteristic equations:

$$\frac{dt}{1} = \frac{dy}{a(b-y) + \frac{p}{b}s(t) - b\cdot q\cdot s(t)\cdot y}$$
$$= \frac{dE_i}{A_i(B_i - E_i) + \frac{P_i}{B_i}s(t) - B_i\cdot Q_i\cdot s(t)\cdot E_i} \qquad (9.i)$$

Two independent coupled differential equations can be extracted from (9.i) for each index value i:

$$\frac{dy}{dt} = a(b-y) + \frac{p}{b}s(t) - b\cdot q\cdot s(t)\cdot y \qquad (10)$$

$$\frac{dE_i}{dt} = A_i(B_i - E_i) + \frac{P_i}{B_i}s(t) - B_i\cdot Q_i\cdot s(t)\cdot E_i \qquad (11.i)$$

Both (10) and (11.i) have the following analytical solutions, depending respectively on arbitrary constants, k_1 and k_{2i}:

$$y\cdot exp\left(\int_0^t h(x)\,dx\right) - \int_0^t g(x)\cdot exp\left(\int_0^x h(z)\,dz\right)dx = k_1 \qquad (12)$$

$$E_i\cdot exp\left(\int_0^t H_i(x)\,dx\right) - \int_0^t G_i(x)\cdot exp\left(\int_0^x H_i(z)\,dz\right)dx = k_{2i} \qquad (13.i)$$

Where:

$$h(t) = a + b\cdot q\cdot s(t) \qquad (14)$$

$$g(t) = a\cdot b + \frac{p}{b}s(t) \qquad (15)$$

$$H_i(t) = A_i + B_i\cdot Q_i\cdot s(t) \qquad (16.i)$$

$$G_i(t) = A_i\cdot B_i + \frac{P_i}{B_i}s(t) \qquad (17.i)$$

Thus, the solutions of (8.i) are given, formally, by:

$$k_{2i} = \Phi_i(k_i) \qquad (18.i)$$

that is:

$$E_i\cdot exp\left(\int_0^t H_i(x)\,dx\right) - \int_0^t G_i(x)\cdot exp\left(\int_0^x H_i(z)\,dz\right)dx =$$
$$\Phi_i\left(y\cdot exp\left(\int_0^t h(x)\,dx\right) - \int_0^t g(x)\cdot exp\left(\int_0^x h(z)\,dz\right)dx\right) \qquad (19.i)$$

In order to find the Φ_i functions, a boundary condition for each equation (8.i) is required. They can be obtained from the differential equations (4) and (5.i) in absence of stimulus, that is, when $s(t) = 0$:

$$\left.\begin{array}{l}\dfrac{dy(t)}{dt} = a(b - y(t)) \\[2mm] y(0) = y_0\end{array}\right\} \qquad (20)$$

$$\left.\begin{array}{l}\dfrac{dE_i(t)}{dt} = A_i(B_i - E_i(t)) \\[2mm] E_i(0) = E_i^{(0)}\end{array}\right\} \qquad (21.i)$$

Following now the same method to obtain $E_i = f_i(y)$ in such a way that (20) and (21.i) remain invariant the result is the differential equation:

$$\frac{dE_i}{dy}a(b-y) = A_i(B_i - E_i) \qquad (22.i)$$

whose outcome, for each i, is:

$$E_i(y) = \begin{cases} B_i : b = y_0 \\[2mm] B_i - \left(B_i - E_i^{(0)}\right)\left(\dfrac{b-y}{b-y_0}\right)^{\frac{A_i}{a}} : b \neq y_0 \end{cases} \qquad (23.i)$$

The partial differential equations (8.i) together with the boundary conditions (23.i) define the *bridge model*. In order to obtain the solutions of the *bridge model*, the Φ_i functions (19.i) must be evaluated under the boundary conditions (23.i). To do this, the Φ_i functions (19.i) for the case $s(t) = 0$ are compared with Equations (23.i).

Therefore, firstly, the restriction $s(t) = 0$ and the isolation of the E_i variables in (19.i) provides:

$$E_i = B_i + exp(-A \cdot t)\left[-B_i + \Phi_i\left(y \cdot exp(a \cdot t) - b(exp(a \cdot t) - 1)\right)\right] \quad (24.i)$$

Secondly, comparing (24.i) with (19.i), the following result is obtained for the Φ_i functions:

$$\Phi_i\left(y \cdot exp(I_1(t)) - I_2(t)\right) = \begin{cases} B_i : b = y_0 \\ B_i - \left(B_i - E_i^{(0)}\right)\left(\dfrac{b - y \cdot exp(I_1(t)) + I_2(t)}{b - y_0}\right)^{\frac{A_i}{a}} : b \neq y_0 \end{cases} \quad (25.i)$$

where:

$$I_1(t) = \int_0^t \left(a + b \cdot q \cdot s(x)\right) dx \quad (26)$$

$$I_2(t) = \int_0^t \left(a \cdot b + \frac{p}{b} s(x)\right) exp\left(I_1(x)\right) dx \quad (27)$$

Finally, by substituting $z(t, y) = y \cdot exp(I_1(t)) - I_2(t)$ in (25.i), the structures for the Φ_i functions are obtained:

$$\Phi_i(t, z) = \begin{cases} B_i : b = y_0 \\ B_i - \left(B_i - E_i^{(0)}\right)\left(\dfrac{b - z}{b - y_0}\right)^{\frac{A_i}{a}} : b \neq y_0 \end{cases} \quad (28.i)$$

Considering in (28.i) the change

$$z = y \cdot exp\left(\int_0^t h(x) dx\right) - \int_0^t g(x) \cdot exp\left(\int_0^x h(z) dz\right) dx$$

and its substitution in (19.i), once E_i is isolated, the functions F_i posed in (6.i) are found:

$$E_i(t, y) = \begin{cases} exp(-J_{1i}(t))[J_{2i}(t) + B_i] : b = y_0 \\ exp(-J_{1i}(t))\left[J_{2i}(t) + B_i - \left(B_i - E_i^{(0)}\right)\left(\dfrac{b - y \cdot exp(I_1(t)) + I_2(t)}{b - y_0}\right)^{\frac{A_i}{a}}\right] : b \neq y_0 \end{cases} \quad (29.i)$$

In (29.i) $I_1(t)$ and $I_2(t)$ are given respectively by (26) and (27), and:

$$J_{1i}(t) = \int_0^t \left(A_i + B_i \cdot Q_i \cdot s(x)\right) dx \quad (30.i)$$

$$J_{2i}(t) = \int_0^t \left(A_i \cdot B_i + \frac{P_i}{B_i} s(x)\right) exp\left(J_{1i}(x)\right) dx \quad (31.i)$$

Equations (29.i) are the solutions of the *bridge model*. To evaluate it, Equations (26), (27), (30.i) and (31.i) must be considered together with (29.i) ones. These solutions are also valid to relate a factor with another but different one. It must be so if the hypothesis of a unique dynamic pattern holds. In fact, if an equation that relates an arbitrary factor E_i with another E_j and time t, $E_i = E_i(t, E_j)$, with $i \neq j$, exist then Equations (29.i),

(30.i) and (31.i) must be invariant. Thus (26) and (27) have to be substituted, respectively, by (30.i) and (31.i) exchanging the subscript i by the subscript j.

In addition, the mathematical structure of these relations allows computing trivially the inverse functions. Effectively, if we identify the subscript value $i = 0$ with the GFP and the other values with the B5F as previously accorded, as well as, the integrals I_0 and I_1 respectively with J_{10} and J_{20}, then Equations (29.i) can be rewritten as:

$$E_i(t, E_j) = \begin{cases} exp(-J_{1i}(t))[J_{2i}(t) + B_i] : B_j = E_j^{(0)} \\ exp(-J_{1i}(t))\left[J_{2i}(t) + B_i - \left(B_i - E_i^{(0)}\right)\left(\dfrac{B_j - E_j \cdot exp(J_{1j}(t)) + J_{2j}(t)}{B_j - E_j^{(0)}}\right)^{\frac{A_i}{A_j}}\right] : B_j \neq E_j^{(0)} \end{cases} \quad (32.ij)$$

Where: $i \neq j$, $0 \leq i, j \leq 5$, $E_0 \equiv y$ (unique trait), $E_1 \equiv E$ (Extraversion), $E_2 \equiv R$ (Responsibility), $E_3 \equiv N$ (Neuroticism), $E_4 \equiv O$ (Openness to Experience), $E_5 \equiv A$ (Agreeableness), $E_i^{(0)}$ are the corresponding initial values in $t = 0$, and A_i, B_i, P_i and Q_i, are the parameters corresponding to each factor.

Equations (32.ij) represent a dynamic equivalence principle among factors. This principle means that a co-evolution of all factors as a consequence of a single dose of a stimulant drug exists. In other words, given a value of an arbitrary factor i, and a value of the stimulus, $s(t)$, in a certain time instant t, the value of another but different factor j can be deduced via (32.ij).

On the other hand, Equations (32.ij) come from assumptions (5.i), which suggest a same dynamic pattern, common to all factors, given by the *response model*. The validation of these equations is performed below, in Section 5.2, and it is centered on the assessment of the particular functions (29.i). Equations (32.ij) represent the second extension of the UPTT towards a unified dynamic theory of personality given by the *response* and *bridge* models. Their validation confirms the common dynamics of all factors and their correlated evolution as a consequence of a single dose of a stimulant drug.

The Experimental Design

Twenty adult subjects participated in the experiment, named as Case 1 to Case 20. They were University students and professors. The mean age was 30.13 with an age range of 21–61 and a standard deviation of 10.2.

The instruments used were two lists of adjectives:

• The Big Five Personality Adjectives List (BFPAL) (Brody & Ehrlichman, 1998). This list is made up of 25 adjectives. A state-format version ("Are you like this at the moment?") was used. The twenty subjects completed the state-format version every 15 minutes to obtain a situational measure of the BFPAL.

Therefore, each one of the five factors obtains a score in the range of [0, 25] units in the hedonic scale.

- The Five-Adjective Scale of the General Factor of Personality (GFP-FAS), (Amigó et al., 2009b). The 5 adjectives are: adventurous, daring, enthusiastic, merry and bored. The GFP-FAS is related positively with Extraversion, Agreeableness and Openness, and negatively with Neuroticism and Conscientiousness. However, it can integrate all basic traits of personality (Amigó et al., 2009b).

The experimental procedure required that: 1. The experimental subjects had to consume no caffeine from the last afternoon before the experiment; 2. The experimental subjects had to take part in the experiment without having breakfast. Once they were all together in the room were the experiment was going to take place, they filled out the two lists of adjectives: BFPAL and GFP-FAS. Next, they had two cups of coffee, with an amount of 330 mg of caffeine (280 cc of coffee with a concentration of 1172 ± 15 mg/liter). From this moment, and during one hour and half, they filled out a form with the two lists of adjectives each 4.5 minutes, until a total of 20 registers.

There is a justified reason for defining an experiment with duration of one hour and half. A previous pilot experimental design with several types of persons demonstrated that, after this time, the subjects showed evidence of boredom, which affected the objectivity of the scores.

Model validation

The model validation process has two parts. The first part confirms the solutions of the *response model* (5.i), given by its numerical computation, for all the studied personality factors. The second part verifies the solutions of the *bridge model* (29.i) among these factors. In other words, both parts bear out the joined evolution of the GFP and the B5F as a consequence of a stimulus produced by a single dose of caffeine. Concretely, the first part constitutes the proof that the personality factors adapt to the model described by Equations (2), (3) and (4), for the GFP, or to Equations (2), (3) and (5.i), for the B5F. The outcomes for the parameter values obtained in this part are used in the second part to validate (29.i).

Due to the high number of figures (eleven per each case), the only figures presented and commented are the corresponding to the average data, as representative of the group, and the ones corresponding to a significant case (Case 1). The quantitative outcomes corresponding to the parameter values of these two cases are also presented. In addition, the quantitative outcomes corresponding to the determination coefficients both for the average data and for each one of the twenty cases are presented and commented in the following sections.

The Response Model Validation

The validation of the *response model* (2), (3) and (4), for the GFP, or the validation of the response model (2), (3) and (5.i), for the B5F, consists in showing the adaptation of the numerical outcomes of the respective differential equations to the data obtained in the experiment. It implies the search of the best fitting parameter values for each equation, considering that α and β parameters are common to Equations (4) and (5.i).

The fitting procedure has been performed with the help of MATHEMATICA 6.0, both for the mean data and for the data corresponding to each one of the twenty cases. The corresponding procedure is constituted by the following steps:

a. Getting the analytical outcome of the stimulus (2) and (3) as a function of time and substituting it in (4). (Process detailed by Amigó et al., 2008).
b. Fitting the numerical solution provided by MATHEMATICA 6.0 for (4), as a non autonomous differential equation, to the data obtained for the GFP (y variable). The optimization of the fitting (finding the optimal values of α, β, a, b, p and q) is attained, in a first stage (tentative values), visually by plotting together the experimental values and the computed values versus time. In a second stage (refinement), the determination coefficient, R^2, is computed between the experimental and the theoretical data, trying to maximize it.
c. Performing the same two stages than in item 2 for (5.i), $1 \leq i \leq 5$, conserving the optimal values of α and β obtained in item 2. The fitting, performed again by the same procedure, provides the optimal values of A_i, B_i, P_i and Q_i parameters, for $1 \leq i \leq 5$.

In both cases, the fitting process has been developed following the method justified and detailed by Caselles et al. (2011). The refining procedure of the initial values given to the parameters is based on an ad-hoc search program that, includes the possibilities of exhaustive searching, random searching and the use of a genetic algorithm, maximizes the determination coefficient R^2 and, tests the randomness of residuals. Theoretically, the optimal values found for the parameters may depend on their initial values (a local minimum can be found) but, the genetic algorithm, that considers a wide range of possible values for the parameters and random mutations and immigrations, makes this situation little probable. Nevertheless, to initiate a new search with another set of initial values is always possible.

This fitting procedure has been initially performed for the mean data, as representative of the group. From the parameter values obtained for the mean data, and by applying the same fitting procedure, the parameters' values corresponding to each one of the twenty cases have been got. The outcomes for the parameters' values corresponding to the average data are showed in Table 1, and the corresponding ones to Case 1 are shown in Table 2.

Let us comment the figures corresponding to the mean data. On the one hand, Figure 2 shows, for the average values, the plot of GFP (Y) together with the curve predicted by Equation (4) versus time. On the other hand, Figures 3 to 6 show, for the average values, respectively, the plots of Extraversion (E), Responsibility (R), Neuroticism (N), Openness to Experience (O) and Agreeableness (A), together with

the curves predicted by Equation (5.i) versus time. The outcomes for the determination coefficient (R^2) can be found in Table 3 and below each figure. They represent a high fitting degree between the experimental data and the theoretical curve. Only in the case of Neuroticism R^2 is notably lower; data presents a certain dispersion that, however, is not present in other cases, for which this R^2 is considered as high enough to be accepted as important.

Let us now comment the figures corresponding to Case 1. On the one hand, Figure 8 shows the plot of GFP (Y) together with the curve predicted by Equation (4) versus time. On the other hand, Figures 9 to 13 show, respectively, the plots of Extraversion (E), Responsibility (R), Neuroticism (N), Openness to Experience (O) and Agreeableness (A) together with the curves predicted by Equation (5.i) versus time. The outcomes for the determination coefficients can be found in Table 3 and below each figure. They reveal a high fitting degree between the experimental data and the theoretical curve, the case of Neuroticism included, which, for this case, is significantly high.

The visual inspection of the theoretical curves together with the experimental data confirm the suitability of the *response model* (Equations (2), (3) and (4) or (2), (3) and (5.i), $1 \leq i \leq 5$) to explain the data. Thus, this model describes successfully the dynamic pattern

Table 1. *The outcomes for the parameters values corresponding to the average data*

	α	β		
Stimulus	0.070	0.040		
	a	b	p	q
Unique Trait	1.0	8.50	1.13	0.0005
	A1	B1	P1	Q1
Extraversion	1.0	10.50	1.63	0.0005
	A2	B2	P2	Q2
Responsibility	1.0	12.65	1.45	0.0005
	A3	B3	P3	Q3
Neuroticism	1.0	9.00	.70	0.0005
	A4	B4	P4	Q4
Openness to Experience	1.0	10.80	1.13	0.0005
	A5	B5	P5	Q5
Agreeability	1.0	11.80	1.55	0.0005

Table 2. *The outcomes for the parameters values corresponding to Case 1*

	α	β		
Stimulus	0.058	0.038		
	a	b	p	q
Unique Trait	1.0	2.00	.38	0.0005
	A1	B1	P1	Q1
Extraversion	1.0	2.00	.36	0.0005
	A2	B2	P2	Q2
Responsibility	1.0	3.50	.60	0.0005
	A3	B3	P3	Q3
Neuroticism	1.0	3.00	.28	0.0005
	A4	B4	P4	Q4
Openness to Experience	1.0	3.00	.55	0.0005
	A5	B5	P5	Q5
Agreeability	1.0	4.00	.65	0.0005

Table 3. *Mean data and Cases 1 to 20. Determination coefficients (R^2) between the experimental data and the theoretical curve given by equations (2), (3) and (4) (for column 2), or by equations (2), (3) and (5.i), $1 \leq i \leq 5$ (respectively, for columns 3 to 7)*

|	R^2(Y)	R^2(E)	R^2(R)	R^2(N)	R^2(O)	R^2(A)
Mean	.94	.96	.79	.35	.92	.94
Case 1	.90	.90	.86	.73	.96	.81
Case 2	.03	.55	.00	.22	.27	.25
Case 3	.74	.67	.25	.33	.00	.30
Case 4	.75	.78	.32	.41	.27	.66
Case 5	.50	.86	.27	.47	.22	.27
Case 6	.31	.72	.03	.61	.22	.69
Case 7	.89	.79	.49	.69	.49	.75
Case 8	.31	.10	.25	.63	.23	.27
Case 9	.29	.42	.40	.18	.07	.15
Case 10	.83	.05	.27	.05	.18	.10
Case 11	.51	.39	.34	.05	.01	.46
Case 12	.68	.61	.50	.08	.00	.80
Case 13	.15	.28	.20	.05	.70	.09
Case 14	.55	.73	.65	.01	.75	.34
Case 15	.28	.57	.08	.00	.21	.05
Case 16	.96	.90	.52	.05	.85	.67
Case 17	.25	.02	.35	.41	.09	.25
Case 18	.13	.01	.14	.02	.10	.03
Case 19	.73	.65	.16	.00	.13	.56
Case 20	.05	.23	.02	.00	.37	.25
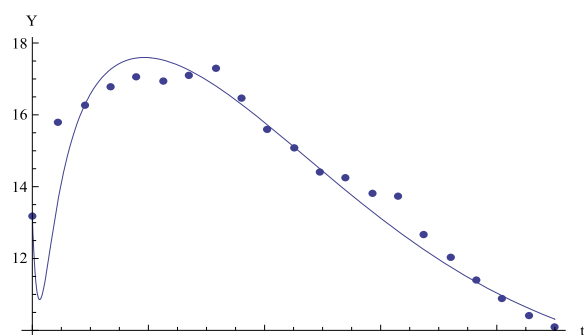
Figure 2: Average values. Experimental data (dots) of the GFP (Y) together with the theoretical prediction (curve) from equation (4) versus time. $R^2 = .94$.
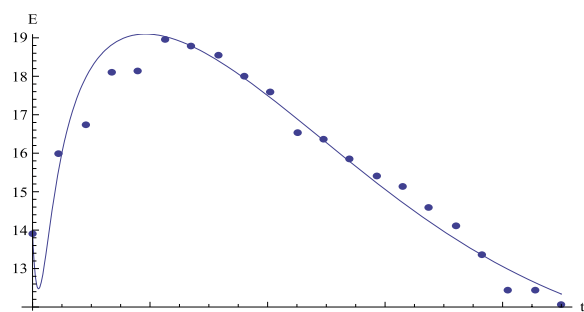

Figure 3: Average values. Experimental data (dots) of Extraversion (E) together with the theoretical prediction (curve) from equation (5.1) versus time. $R^2 = .96$.
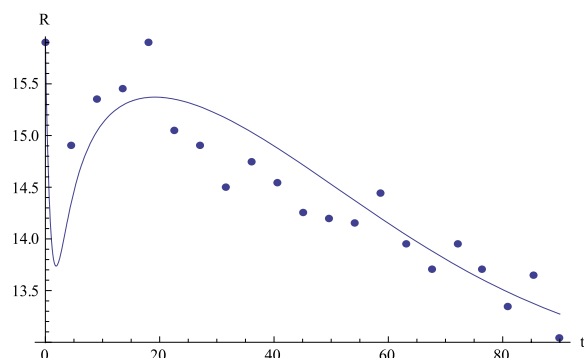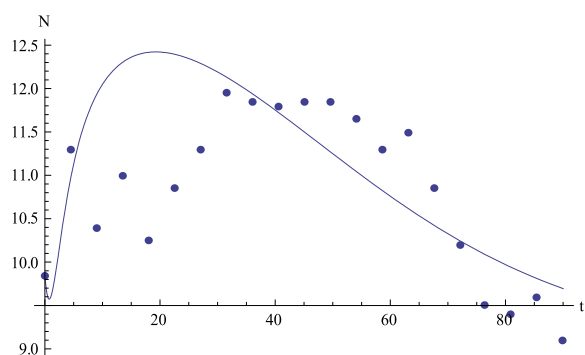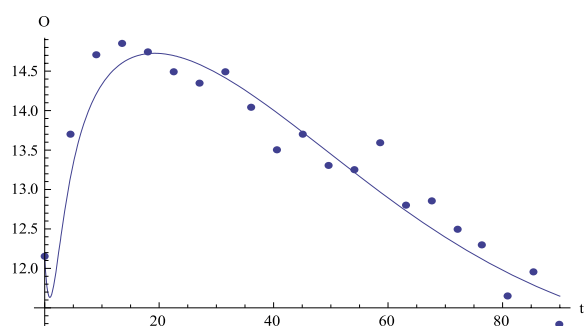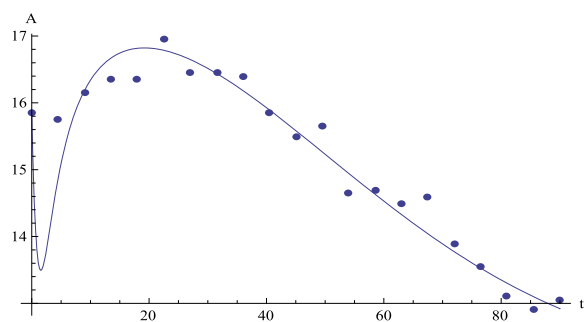

Figure 4: Average values. Experimental data (dots) of Responsibility (R) together with the theoretical prediction (curve) from equation (5.2) versus time. $R^2 = .79$.

Figure 5: Average values. Experimental data (dots) of Neuroticism (N) together with the theoretical prediction (curve) from equation (5.3) versus time. $R^2 = .35$.

Figure 6: Average values. Experimental data (dots) of Openness to Experience (O) with the together theoretical prediction (curve) from equation (5.4) versus time. $R^2 = .92$.

Figure 7: Average values. Experimental data (dots) of Agreeableness (A) together with the theoretical prediction (curve) from equation (5.5) versus time. $R^2 = .94$.

of the GFP and the B5F as a consequence of the consumption of a stimulant drug as caffeine is. The determination coefficients for all cases can be found in Table 3. Jointly viewed, they constitute a set of determination coefficients that are high enough to support this confirmation despite the fact that there are some uncorrelated cases or factors. Our hypothesis is that the uncorrelated cases or factors are due to the null effect that caffeine can produce on some individuals as a consequence of the weakness of caffeine as a stimulant

drug or as a consequence of habituation in these individuals. Experiments with stimulant drugs with stronger effect perhaps provide higher determination coefficients in these cases.

An important consequence of the response model fitting to the experimental data is that, on the one hand, the model provides a general pattern to reproduce personality dynamics as a consequence of caffeine consumption, and, on the other hand, this fitting provides simultaneously knowledge about between-persons
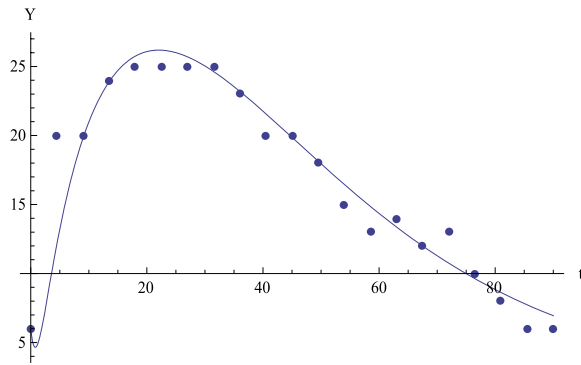
Figure 8. Case 1. Experimental data (dots) of GFP (Y) together with the theoretical prediction (curve) from equation (4) versus time. $R^2 = .90$.
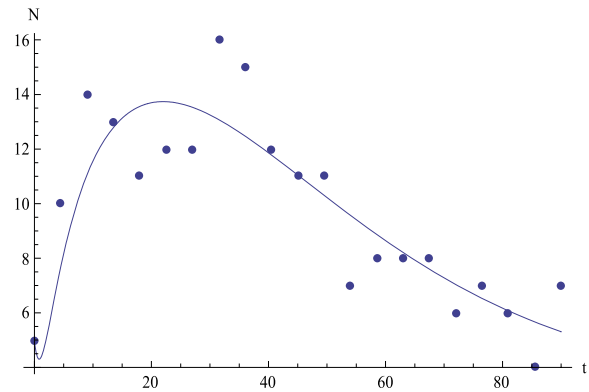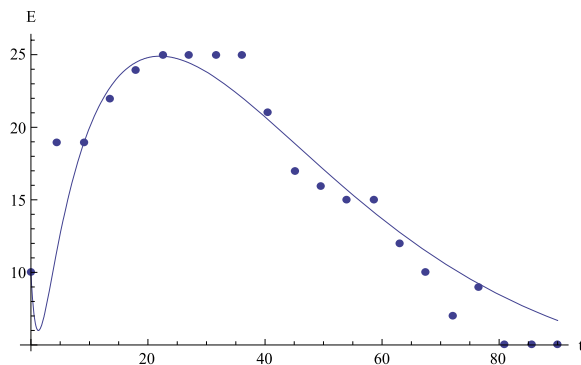

Figure 9. Case 1. Experimental data (dots) of Extraversion (E) together with the theoretical prediction (curve) from equation (5.1) versus time. $R^2 = .90$.
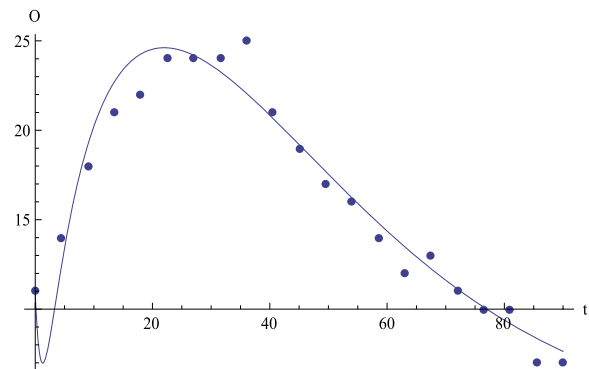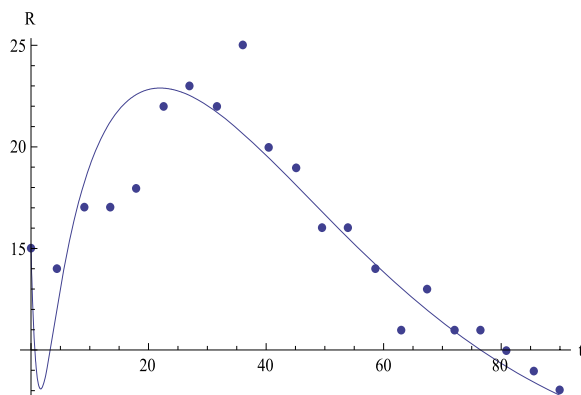

Figure 10. Case 1. Experimental data (dots) of Responsibility (R) together with the theoretical prediction (curve) from equation (5.2) versus time. $R^2 = .86$.
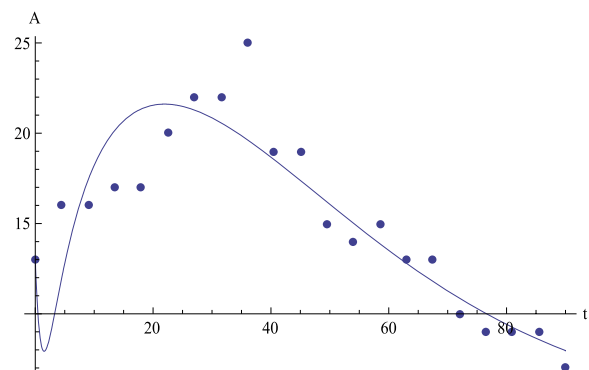

Figure 11. Case 1. Experimental data (dots) of Neuroticism (N) together with the theoretical prediction (curve) from equation (5.3) versus time. $R^2 = .73$.

Figure 12: Case 1. Experimental data (dots) of Openness to Experience (O) together with the theoretical prediction equation (curve) from equation (5.4) versus time. $R^2 = .96$.

Figure 13. Case 1. Experimental data (dots) of Agreeableness (A) together with the theoretical prediction (curve) from equation (5.5) versus time. $R^2 = .81$.

variation through the individual differences given by the particular parameter values of the response model. The individual differences can be appreciated in the particular parameter values in Table 1 (for the average data) and in Table 2 (for the Case 1 data), which are a consequence of a different individual biology.

The Bridge Model Validation

The validation of the solutions of the *bridge model* ((29.i), $1 \leq i \leq 5$), has also been performed for the average data and for each one of the twenty cases. It consists on showing the good adaptation of the model

to the data obtained in the experiment. The parameter values are obtained in Section 5.1. The fitting procedure has been performed again with the help of MATHEMATICA 6.0. The procedure is constituted by the following steps:

a. Getting the functions $E_i(t,y)$, $1 \leq i \leq 5$, by substitution of the parameter values obtained in section 5.1. Note that α, β, a, b, p and q parameters are common to the five equations that provide each one of the B5F as a function of time and the GFP.
b. Plotting together the experimental values of the B5F and the computed ones by Equation (29.i) versus experimental GFP values. A complete three-dimensional plot, i.e., versus time and GFP, is not suitable to show visually the fitting degree between the experimental and the theoretical data. In addition, the determination coefficients, R^2, are computed in order to quantify the fitting degree.

The results of this procedure for the average values are described in the following. Figures 14 to 18 show, respectively, the plots of Extraversion (E), Responsibility (R), Neuroticism (N), Openness to Experience (O) and Agreeableness (A), together with the values predicted by Equation (29.i) versus the GFP experimental values. The outcomes for the determination coefficients can be found in Table 4 and inside figure captions. They reveal a high fitting degree between the experimental and the theoretical data with the only exception of Neuroticism (Figure 5) were such degree is notably lower. In all the other cases the determination coefficient is high enough to be accepted as important, as it can be observed in Table 4.

The results corresponding to Case 1 appear in Figures 19 to 23 that represent respectively the plots of Extraversion (E), Responsibility (R), Neuroticism (N), Openness to Experience (O) and Agreeableness (A), together with the values predicted by Equation (29.i) versus the GFP experimental values. The corresponding determination coefficients are in Table 4 and below each figure. They reveal a high fitting degree between the experimental data and the theoretical curve (the case of Neuroticism included, which is notably high).

The visual inspection of the theoretical values together with the experimental ones confirms the suitability of the model (29.i), $1 \leq i \leq 5$, to explain the experimental results. Thus, the solutions of the *bridge model* (29.i) describe successfully the functional relations of the B5F with respect to time and GFP, as a consequence of a stimulant drug (caffeine) intake. The determination coefficients for all cases can be found in Table 4. Jointly viewed, they are high enough to support
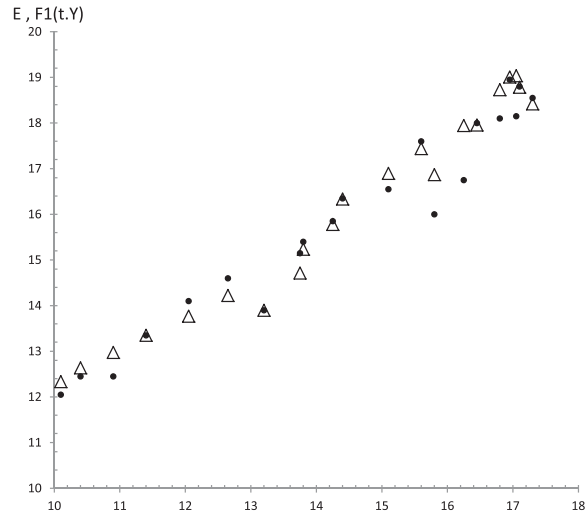

Figure 14. Average values. Experimental data (dots) of Extraversion (E) together with the theoretical values $F_1(t,y)$ (triangles) from equation (29.1) versus experimental values of the GFP (Y). $R^2 = .96$.
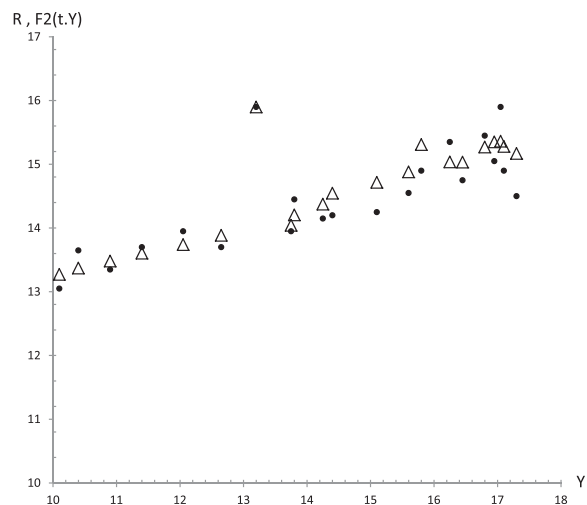

Figure 15. Average values. Experimental data (dots) of Responsibility (R) together with the theoretical values $F_2(t,y)$ (triangles) from equation (29.2) versus experimental values of the GFP (Y). $R^2 = .82$.

this confirmation despite there are some uncorrelated cases or factors. Our hypothesis about these uncorrelated cases is the same than the one exposed in Section 5.1: it is due to the null effect that caffeine can produce in some individuals as a consequence of the weakness of caffeine as a stimulant drug or as a consequence of habituation.

Discussion

A series of studies has concluded that the GFP is a common factor to the B5F and can be obtained from them (Amigó et al., 2010; Musek, 2007; Rushton & Irwing, 2008;
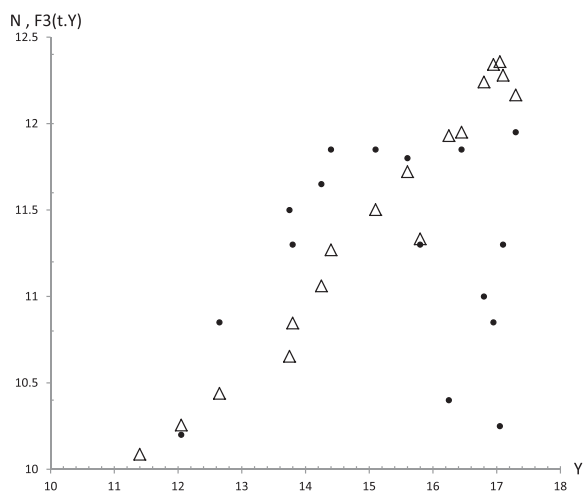
Figure 16. Average values. Experimental data (dots) of Neuroticism (*N*) together with the theoretical values $F_3(t,y)$ (triangles) from equation (29.3) versus experimental values of the GFP (*Y*). $R^2 = .38$.

Figure 18. Average values. Experimental data (dots) of Agreeableness (*A*) together with the theoretical values $F_5(t,y)$ (triangles) from equation (29.5) versus experimental values of the GFP (*Y*). $R^2 = .96$.
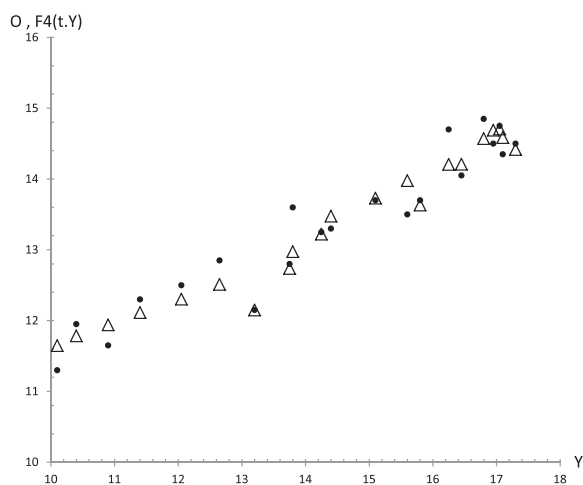

Figure 17. Average values. Experimental data (dots) of Openness to Experience (*O*) together with the theoretical values $F_4(t,y)$ (triangles) from equation (29.4) versus experimental values of the GFP (*Y*). $R^2 = .93$.

Table 4. *Mean data and Cases 1 to 20. Determination coefficients (R²) between the experimental data and the values given by equation (29.i), $1 \leq i \leq 5$ (respectively, for columns 2 to 6)*

	$R^2(E)$	$R^2(R)$	$R^2(N)$	$R^2(O)$	$R^2(A)$
Mean	.96	.82	.38	.93	.96
Case 1	.80	.50	.76	.76	.66
Case 2	.57	.22	.00	.17	.06
Case 3	.62	.24	.39	.01	.47
Case 4	.84	.52	.60	.50	.24
Case 5	.87	.04	.50	.03	.31
Case 6	.47	.04	.23	.26	.76
Case 7	.83	.68	.69	.54	.78
Case 8	.15	.37	.37	.08	.03
Case 9	.04	.41	.33	.01	.09
Case 10	.07	.31	.04	.19	.01
Case 11	.56	.34	.05	.05	.46
Case 12	.61	.54	.10	.01	.84
Case 13	.01	.09	.00	.71	.07
Case 14	.70	.70	.18	.75	.39
Case 15	.56	.05	.00	.26	.05
Case 16	.87	.50	.03	.83	.64
Case 17	.10	.40	.12	.03	.10
Case 18	.01	.14	.02	.07	.26
Case 19	.72	.15	.16	.10	.59
Case 20	.85	.02	.02	.18	.25

Rushton et al., 2008). A scheme of the structure of relations between the GFP and the B5F is obtained in this paper. Nevertheless, personality has a powerful dynamic component that is explained by the *response model*, as it can be observed in the results corresponding to the application case presented (see Figures 2 to 13). These results agree with the psychological and biological results of similar works such as the following ones:

• The work of Amigó et al., (2008), which studies the dynamic response of the brain activation level (as a biological base of the GFP) as a consequence of a generic stimulant drug intake.
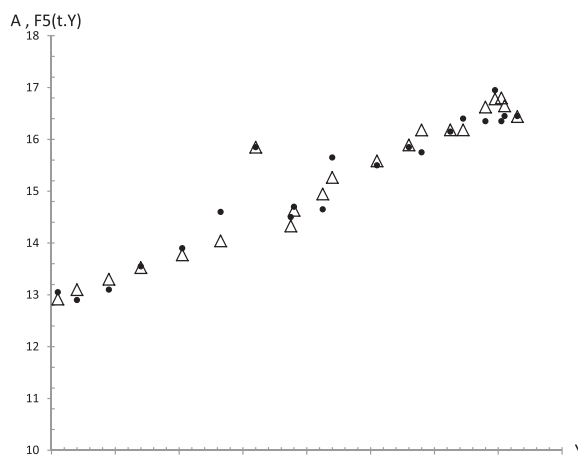
• The work of Caselles, Micó, and Amigó (2011), which studies the dynamic response of the GFP as a consequence of an intake of caffeine.

• The work of Micó, Amigó, and Caselles (2012), which studies the dynamic response of the *GFP* and the regulator gene *c-fos* (as a biological base of personality) as a consequence of a dose of methylphenidate.
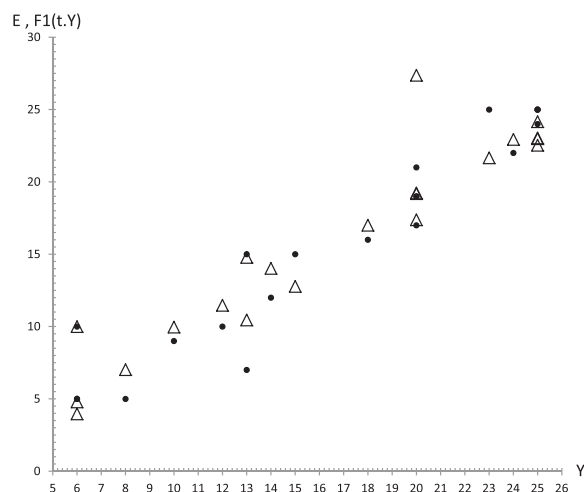
Figure 19. Case 1. Experimental data (dots) of Extraversion (*E*) together with the theoretical values $F_1(t,y)$ (triangles) from equation (29.1) versus experimental values of the GFP (*Y*). $R^2 = .80$.

Figure 21. Case 1. Experimental data (dots) of Neuroticism (*N*) together with the theoretical values $F_3(t,y)$ (triangles) from equation (29.3) versus experimental values of the GFP (*Y*). $R^2 = .76$.
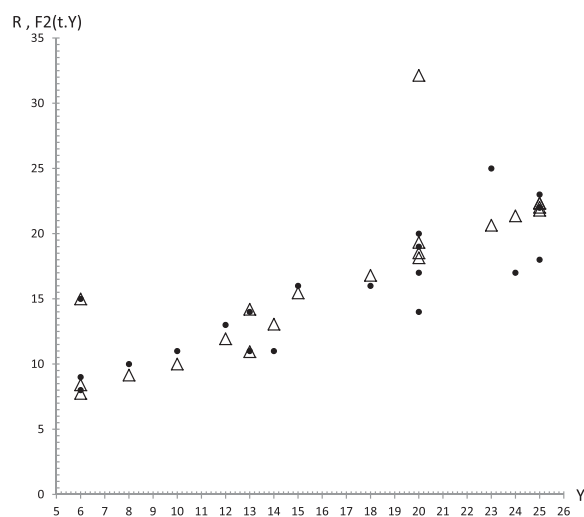

Figure 20. Case 1. Experimental data (dots) of Responsibility (*R*) together with the theoretical values $F_2(t,y)$ (triangles) from equation (29.2) versus experimental values of the GFP (*Y*). $R^2 = .50$.

Figure 22. Case 1. Experimental data (dots) of Openness to Experience (*O*) together with the theoretical values $F_4(t,y)$ (triangles) from equation (29.4) versus experimental values of the GFP (*Y*). $R^2 = .76$.

- In these three studies it is verified that the *response model* reproduces the dynamics of the brain activation level.
- The work of Amigó et al., (2009a) studies the temporary change of the GFP in relation to the concentration of glutamate in blood (as a biological substratum of personality) as a consequence of a dose of methylphenidate, being observed that as much the GFP as the glutamate responds to a dynamic pattern similar to the one reproduced by the *response model.*
- The work of Amigó, Caselles, and Micó (2013) studies the temporary change of the GFP in relation with the regulating gen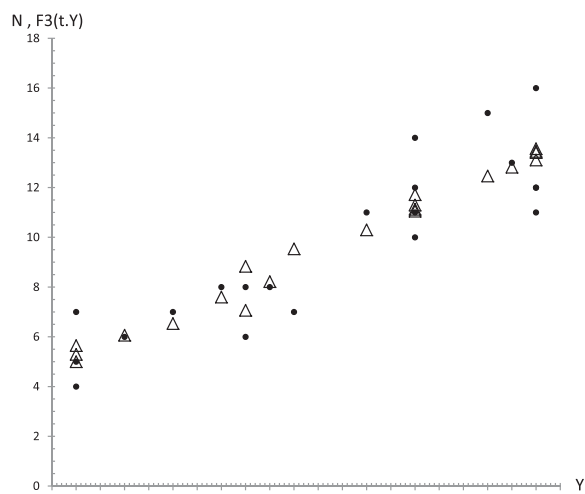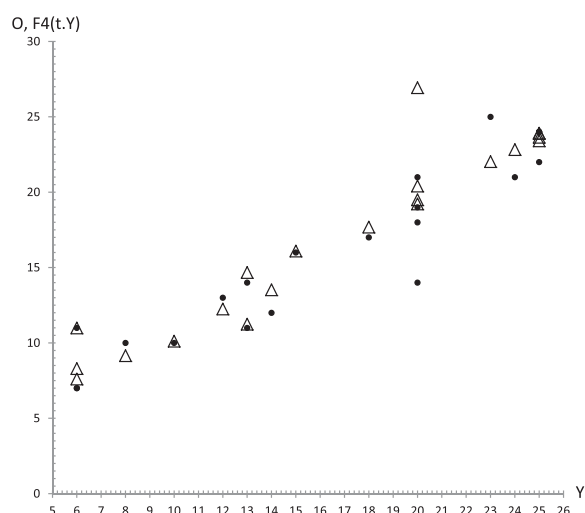e DRD3 (like another biological substratum of personality) as a consequence of a suggestion technique, being observed that as much the GFP as the DRD3 respond to a dynamic pattern similar to the one reproduced by the *response model.*

In the results presented in this paper (see Figures 2 to 13), it is observed that also the *response model* reproduces the dynamics of the B5F. Therefore, we consider a main result of the present work the verification of the fact that the dynamics of the main aspects of personality, as a consequence of a stimulus, can be reproduced with the *response model.*
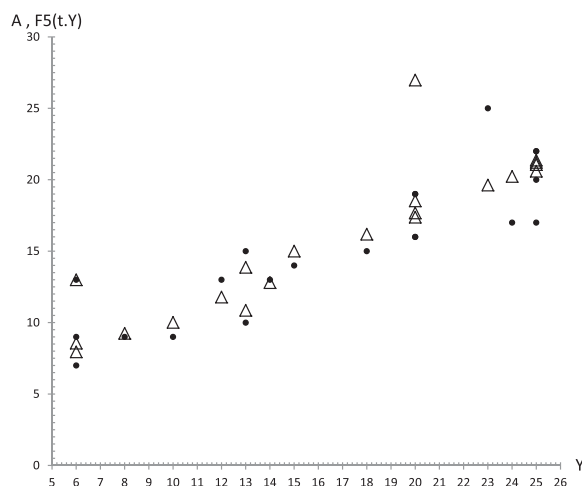
Figure 23. Case 1. Experimental data (dots) of Agreeableness (*A*) together with the theoretical values $F_5(t,y)$ (triangles) from equation (29.5) versus experimental values of the GFP (*Y*). $R^2 = .67$.

In addition, given the dynamic nature of personality, what we demonstrated in this article is that the *bridge model* quantitatively relates the GFP and the B5F. We have not found any previous study with the objective of relating the B5F from the point of view of the dynamic relations considered by the *bridge model*. Figures 14 to 19 show its predictive power.

On the other hand, let us recall that we left from the UPTT, whose fundamental postulate is (Amigó, 2005):

a. The UPTT proposes a hierarchical model of personality where the highest level corresponds to the GFP which includes the B5F. Nevertheless, considering the contributions of the *response model* and the *bridge model*, two new postulates of dynamic character would be needed in the UPTT base:

b. The GFP and the B5F have a dynamic character. This dynamics can be represented mathematically by the *response model,* which is valid and common to reproduce it as a consequence of a drug intake and, possibly, of any stimulus.

c. The evolutions of the GFP and the B5F are not independent but related. These relations can be represented mathematically by the *bridge model.*

Thus, following Postulates 1, 2 and 3, the UPTT can be considered as a unified dynamic theory of personality. Postulates 2 and 3 represent the co-evolution of all factors here considered, included the GFP. Postulate 2 is suggested by the results presented in this paper and the results of the works listed above, while Postulate 3 is suggested only by the results presented in this paper. The theory, in the future, should be contrasted for

other types of stimuli, such as non stimulant drugs or all those related with the human senses.

The application case presented in this paper to verify Postulates 2 and 3, consists of an experimental group with twenty adult subjects that consumed coffee on an empty stomach, where the GFP and the B5F are measured by two scales of adjectives: the Big Five Personality Adjectives List (BFPAL) (Brody & Ehrlichman, 1998) and the Five-Adjective Scale of the General Factor of Personality (GFP-FAS, Amigó et al., 2009b). These ones are two scales of adjectives in state-format that are completed several times after taking the coffee. This allows making an analysis of the change and the dynamics of personality, necessary to validate the *response model* and the *bridge model*.

We can mention several limitations of this study. In the first place, and as we have already indicated, it would be advisable to repeat the study with other environmental stimuli, may be other stimulating drugs, but also with depressing drugs, for the sake of the generalization of the results and the most complete validation of the model. It would be also advisable, in future studies, to consider the previous experience of the participants with the drug that is being used, that is to say, if they are non-consumers, occasional consumers or frequent consumers. We have seen that the response model without the delay parameter can be validated for the caffeine stimulus. However, avoiding this parameter is not possible in general. For instance, the response model needs to consider the delay when the stimulus is methylphenidate (Micó et al., 2012). Thus, a generalization of the bridge model that contains the delay parameter must be investigated. Obviously, it is assumed that the model is considered as a hypothesis that has resulted as validated through its contrast with real data from experience. The origins of the model have been to try to explain mathematically the biological and psychological processes previously observed by researchers and to try to extract consequences from it.

But, why is the response model chosen to fit the experimental data and not another kind of model? Because:

• A fundamental hypothesis of the UPTT is that personality has a dynamic character, thus a dynamic model is needed. The response model has this required dynamic character and has been validated in other contexts to evaluate personality dynamics (Amigó et al., 2008; Caselles et al., 2011; Micó et al., 2012) (see above in this section about the discussion of these papers). Moreover, the data are observed on a time sequence (they are not static data).

• The response model, as a differential equation, provides quantitatively partial dynamic processes of the

personality theory with biological sense, such as the homeostatic control, the excitation effect, the inhibitor effect and the stimulus. Also, the model parameters have all a biological sense (see Section 2 about the response model).

Other competitive models perhaps could fit the experimental data; for example, Structural Equations Modeling (SEM) approach, time series or network models. However:

- The authors consider that the response model is a consolidated knowledge, its equations and parameters have a biological sense and the bridge model can be deduced from it to relate the B5F and the GFP conserving the biological sense of the parameters. Observe that once the response model is accepted as a consolidated knowledge, the bridge model is deduced from the hypothesis that the dynamics of GFP and the B5F is invariant, i.e., their dynamics holds the response model. Thus, the bridge model is a consequence of the assumptions stated to deduce the response model. The *SEM* approach hardly if not impossible (we could not achieve it), can respect the causal diagram of Figure 1 with the biological sense of its parameters, concepts and structure.
- On the other hand, the time series and the network models are only input-output models that could not provide any explanation about the biological mechanisms of the personality dynamics, such as the homeostatic control, the excitation effect or the inhibition effect.

A final question to discuss is whether the data described are comparable or not to, for example, time-course data in the positive sciences such as physics or chemistry, when the data are measured by a machine that is not getting bored and that is capable of performing a measurement every second or even millisecond. It seems evident that the data collected in the experimental design have a greater measurement error. The authors assume that any measure has an error due to the method of measure and the device of measure. In the context of the GMM, the consideration of error in models converts them into stochastic models. The GMM contemplates two modeling possibilities: deterministic and stochastic. The stochastic models arise when either the randomness of some input variables can be deduced from a group of data or when some fitting functions are needed to obtain the model from experimental or historical data. The deterministic models arise when none of these two options is possible or necessary. When convenient, the detailed method to obtain a stochastic model can be found in the works of Caselles (1992b, 2008). An example of

stochastic model obtained following this method in the context of social systems is the work of Sanz, Micó, Caselles, and Soler (2014). In the context of the present study, the randomness of some variables could be deduced from the person-variability in the group (which would include personal differences and measurement errors). However, this approach should be a future work, when more deterministic approaches consolidate the model.

In general, the *response model* and the *bridge model* open a way to be followed in a future time, not only with psychological instruments, but with measures of biological character that provide a better understanding of the dynamic and biological nature of the human personality.

An epistemological limitation of the presented formalism is that the *response* and *bridge models* can turn out too complex to be used in Psychological research. But we want here to break a lance in favor of the contribution of the General Systems Theory to expand the horizon of research. In the context of this trans-disciplinary vocation, the research has got together psychologists, mathematicians and physicists who have collaborated very closely. This collaboration has allowed elaborating the *response model* like a system of three connected differential equations, and the *bridge model* like a partial derivative equation, contributing of this way to give an epistemological status to Personality Theory similar to that of applied sciences, such as it is asserted in the introduction of this paper. This article is a clear bet for the inter-disciplinary study of high level, and the result has been to enrich the UPTT with two new postulates of dynamic character.

This article offers the possibility of integrating in a high level important theoretical and methodological aspects like:

a. The structural perspective of personality as opposed to the dynamic one.
b. The perspective of trait as opposed to the one of state in the studies of personality (it has been used here lists of adjectives in state-format).
c. The study of the basic components of personality as opposed to the global and holistic conception of the same one (represented by the GFP).
d. The experimental study of personality on the one hand, and on the other one, the elaboration of two complex mathematical models based on the Theory of Systems.
e. The internalist perspective of personality as opposed to the environmentalist perspective (represented by the changes of personality in response to a drug intake).

These complex mathematical models (the *response model* and the *bridge model*), will allow us to describe

personality in all its complexity and to predict its changes in response to environmental stimuli, as it can be the consumption of a drug. Thus, as much from a theoretical point of view as from an applied one, the models here proposed open a new perspective in the understanding and study of personality like a global system that interacts intimately with the environment. As we above said, this study is a clear bet for the high level inter-disciplinary research, a bet that will have to be perfected but that it is very important so that the future science is based on the integration of the human knowledge.

References

Amigó S. (2005). *La teoría del rasgo único de personalidad. Hacia una teoría unificada del cerebro y la conducta* [The unique-trait personality theory. Towards a unified theory of brain and conduct]. Valencia, Spain: Editorial de la Universidad Politécnica de Valencia.

Amigó S., Caselles A., & Micó J. C. (2008). A dynamic extraversion model: The brain's response to a single dose of a stimulant drug. *British Journal of Mathematical and Statistical Psychology*, 61, 211–231. http://dx.doi.org/10.1348/000711007X185514

Amigó S., Caselles A., & Micó J. C. (2010). The General Factor of Personality Questionnaire (GFPQ): Only one factor to understand the personality? *The Spanish Journal of Psychology*, 13, 5–17. http://dx.doi.org/10.1017/S1138741600003644

Amigó S., Caselles A., & Micó J. C. (2013). The self-regulation therapy to reproduce drug effects: A suggestion technique to change personality and the DRD3 gene expression. *International Journal of Clinical and Experimental Hypnosis*, 61, 282–304. http://dx.doi.org/10.1080/00207144.2013.784094

Amigó S., Caselles A., Micó J. C., & García J. M. (2009a). Dynamics of the unique trait of personality: Blood's glutamate in response to methylphenidate and conditioning. *Revista Internacional de Sistemas*, 16, 35–40.

Amigó S., Micó J. C., & Caselles A. (2009b). Five adjectives to explain the whole personality: A brief scale of personality. *Revista Internacional de Sistemas*, 16, 41–43.

Becker P. (1999). Beyond the Big Five. *Personality and Individual Differences*, 26, 511–530. http://dx.doi.org/10.1016/S0191-8869(98)00168-8

Brody N., & Ehrlichman H. (1998). *Personality psychology. The science of individuality*. New Jersey, NJ: Prentice Hall, Inc.

Caselles A. (1992a). Structure and behavior in general systems theory. *Cybernetics and Systems: An International Journal*, 23, 549–560. http://dx.doi.org/10.1080/01969729208927481

Caselles A. (1992b). Simulation of Large Scale Stochastic Systems. In R. Trappl (Ed.), *Cybernetics and systems'92* (pp. 221–228) Singapore, Republic of Singapore: World Scientific.

Caselles A. (1993). Systems decomposition and coupling. *Cybernetics and Systems: An International Journal*, 24, 305–323. http://dx.doi.org/10.1080/01969729308961712

Caselles A. (1994). Improvements in the systems-based models generator SIGEM. *Cybernetics and Systems: An International Journal*, 25, 81–103. http://dx.doi.org/10.1080/01969729408902317

Caselles A. (1995). Systems autonomy and learning from experience. *Advances in Systems Science and Applications, Special Issue I*, 1–6.

Caselles A. (2008) *Modelización y simulación de sistemas complejos* [Modeling and simulation of complex systems]. Valencia, Spain: Universitat de València.

Caselles A., Micó J. C., & Amigó S. (2010). Cocaine addiction and personality: A mathematical model. *British Journal of Mathematical and Statistical Psychology*, 63, 449–480. http://dx.doi.org/10.1348/000711009X470768

Caselles A., Micó J. C., & Amigó S. (2011). Dynamics of the general factor of personality in response to a single dose of caffeine. *The Spanish Journal of Psychology*, 14, 675–692. http://dx.doi.org/10.5209/rev_SJOP.2011.v14.n2.16

Childs E., & de Wit H. (2006). Subjective, behavioral, and physiological effects of acute caffeine in light, nondependent caffeine users. *Psychopharmacology*, 185, 514–523. http://dx.doi.org/10.1007/s00213-006-0341-3

Corr P. J., & Kumari V. (2000). Individual differences in mood reactions to d-amphetamine: A test of three personality factors. *Journal of Psychopharmacology*, 14, 371–377. http://dx.doi.org/10.1177/026988110001400406

Costa P. T., & McCrae R. R. (1992). *NEO-PIR: Professional Manual*. Odessa, FL: Psychological Assessment Resources.

Digman J. M. (1990). Personality structure: Emergence of the Five-Factor Model. *Annual Review of Psychology*, 41, 417–440. http://dx.doi.org/10.1146/annurev.ps.41.020190.002221

Digman J. M. (1997). Higher-order factors of the Big Five. *Journal of Personality and Social Psychology*, 73, 1246–1256. http://dx.doi.org/10.1037/0022-3514.73.6.1246

Eysenck H. J. (1991). Dimensions of personality: 16, 5 or 3? Criteria for a taxonomic paradigm. *Personality and Individual Differences*, 12, 773–790. http://dx.doi.org/10.1016/0191-8869(91)90144-Z

Eysenck H. J. (1992). A reply to Costa and McCrae. P or A and C–the role of theory. *Personality and Individual Differences*, 13, 867–868. http://dx.doi.org/10.1016/0191-8869(92)90003-8

Figueredo A. J., Vásquez G., Brumbach B. H., Schneider S. M. R., Sefcek J. A., Tal I. R., … & Jacobs W. J. (2006). Consilience and life history theory: From genes to brain to reproductive strategy. *Developmental Review*, 26, 243–275. http://dx.doi.org/10.1016/j.dr.2006.02.002

Forrester J. W. (1961). *Industrial dynamics*. Cambridge, MA: MIT Press.

Forrester J. W. (1970). *Urban dynamics*. Cambridge, MA: MIT Press.

Grossberg S. (2000). The imbalanced brain: From normal to schizophrenia. *Biological Psychiatry*, 48, 81–98. http://dx.doi.org/10.1016/S0006-3223(00)00903-3

McCrae R. R., & Costa P. T. (1987). Validation of the Five-Factor model of personality across instruments and observers. *Journal of Personality and Social Psychology*, 52, 81–90. http://dx.doi.org/10.1037//0022-3514.52.1.81

McCrae R. R., & Costa P. T. (1997). Personality trait structure as a human universal. *American Psychologist*, *52*, 509–516. http://dx.doi.org/10.1037/0003-066X.52.5.509

McNair D. L. M., & Droppleman L. (1971). *Profile of mood states*. San Diego, CA: Educational and Industrial Testing Service.

Micó J. C., Amigó S., & Caselles A. (2008, December). Biological and dynamic nature of personality: A dynamic system approach. *Paper presented at the VII Congress of the European Systems Union*. Lisboa, Portugal.

Micó J. C., Amigó S., & Caselles A. (2012). Changing the general factor of personality and the c-fos expression with methylphenidate and self-regulation therapy. *The Spanish Journal of Psychology*, *15*, 850–867. http://dx.doi.org/10.5209/rev_SJOP.2012.v15.n2.38896

Micó J. C., Caselles A., Amigó S., Cotolí A., & Sanz M. T. (2013). A mathematical approach to the body–mind problem from a system personality theory (a systems approach to the body–mind problem). *Systems Research and Behavioral Science*, *30*, 735–749. http://dx.doi.org/10.1002/sres.2241

Musek J. (2007). A general factor of personality: Evidence for the big one in the Five-Factor model. *Journal of Research in Personality*, *41*, 1213–1233. http://dx.doi.org/10.1016/j.jrp.2007.02.003

Nehlig A. (1999). Does caffeine lead to psychological dependence? Studies in animals and humans reveal that it may lead to dependence only at very high doses. *CHEMTECH*, *29*, 30–35.

Pelechano V. (1973). *Personalidad y adaptación: Tres escuelas y un modelo* [Personality and adaptation: Three schools and one model]. Barcelona, Spain: Vicens Vives.

Pelechano V. (2000). *Psicología sistemática de la personalidad* [Systematic psychology of personality]. Barcelona, Spain: Ariel.

Rushton J. P., Bons T. A., & Hur Y-M (2008). The genetics and evolution of the general factor of personality. *Journal of Research in Personality*, *42*, 1173–1185. http://dx.doi.org/10.1016/j.jrp.2008.03.002

Rushton J. P., & Irwing P. (2008). A general factor of personality (GFP) from two meta-analyses of the Big Five: Digman (1997) and Mount, Barrick, Scullen, and Rounds (2005). *Personality and Individual Differences*, *45*, 679–683. http://dx.doi.org/10.1016/j.paid.2008.07.015

Sanz M. T., Micó J. C., Caselles A., & Soler D. (2014). A stochastic model for population and well-being dynamics. *Journal of Mathematical Sociology*, *38*(2), 75–94.

Saucier G., & Goldberg L. R. (2003). The structure of personality attributes. In M. R. Barrick & A. M. Ryan (Eds.), *Personality and work* (pp. 1–29). San Francisco, CA: Jossey-Bass.

Schutte N. S., Malouff J. M., Segrera E., Wolf A., & Rodgers L. (2003). States reflecting the Big Five dimensions. *Personality and Individual Differences*, *34*, 591–603. http://dx.doi.org/10.1016/S0191-8869(02)00031-4

Solomon R. L., & Corbit J. D. (1974). An opponent-process theory of motivation I. Temporal dynamics of affect. *Psychological Review*, *81*, 119–145. http://dx.doi.org/10.1037/h0036128

Wiggins J. S., & Trapnell P. D. (1996). A dyadic-interactional perspective on the Five-Factor Model. In J. S. Wiggins (Ed.), *The Five-Factor Model of personality. Theoretical perspectives* (pp. 88–162). New York, NY: Guilford.

Zuckerman M., & Lubin B. (1965). *Manual for the Multiple Affect Adjective Check List*. San Diego, CA: Edits.