Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Reinforcement sensitivity theory may predict COVID-19 infection outcome and vulnerability☆

Marco A. Pulido [a,b,*], Fernanda Brown [a], Renata Cortés [a], Miriam Salame [a]

[a] Universidad Anáhuac México, Mexico
[b] Centro de Estudios Superiores Monte Fénix, Mexico

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ABSTRACT

Research suggests that specific behavior patterns may be related with the outcome and vulnerability of a COVID-19 infection; nevertheless, much of this information has been obtained by means of psychological paradigms that are not based on research conducted using experimental designs. Thus, the purpose of the present study was to identify behavior patterns associated with COVID-19 outcome and vulnerability from the point of view of the Reinforcement Sensitivity Theory. A total of 464 college students from Mexico-City participated in the study. Participants answered the Behavior Inhibition, Behavior Activation scales (Carver & White, 1994), the Reinforcement Sensitivity Theory Personality Questionnaire (Corr & Cooper, 2016) and a COVID-19 symptom checklist. Data showed that those individuals who respond in an enthusiastic way to rewards develop less symptoms of COVID-19. Additionally, individuals who are keen in the exploration and identification of new rewarding opportunities are less likely to develop a COVID-19 infection. Both findings suggest that a potent Behavior Activation System could protect individuals during the present pandemic. These results are in general agreement with others produced within the same framework.

1. Introduction

In 2019, a virus of zoonotic origin SARS-COV-2 was detected in the province of Wuhan, China. The rapid spread of the virus, and its lethality, lead the World Health Organization to declare a pandemic on March 2020. Data obtained in November 2021 suggests that >5 million individuals have died from the disease (Covid-19). Research has identified a number of medical conditions associated with complications (and even death) from Covid-19 (Gao et al., 2021; Sanche et al., 2020). Nevertheless, behavioral attributes of individuals have also been linked with poor Covid-19 infection prognosis and even death. For instance, using a cohort design Nemani et al. (2021) compared a total of 7348 psychiatric and non-psychiatric individuals. Results showed significantly higher Covid-19 mortality in the former group. Toubasi et al. (2021) conducted a meta-analysis of 16 studies that linked mental health and Covid-19 mortality. Their data showed increased mortality in individuals with mental disorders. This trend was particularly conspicuous in individuals with schizophrenic and delusional traits. Vai et al. (2021) also conducted a meta-analysis that included 33 studies and nearly a million and a half individuals. Their analysis suggest that Covid-19 mortality rates increase significantly in individuals with psychotic and mood disorders. Mortality rates are also significantly elevated in individuals with antipsychotic, antidepressant and anxiolytic consumption. Behavioral attributes have also been associated to a higher probability of Covid-19 contagion. For instance, Frías-Armenta et al. (2021) explored personality traits and their relation with Covid-19 frequency symptoms, in a sample of 709 Mexican individuals. Their results suggested that impulsive individuals presented more symptoms related to a Covid-19 infection. Rolón et al. (2021) used the Big-Five short version to determine if extroverted individuals were more likely to develop a COVID-19 infection. Data confirmed their hypothesis, thus they consequently titled their paper "Extraversion Kills". Some data produced by Glei and Weinstein (2022) appears to support their conclusions. However, their paper lacks mortality data, (and sampling problems make it difficult to interpret their results, Brauer & Proyer, 2022).

One of the most prolific endeavors within the field of psychology is the development of personality theories (Boyle et al., 2008).

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* Corresponding author at: Avenida Universidad #1330, A, 1102, Colonia del Carmen Coyoacán, Ciudad de México, C.P. 04100, Mexico.
E-mail addresses: mpulidor100@gmail.com (M.A. Pulido), renata.cortezgu@anahuac.mx (R. Cortés).

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Nevertheless, most of these theories are developed based on one-on-one clinical interventions, where objectivity, proper control of extraneous variables and the use of experimental designs are complicated. One exception to this procedure (not the only one) is Gray's (1973) Reinforcement Sensitivity Theory (RST). Originally developed with potent experimental designs, and using non-human animals as subjects, it eventually demonstrated generality across species (Canli, 2006; Smillie, 2008). This last development led to the construction of self-report scales and questionnaires designed to assess personality in agreement with RST (Corr, 2016; Kramer & Rodriguez, 2018). So far, questionnaires and scales based on RST have shown the empirical capacity to replicate relevant findings within the behavioral sciences (Bijttebier et al., 2009; Gaher et al., 2015) and sometimes to extend and correct these findings (Corr, 2010; Loxton & Tipman, 2017; Pulido et al., 2021).

In the original RST (Gray, 1987) behavior is understood in terms of the relative strength two opposing bio-behavioral systems. These systems mediate approach and withdrawal behaviors. Data produced both in the laboratory (Blanchard et al., 1990; Blanchard & Blanchard, 1988) in psychometric research (see Cooper et al., 2007 for a review), and from other sources (see Perkins et al., 2007 for a review) led Gray and McNaughton (2000) to revise RST. Revised RST (r-RST) is a three-system model. The BIS (Behavior Inhibition System) is activated by conflicting events (stimuli that may be equally associated with reinforcement or punishment); the BIS "analyzes" these events and "a result is produced". The result leads to, either the activation of the BAS (Behavior Activation System) or the Fight, Flee, Freeze System (FFFS). Self-report scales have been developed to assess both models; some of them have shown acceptable psychometric properties (Corr, 2016; Krupić et al., 2016).

Thus, given that studies have shown that behavioral patterns have been associated with the evolution and outcome of a COVID-19 infection. Additionally, given that most of the studies that have been published on the subject exist in the context of personality theories that lack proper scientific support (i.e., they have not been developed using experimental designs), the purpose of the present study is to determine if RST and r-RST may predict the outcome of a COVID-19 infection. In a similar vein, a second purpose of the present study was to determine if RST and r-RST may predict risk of infection by COVID-19.

Studies conducted by Bacon and Corr in samples taken in the UK and using the RST-PQ (Bacon & Corr, 2020a, 2020b) suggest that individuals with high BAS scores (especially Goal Drive Persistence) are more likely to show conformity to social norms (such as those implemented to prevent COVID-19 spread). They have also shown that high BAS scores (especially regarding Reward Responsiveness), correlate with motivation to take positive actions to avoid COVID-19 contagion. Thus, the present authors hypothesize that high BAS scores in Goal Drive Persistence and Reward Responsiveness may be associated with other relevant COVID-19 manifestations, such as symptom frequency during and infection, and vulnerability to develop a COVID-19 infection.

2. Material and methods

2.1. Participants

A convenience sample of 464 Mexican, undergraduate college students participated in the study. The average age of the participants was 22.5 years, with a standard deviation of 4.7 years. Of the total sample, 31.7 % had received one or more laboratory diagnosis that indicated that they tested positive to COVID-19 (from March 2020 to October 2021). The exact dates of these tests were not recorded. Most participants were female (62.5 %), single (92.8 %) and lived with their parents (79.4 %). Participation in the study was voluntary, prior digital signing of the informed consent form. The study was presented to the Direction of Psychology of the Anáhuac University in Mexico City during the month of July 2021. The study was authorized, and research activities initiated in August of the same year.

2.2. Instruments

Participants received a battery consisting of: a) the informed consent letter, b) a brief questionnaire to gather demographic data, c) the Behavior inhibition, Behavior Activation Scales (BIS/BAS scales) developed by Carver and White (1994), d) the Reinforcement Sensitivity Theory Personality Questionnaire (RST-PQ) developed by Corr & Cooper, 2016 and e) the COVID-19 symptoms check list, developed by the present authors. Perhaps the reader may be surprised by the fact that the BIS/BAS scales were used in the study, (as the model that gave origin to this scale has been extensively modified and corrected (Corr, 2004)). However, the present authors reasoned that the results produced by the RST-PQ needed "some sort of confirmation." As the BIS/BAS scales are the only valid and reliable RST measurement adapted for Mexican college students (Pulido et al., 2016), it was decided to include them in the present study.

Regarding the BIS/BAS scales, they were designed to assess the original RST developed by Gray (1973) and consists of 20 items that may be answered on a four point Likert-type scale. In agreement with the original RST the scales assess how individuals describe themselves regarding different indicators of the behavior activation and behavior inhibition systems. It consists of four subscales, one of this contains items designed to measure the BIS (seven items). Measurement of the BAS is divided into three subscales. The first one, BAS "Fun-seeking (BAS-F)", consists of four items that allow the individual to describe himself in terms of the degree in which he considers that he is keen in the pursuit of new sources and forms of rewarding activities. The second sub-scale of the BAS receives the name of "Reward-responsiveness (BAS-R)". It consists of five items and helps the individual describe himself in terms of how he "reacts" to rewards. The third and final subscale of the BAS receives the name of "Drive (BAS-D)". This subscale consist of four items that allow the individual to describe his specific motivational state regarding rewards. Individuals rate how well items describe them on a 4 point scale that ranges from "strongly disagree" to "strongly agree". An example of the items of the BIS/BAS scales is as follows: "I go out of my way to get the things I want". The scales showed good internal consistency (0.853); all scales showed adequate internal consistency (BIS = 0.848, BAS-R, 0.790, BAS-F = 0.713, BAS-D = 0.776). Exploratory factor analysis suggested the items loaded on their hypothesized subscales.

Regarding the RST-PQ, the questionnaire was designed to assess (r-RST) by Corr and Cooper (2016). The RST-PQ was developed with the intention of designing a self-report instrument that reflects the changes that been made in the original RST. It consists of 65 items that are answered in a four point Likert-type scale. A total of 23 items assess the BIS scale and 10 items assess the FFFS scale. Regarding the BAS scale, it is divided into four subscales. Reward interest (RI) includes 7 items and helps the individual report his perceived interest in exploring new reinforcing events and opportunities. Reward reactivity (RR) allows individuals to assess their perceived reaction towards rewards. Also within the BAS domain is Goal Drive Persistence (GDP). This subscale is comprised of 10 items and it allows individuals to assess their capacity to plan long-term goals (and pursue them in a persistent manner). Finally, the BAS also includes and Impulsivity (IMP) subscale. It consists of 8 items and allows individuals to assess the way in which they react when the reward is at hand (impulsively or with restraint). Individuals rate how well the items describe them on a 4-point scale that ranges from "Not at all" to "Highly". An item example is as follows, "I am especially sensitive to reward". The RST-PQ has shown adequate internal consistency in samples of Mexican college students (0.928). Most sub-scales of the RST-PQ have also shown adequate internal consistency (BIS = 0.873, FFFS = 0.911, RI = 0.835, GDP = 0.860, IMP = 0.539, RR = 0.724). It has also shown the capacity to replicate well established empirical findings (Pulido et al., 2021).

Finally, the present authors, based on the CDC Coronavirus Self-Checker, developed the COVID-19 symptoms checklist (C-19SCH). The C-19SCH consists of 33 questions that are answered using dichotomous

(yes, no) scale. The most common symptoms known to science are organized in the three most frequently used categories (mild-to moderate, severe, and critical). An item example is as follows, "Do you have difficulty breathing?" The C-19SCH was revised by two licensed medical professionals, and their recommendations were included in the checklist final form. Also the professionals were asked regarding the pertinence of the items to measure COVID-19 symptoms. As both of them agreed with the adequacy of the items, the present authors suggest that the C-19SCH may possess criterion validity. The internal consistency of the C-19SCH was established at 0.957. When symptoms were grouped in their respective categories, all of them showed adequate internal consistency (mild = 0.919, severe = 0.911, critical = 0.868). The C-19SCH is scored simply by adding one point for each symptom marked by the individual.

2.3. Procedure

The battery was uploaded in a Google Forms platform and a link to the questionnaires generated. Previous authorization of the Direction of Psychology of the Universidad Anáhuac, the link was shared with a pool of undergraduate students via email. The link was sent only once and it stated that participation was voluntary. Data recollection started during September first 2021 and ended the first of October of the same year.

2.4. Data analysis

Only complete questionnaires were used in the analyses. Questionnaires were considered complete if no more than one question was missing (in each one of the two personality questionnaires). And no more than two questions were missing overall in the battery. Data were analyzed using IBM SPSS version 23. Both correlations and regressions were assessed using total individual averages for personality subscales and C-19SCH symptom checklist scores. Correlations and regressions only used data from individuals who had been infected with COVID-19 (n = 147). Chi-square analyses used data from both infected and non-infected participants (n = 464).

3. Results

Table 1 shows Pearson correlations between the average scores obtained in the different factors of the BIS/BAS scales, and the total sum of symptoms presented by those individuals that reported at least one COVID-19 episode.

Table 1, shows that factors of the BIS/BAS scales maintain negative and statistically significant correlations with COVID-19 symptoms sum (BAS-F and BAS-R).

Table 2 shows the results of a multiple regression analysis using the factors of the BIS/BAS scales as independent variable and the total sum of symptoms presented by those individuals that reported at least one COVID_19 episode as dependent variable. No multicollinearity was found between the IV as VIF scores were way below 5 (BIS = 1.2, BAS-D = 1.5, BAS-F = 1.5, BAS-*R* = 1.6).

Table 2 shows that BAS-R is a negative and statistically significant predictor of C-19SCH scores. Given the disparities between men and women during the sampling process, separate regression analyses were conducted for each sex (see Appendix A). The highest regression coefficient for men was BAS-R (−0.359). The coefficient attained statistical significance (p = .04). No other coefficient achieved statistical significance. Regarding women, the highest regression coefficient was, again BAS-R (−0.208), nevertheless it did not attain statistical significance (p = .136).

In an attempt to determine if the BIS/BAS scales differentiate between individuals that have developed a COVID-19 infection (and those that have not) two-group chi-square tests were conducted. The first group was simply a dichotomous variable that established if the individual had had, at any moment previous to the study, a certified positive diagnosis of COVID-19 infection. The second group was developed with the objective of transforming the continuous data from each BIS/BAS scale into four discrete values. This was accomplished by calculating the quartiles for each scale and assigning a number one to all individuals in the lower quartile (and so on). Table 3 shows the results of the analyses.

Table 3 found no statistically significant relationship between the result of COVID-19 diagnosis and the quartiles of the BIS/BAS scales. In order to "make the most" of the quantitative independent variables of the study, logistic regression analysis was also conducted (see appendix 2). The scales of the BIS/BAS test were used as independent variables; having (or not) a COVID diagnosis was used as dependent variable. BAS-D was associated with the highest regression coefficient (0.355), however it did not reach statistical significance according to a Wald test (0.07 > 0.05).

Table 4 shows the Pearson correlations between the scales of the RST-PQ and C-19SCH scores.

Table 4, shows that RR maintains an inverse and statistically significant relationship with C-19SCH scores.

Table 5 shows the results of a multiple regression analysis using the factors of the RST-PQ as independent variables and the total sum of symptoms presented by those individuals that reported at least one COVID_19 episode as dependent variable. No multicollinearity was found between the IV as all VIF scores were way below 5 (BIS = 1.5, FFFS = 1.4, RR = 1.7, RI = 1.6, GDP = 1.7, IMP = 1.4).

Table 5 shows that RR is a negative and statistically significant predictor of C-19SCH scores. Given the disparities between men and women during the sampling process, separate regression analyses were conducted for each sex (see Appendix C). The highest regression coefficient for men was RR (−0.452). The coefficient attained statistical significance (p = .05). No other coefficient for men achieved statistical significance. Regarding women, the highest regression coefficient was, again RR (−0.177), nevertheless it did not attain statistical significance (p = .234).

Table 6 was developed in an identical way as Table 3 however; group two of the Chi-square test corresponds to the quartiles of the RST-PQ factors.

Logistic regression analysis was also conducted (see Appendix D).

Table 1
Pearson correlations between the BIS/BAS scales and C-19SCH scores.

Variables	BIS	BAS-D	BAS-F	BAS-R
C-19SCH scores	0.084	−0.126	−0.182*	−0.310**

* p < .05.
** p < .01

Table 2
Linear regression analysis between the BIS/BAS scales and C-19SCH scores.

	β	*t*	*p*
BAS-R	−0.28	−2.71	0.00**
BAS-F	−0.08	−0.75	0.45
BAS-D	0.04	0.83	0.67
BIS	0.13	1.49	0.14
Constant		5.94	0.00**

df. = 4/144
* $p \leq .05$.
** $p \leq .01$.

Table 3
Chi-square tests. BIS/BAS scales quartiles vs Positive COVID-19 Diagnosis.

BAS-R	$X^2(3) = 2.48$, p. = 0.478
BAS-F	$X^2(3) = 0.293$, p. = 0.961
BAS-D	$X^2(3) = 2.21$, p. = 0.531
BIS	$X^2(3) = 2.24$, p. = 0.525

Table 4
Pearson correlations between the RST-PQ and C-19SCH scores.

Variables	BIS	FFFS	RR	RI	GDP	IMP
C-19SCH scores	0.103	0.047	−0.257**	−0.131	−0.092	0.041

* $p \leq .05$.
** $p < .01$.

Table 5
Linear regression analysis between the RST-PQ and C-19SCH scores.

	ß	t	P
RR	−0.259	−2.234	0.027*
RI	−0.048	−0.419	0.676
GDP	0.075	0.653	0.515
IMP	0.155	1.484	0.141
FFFS	−0.012	−0.115	0.909
BIS	0.132	1.225	0.223
Constant		4.657	0.000**

df. = 6/142.
* $p < .05$.
** $p < .01$.

Table 6
Chi-square tests. RST-PQ factor quartiles vs Positive COVID-19 Diagnosis.

RR	$X^2(3) = 2.83$, p. = .418
RI	$X^2(3) = 8.10$, p. = .044*
GDP	$X^2(3) = 3.98$, p. = .263
IMP	$X^2(3) = 6.41$, p. = .093
FFS	$X^2(3) = 1.10$, p. = .776
BIS	$X^2(3) = 0.493$, p. = .920

* $p < .05$.

The scales of the RST-PQ test were used as independent variables; having (or not) a COVID diagnosis was used as dependent variable. RR and RI were associated with the highest regression coefficient (0.379 and 0.320), however they did not reach statistical significance according to a Wald test ($0.193 > 0.05$ and $0.209 > 0.05$).

4. Discussion

In general, the results of the present study suggest that regardless of the scale used to measure personality, COVID-19 symptom frequency is an inverse function of the "potency" of the BAS, specifically of the way individuals react towards reinforcing stimuli (RR). Data suggest that those individuals that value rewards in a positive and enthusiastic way, may develop less COVID-19 symptoms. This finding is particularly conspicuous in male individuals. These results confirm the hypothesis regarding Reward Responsiveness as an inverse predictor of COVID-19 symptomatology. However, they are at odds with the hypothesis that Goal Drive Persistence serves the same function.

In contrast with the previous finding, only the RST-PQ may help predict the risk of a COVID-19 infection. Specifically the RI factor of the questionnaire presents statistically significant differences in frequency distribution between individuals that have suffered an infection, and those that have not. An analysis of frequency distribution shows that non-infected individuals are usually located in the higher quartiles (3 and 4) of the RI factor. Frequency distribution also shows that the number of non-infected individuals increases consistently across quartiles of RI. The finding suggests that those individuals that are keen in the search of new sources of reinforcement, may be less prone to develop a COVID-19 infection. This last finding is at odds with the present study hypotheses, as neither RR nor GDP predicted contagion vulnerability. The finding is also a rather tenuous one, as it may be identified using the chi-square test but not in the logistic regression analysis.

Research on COVID-19 and RST is scarce, nevertheless the findings of the present study align with data produced by Bacon and Corr (2020a) in the sense that social behaviors oriented towards protecting others from COVID-19 depend on the BAS. They also align well with data produced by Bacon and Corr (2020b) in the sense that individuals that actively protect themselves (and others from COVID-19) show higher BAS scores (relative to individuals that do not protect themselves). In a similar vein, Katz and Yovel (2021) produced data that suggest that individuals with high BAS scores were better suited for coping with the stress produced by the COVID-19 pandemic, (than those with low scores). This last finding could possibly explain the results of the present study. Selye (1956) suggested that stress is a non-specific response of the body to external demands of the environment (and the way we perceive these demands). At first, it helps the individual cope with the new situation (by mobilizing the resources of the body to attend the situation). However, as the stress response persists in time, it drains the resources of the body (including its ability to fight off disease, Khansari et al., 1990). Thus, if a potent BAS helps the individual cope with stress, he/she may possess a stronger immune response (thus decreasing the capacity of the SARS-COV-2 virus to infect the body). Further research may help validate this premise. Taken together, the studies conducted from the perspective of RST and r-RST suggest that screening individuals with high and low BAS scores may help predict symptom frequency. Such screening may also help identify individuals whose general behavior could pose infection risk towards others.

As was mentioned in the introduction of this paper, other scientists have tried to predict the outcome of a COVID-19 infection based on personality traits. Efforts have also been made to try to identify "personalities" related to the spread of COVID-19. It is not easy to compare the previously mentioned research with the present data because most of it comes from different, and contrasting, psychological paradigms. Nevertheless, an effort will now be made to review this research, and compare it with the present data. First, a meta-analysis conducted by Vai et al. (2021) covering 33 studies on peer-reviewed journals suggests that both mortality and hospitalization by COVID-19 are related to mental disorders, more specifically to psychosis and mood disorders. Interestingly, neither dependent variable is related to anxiety. This last finding could loosely be considered to coincide with the findings of the present paper (that suggest that neither the BIS nor the FFFS predict COVID-19 symptom frequency). The results of the meta-analysis coincide with the ideas proposed by Galea and Ettman (2021).

Regarding individuals with personalities associated with "COVID-19 spreading behaviors", Rolón et al. (2021) produced data that suggest that individuals with COVID-19 infection were more likely to be "extroverts". In a similar vein, Carvalho, Pianoswski and Goncalvez (2020) published data that suggest that extroverts are less likely to comply with COVID-19 containment measures (social distancing in particular). If extroversion could be loosely linked to certain aspects of the BAS (Matthews & Gilliland, 1999 have linked these constructs before), the data appear to be at odds with the findings of the present study. This apparent incongruence could either be attributed to semantics, or methodological issues. Further studies may help clarify the issue.

The present authors recognize that most of the implications of the present study may not be taken lightly. Especially in the context of our relatively small sample size and sampling procedure. Perhaps future studies may throw further and clearer light on the present issues. Another important limitation of the present study is that it was conducted exclusively with college students. Given their relatively young age and strong immune systems, their responses may not necessarily represent those of older more vulnerable individuals. Once again, future studies may help clarify this issue.

CRediT authorship contribution statement

Marco A. Pulido: Conceptualization, Formal analysis, Project administration, Supervision, Validation, Visualization, Writing –

original draft, Writing – review & editing. **Fernanda Brown:** Data curation, Investigation, Methodology, Software. **Renata Cortés:** Data curation, Investigation, Methodology, Software. **Miriam Salame:** Data curation, Investigation, Methodology, Software.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.paid.2022.111867.

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