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Original and revised reinforcement sensitivity theory in the prediction of executive functioning: A test of relationships between dual systems

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ABSTRACT

Executive functioning relates to cognitive processes that are effortful and controlled, whereas processes underlying personality are assumed to be routine and automatic (Elliot & Thrash, 2002, 2010). We evaluated potential influences between these dual systems by examining the link between executive functioning and biologically based personality measures associated with original reinforcement sensitivity theory (o-RST) and revised reinforcement sensitivity theory (r-RST). Results showed that flight (a tendency to commit to poorly planned, escape behavior) negatively predicted executive functioning. We find partial support for the general hypothesis of links between the dual systems. Generally, r-RST was a better predictor of executive functioning than o-RST. The proposed structure of the r-RST measurement model was confirmed.

1. Introduction

Executive functions are neurocognitive processes of the frontal cortex that maintain an appropriate problem solving mindset concerned with future goal attainment (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Underlying cognitive processes involve working memory, inhibition and planning, understanding space and time, selective inhibition, response preparation, goal formation tendencies, and adaptability (e.g., Suchy, 2009). Poor executive functioning is associated with deficits in goal formation tendencies, reduced capacity for self-control, emotional lability, flattened affect, irritability, impulsivity, carelessness, rigidity, and difficulty in shifting attention. Executive functions are thought of as being "effortful" and "controlled." In contrast, neurocognitive processes underlying biologically based personality scales of temperament such as Gray's (1970) original Reinforcement Sensitivity Theory (o-RST) and Gray and McNaughton's (2000) revised Reinforcement Sensitivity Theory (r-RST) are often thought of as being "routine" and "automatic" (e.g., Cury, Elliot, Fonseca, & Moller, 2006; Elliot & Thrash, 2002, 2010; Gray, 1970; Gray & McNaughton, 2000; Jackson, 2008a, 2011).

Relationships between RST variables and executive functions would be interesting to identify since they would provide further evidence for the general neurocognitive architecture of the type proposed by the dual systems models of Elliot and Thrash (2002, 2010) and Jackson (2008a, 2011). In these dual system models, automatic and routine processes are honed by effortful and controlled processes to produce effective and functional behavior. Elliot and Thrash (2002, p. 806) argue that goal orientations are channels through which biological drives are directed, such that biological drives are energizers whereas goal orientations are specific, cognitive forms of self regulation that provide focus and direction. Elliot and Thrash (2002, 2010) and Jackson (2008a, 2011) maintain that relationships between these dual systems provide the theoretical basis for more informed models of personality compared with those derived from exploratory factor analysis. We choose RST and executive functioning because they typify these two contrasting neurocognitive processes as opposed to other processes (such as positive and negative affect) which are less easy to define in these terms.

Empirical evidence in favor of dual systems models is somewhat lacking. One study finds little evidence in favor of dual process theory (Gillespie, Cloninger, Heath, & Martin, 2003). The current study will add to the small literature aimed at identifying whether or not the dual systems are related as argued by Elliot and Thrash (2002, 2010) and Jackson (2008a, 2011). We test this idea using objectively measured executive functions as opposed to the self-report measures used previously.

Gray's (1970) o-RST is a theoretical model of the biological basis of personality consisting of the original Behavioral Inhibition System (or o-BIS; aligned with a mix of anxiety and fear; Jackson, 2009; Smillie, Pickering, & Jackson, 2006) and the original

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Behavioral Approach System (or o-BAS; aligned with extraversion; Smillie et al., 2006). Gray and McNaughton's (2000) r-RST consists of a Fight/Flight/Freezing system (r-FFFS, which is an avoidance system related to fear; Smillie et al., 2006), r-BIS (now a defensive approach and conflict management system related to anxiety; Smillie et al., 2006) and r-BAS (closely aligned to extraversion; Jackson, 2009; Smillie et al., 2006).

Prior to the development of r-RST (Gray & McNaughton, 2000), the avoidance system of o-RST was generally associated with the neuroticism/anxiety cluster of traits found in the Five Factor Model, the Giant Three and the o-BIS. This is important because neuroticism has been associated with poorer executive functioning such as impaired response selection (i.e. conflict detection/resolution, error monitoring) in tasks such as the Stroop test (e.g., Luu, Collins, & Tucker, 2000). This suggests:

Hypothesis 1. o-BIS will be negatively related to executive functioning performance.

In r-RST, the avoidance system broadly consists of r-FFFS associated with fear, and r-BIS associated with anxiety. Gray and McNaughton (2000) argued that the r-FFFS mediates escape from aversive stimuli (r-Flight), submission (r-Freezing), and vociferous defensive aggression (r-Fight); the latter possibly also being partially interpretable as an approach behavior since defensive aggression involves attacking the fear-inducing stimulus (for examples see Jackson, 2009). How fear relates to executive functioning is not well known (Rothbart, Ellis, & Posner, 2004), but using general principles of resource allocation theory (e.g., Kanfer & Ackerman, 1989; Norman & Bobrow, 1975), we think it is likely to severely inhibit executive functioning by curtailing cognitive resources to maximize the success of a fast and furious fight or escape response. This suggests:

Hypothesis 2. The cluster of traits associated with r-FFFS will be negatively related to executive functioning performance.

The difference between Hypothesis 1 and Hypothesis 2 lies at the core of how r-RST and o-RST are different from each other and how fear is different from anxiety. One example demonstrates how differential evidence in favour or against Hypothesis 1 and Hypothesis 2 will affect the literature in an important way. Time estimation plays a key role in efficient performance of many daily activities and is an executive function since effective timing is implied by effective executive functioning and problems with time estimations are observed in clinical groups with executive dysfunction (e.g., Barkley, 1997). There is a strong literature indicating that strong emotions (often referred to as high fear and high anxiety) are related to overestimates of time (e.g., Lake & LaBar, 2011); by measuring fear and anxiety separately, this study determines which are related to executive functions.

Both o-BAS (Gray, 1970) and r-BAS (Gray & McNaughton, 2000) are highly related to reward sensitivity (Smillie et al., 2006). There is evidence that the approach system may differentially influence different executive functions. Greater neural efficiency during working memory tasks has been observed in individuals with higher self-reported o-BAS (Gray et al., 2005). Moreover, high reward sensitivity is related to faster reversal learning (Gullo, Jackson, & Dawe, 2010) and adult extraverts appear to have better working memory performance than introverts (Lieberman & Rosenthal, 2001). In contrast, in studies of children, high o-BAS has been associated with poorer executive functioning (Blair, Peters, & Granger, 2004). This also seems reasonable since deficits in executive functioning are likely related to impulsiveness and impulsiveness is related to o-BAS (Gray, 1970). Although the evidence is not strong given possible opposite effects, the possibility of greater neural efficiency in reward sensitive individuals suggests:

Hypothesis 3. Approach tendencies (o-BAS, r-BAS) will be positively related to executive functioning performance.

In summary, our research determines how o-RST and r-RST are related to executive functioning with the aim of testing the dual system model of personality.

2. Method

2.1. Participants

Participants were 336 Australian full-time workers (mean age = 39.08 years, range 18 to 69 years, *SD* = 13.16; male: 56%; female 44%) who were recruited from a Sydney-based website offering people willing to engage in research. The highest education of participants was: school, 31.4%; trade, 17.3%; undergraduate degree, 35.7%; masters degree, 13.4%, PhD, 2.1%). Seniority of participants in the workplace was: staff, 39.8%; junior manager, 28.5%; senior manager, 31.7%.

2.2. Procedure and measures

Participants completed a battery of objective tests of executive functioning and personality questionnaires that were modules of the YWeDo online cognitive laboratory (Jackson, 2010) located at www.YWeDo.com/lab.asp. Participants were paid for their contribution. Fraser and Boag (2010) compared tests administered using the YWeDo online laboratory with paper-based tests and reported few differences. The study was approved by the UNSW ethics committee and participants provided informed consent.

2.3. Measures of executive function

2.3.1. Color Stroop

The color Stroop involves presentation of names of colors presented in different colored text (e.g., the word "green" presented as green text or a different color such as blue text). Five different color choices are presented. Participants choose the color of the word.

The color Stroop task indexes the ability to inhibit well-learned responses as shown by the difference in reaction time to respond between the congruent condition (where the spelling matches the color) and the incongruent condition (where the spelling does not match the color). There were 20 congruent trials and 20 incongruent trials.

2.3.2. Trail making

This version of the trail making consists of 20 squares. In the congruent task, the squares are numbered 1–20, and the participant clicks on each square in ascending numerical order. In the incongruent task, the squares consist of numbers (1–10) or letters (A–J) and the participant clicks squares in ascending order alternating between the numbers and letters (i.e., 1-A-2-B-3-C, etc.).

The difference in time between the two tasks is a measure of interference control and a measure of executive functioning. Errors must be corrected before continuing and add to the completion time.

2.3.3. Time estimation

Time perception is often thought of as an executive function (e.g., Barkley, 1997). In this study two online time estimation tasks were conducted:

2.3.4. Estimated time to complete an action

Participants answered the following Time to do questions developed by Jackson (2008b). How many minutes would you