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THE BIOLOGICAL BASIS OF IMPULSIVENESS: THE SIGNIFICANCE OF TIMING AND RHYTHM DISORDERS

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Summary—High-impulsive subjects often do and say things on the spur of the moment and/or make up their minds quickly. The description of impulsivity as a personality trait involves a number of basic research questions including:

1. From a psychometric viewpoint, how inclusive or broad is impulsivity as a personality trait?
2. How does impulsivity relate to other personality traits?
3. Is there a pattern of biological correlates of impulsivity that is distinct from other personality traits?
4. What is the relationship between cognitive and behavioral impulsivity?

This paper addresses those four questions. Psychometric analysis of issues in impulsivity indicates the need for a distinction between broad and narrow impulsivity traits and further redefinition of the latter in terms of cognitive and motor components. This research has also shown that impulsiveness has an orthogonal relationship with measures of anxiety. In perceptual–motor tasks, high-impulsive subjects perform less efficiently and with greater variability on a wide range of these tasks, and in particular when the task involves responding to two or more sequential stimuli. High-impulsive subjects underproduce time intervals in time-judgment tasks; this and other findings suggest that high-impulsive subjects have a faster cognitive tempo than low-impulsive subjects. The interaction of impulsivity and anxiety in the performance of perceptual–motor tasks is also reflected in psychophysiological measures; differences in impulsivity are more evident with electrocortical measures and differences in anxiety are reflected in ANS measures while performing the tasks.

The study of the biological bases of individual differences in personality suffers from the lack of a generally-accepted, broad model that inter-relates behavioral, cognitive, biological and environmental (including social) concepts. Even among non-biologically-oriented personality theorists, the debate between trait theorists and the interactional theorists who consider personality in cognitive–behavioral–situational contexts is but one example of the need for a more comprehensive, universally-accepted personality model. Fiske (1971) broaches this need in his book, *Measuring the Concepts of Personality*, in which he discusses six modes for measuring personality including the psychophysiological mode. In discussing the biological bases of impulsiveness, Barratt and Patton (1983) recently proposed that a model similar to that presented by Ashby (1960) in his book, *Design for a Brain*, and elaborated upon by Diamond, Balvin and Diamond (1963) is one possible model that allows for a synthesis of the basic concepts involved in personality research. Conceptually, this model has much in common with the approach to personality measurement proposed by Fiske. Within our modification of Ashby's model, personality traits are defined by a profile of biological, cognitive, behavioral and environmental stimulus measures (including social stimuli) (Barratt and Patton, 1983). Within this context, four questions related to impulsiveness research will be discussed briefly in this paper:

(1) From a psychometric viewpoint, how inclusive or broad is impulsiveness as a personality trait?

(2) How does impulsiveness relate to other personality traits?

(3) Is there a pattern of biological correlates of impulsiveness that is distinct from other personality traits?

(4) What is the relationship of cognitive and behavioral impulsiveness?

The discussion of these four questions will provide the background for a brief overview of our current research on the biological bases of timing and rhythm behaviors related to impulsiveness and other personality traits.

From a psychometric viewpoint how inclusive or broad is impulsiveness as a personality trait? Most trait theories of personality were developed using multivariate correlational analyses of self-report questionnaires. Within this approach, it is important to consider not only the part-remainder correlations of the individual items with the total scores, but also the higher-order factors that result from the combination of items. In research designed to clarify the definition of impulsiveness, the Eysencks (Eysenck and Eysenck, 1977) have made a distinction between Impulsiveness Narrow (I_N) and Impulsiveness Broad (I_B). The item with the highest loading for both males and females on the I_N factor was "Do you generally do and say things without stopping to think?" Our research would be consistent with this item encompassing the essence of impulsiveness in self-report questionnaires. However, clinically speaking, impulsiveness has usually been measured using scales that are more inclusive (Barratt, 1965; Barratt and Patton, 1983; Twain, 1957). Within I_B, the Eysencks defined three other factors from their item pool: Risk Taking, Non-Planning and Liveliness. The purpose of the inclusion of this discussion within this paper is not to settle the psychometric issues of I_N vs I_B, but, rather, to emphasize the importance of the factorial complexity of the items which comprise most measures of impulsiveness. As Barratt and Patton (1983) have indicated, not all measures of impulsiveness correlate substantially or even significantly with each order.

This leads to our second question: *How does impulsiveness relate to other personality traits?* Since the above discussion about items on impulsiveness measures is true for all self-report personality questionnaires, the problem becomes even more complex when comparing several personality traits. If the personality measures being considered represent higher-order factors, the chances of finding significant correlations among item clusters across the different scales is increased. Our research has indicated that two broad clusters of items, Impulsiveness as measured by the Barratt Impulsiveness Scale (BIS; Barratt, 1965) and Anxiety as measured by the State–Trait Anxiety Index (STAI; Spielberger, Gorsuch and Lushene, 1970) are orthogonal or at most, have a low-order relationship with each other (Barratt and Patton, 1983). We have also found that both the STAI and BIS correlate significantly with a wide range of measures including Eysenck's measures of extraversion (E) with the BIS and neuroticism (N) with the STAI. On the basis of several correlational studies involving a wide range of personality items, we have identified two broad clusters of items, similar to Eysenck's E and N factors. We have labeled these items 'Action-Oriented' and 'Mood-Feeling' dimensions. The Action-Oriented cluster includes impulsiveness, sensation seeking and extraversion items. The Mood-Feeling cluster includes anxiety, neuroticism and 'sadness' or depression items. Again, the purpose for including this discussion in this paper is not to settle the psychometric issues involved in defining personality traits, but, rather to emphasize the relevance of this issue to the research for the biological bases of individual differences in personality. If psychophysiological correlates of only one personality trait are studied, a biased picture may result. Our research indicates that personality traits like impulsiveness and anxiety interact in both behavioral and psychophysiological studies. High-impulsive, low-anxiety (HILA) *S*s perform perceptual–motor tasks differently, for example, than do low-impulsive, high-anxiety (LIHA) subjects. In a study of EEG and ANS habituation to the on-and-off presentation of auditory tones (Barratt, 1967) we found that HILA *S*s habituated ANS responses before the EEG habituated while the reverse was true for LIHA *S*s. The two groups with other combinations of impulsiveness and anxiety were not significantly different from each other.

Let us next explore, briefly, the last two questions: *Is there a pattern of biological correlates of impulsiveness that is distinct from other personality traits?* and *What is the relationship of cognitive and behavioral impulsiveness?* Our answer to the first question is that we think that there are distinct psychophysiological patterns related to the two broad higher-order clusters of personality traits that were discussed above but not necessarily to the separate lower-order factors within each group. Another way of stating our answer is that personality traits can be measured at levels of specificity that cannot be matched by unique patterns of psychophysiological, biochemical or physiological measures at our current level of knowledge about biology. For example, high or low levels of MAO or measures of augmenting–reducing have a significant relationship with a wide range of personality measures. If we consider the interactional personality theories, this problem becomes even more complex. This caution should not deter us from forging ahead, however, with the search for biological correlates of personality traits which I shall do now for impulsiveness.

In 1972, I wrote:

> "We propose that impulsiveness involves a neural system which includes primarily interrelationships among orbito-frontal cortex, selected limbic system nuclei, and the cerebellum. Anxiety involves essentially the hypothalamic–hypophyseal axis, the ascending reticular activating system, and the orbito-frontal cortex: the effects of the reticular system in cortical functioning are especially important here." (Barratt, 1972)

Although we have modified this position in line with more recent neural science data (e.g. limbic activating concepts), we still consider selected limbic input into the frontal and prefrontal cortex to be important in impulsiveness while the hypothalamic–hypophyseal axis is more important in state–trait anxiety. Let me present a few results that have led to this proposal. In doing so, I will also address the relationship of cognitive and behavioral impulsiveness.

Our laboratory research has shown that high-impulsive *S*s, especially HILA *S*s, are more variable and less efficient in performing a broad range of cognitive, behavioral tasks. In reaction-time tasks, when there is a warning signal, imperative signal interval of 600 msec or longer, high-impulsive *S*s respond significantly slower than do low-impulsive *S*s. That is, if high-impulsive *S*s are signaled to wait before responding, a 'set' appears to be established that interferes with their ability to respond as efficiently as low-impulsive *S*s. High-impulsive *S*s also have a significantly lower magnitude of Contingent Negative Variation (CNV) while performing this task. High-impulsive *S*s also significantly underproduce time intervals in time-judgment experiments, indicating a fast cognitive tempo. At this point, let us reconsider the item that had the highest loading on the Eysencks' I_N factor: Do you usually do and say things without stopping to think? This item suggests an interplay (or lack of interplay) of cognitive and motor processes—acting without thinking. We propose that in tasks involving a cognitive component prior to making a response, especially 'timed' discrimination reaction time or rhythm responses, the cognitive tempo or rate of information processing of high-impulsive *S*s is out of synchrony with the task demands and results in less-efficient performance. The results of our recently published study (Barratt, Patton, Olsson and Zuker, 1981) on the relationship of impulsiveness to paced tapping were consistent with this proposal. We found that impulsiveness was negatively related to an algebraic error of tapping accuracy when the pacing tone was not present but was not related to pacing accuracy when the tone was present. Using an intra-individual variability measure of tapping error which summarizes the variability of tapping in terms of successive interval deviations and is negligibly affected by slow changes in rate of tapping over a sequence, the opposite results were obtained. These overall results suggest that the rate of information processing of cognitive tempo is related to impulsiveness. Performance on these reaction-time, time-judgment and tapping experiments along with concurrently recorded psychophysiological responses pointed our research toward a study of the biological bases of timing and rhythm behaviors.

In the study of motor behavior, especially fine perceptual–motor, discriminative behaviors, much attention is being focused on the cognitive processes that precede the motor responses. Following Lashley's (1951) classical article on serial order behavior, a wide range of models involving cognitive, behavioral and physiological variables have been proposed (Michon, 1974; Adams, 1981; Newell, 1978). We are currently extending the use of these models to our personality research. In our current studies, we are relating topographical maps of event-related cortical potentials (ERPs) recorded while *S*s with different levels of impulsiveness and anxiety perform timing and rhythm tasks.

The analyses of topographical displays of ERPs has been used to study both psycholinguistics (e.g. Brown and Lehmann, 1978) and reaction time (e.g. Ragot and Remond, 1978). In this procedure, ERPs recorded from arrays of electrodes over the scalp are analyzed sequentially (cross sectionally) to locate the main positive and negative dipoles within the brain at the various stages of performance (including cognition) of selected tasks. The assumption is that shifts in the dipoles relate to information processing during the performance of the various tasks. Parenthetically, several powerful topographical-like procedures for analyzing the EEG have been developed to study changes or shifts in electrical activity related to information processing during task performance (e.g. Gevins, Zeitlin, Doyle, Yingling, Schaffer, Callaway and Yeager, 1979). The isopotential voltage lines that surround the major dipoles in the topographical displays vary over time as information is processed. We are interested in developing an index of the rate of change of these isopotential voltage lines that signal the onset of the shifts of the dipoles. Gevin's (Gevins *et al.*, 1979) analytical procedure approaches this problem by considering "the brain as a local distributed computational network".

Our initial exploratory research with topographical displays indicates that the rate of change of ERP peaks (dipole shifts) from the sensory to frontal to premotor areas is related to the interaction of impulsiveness and anxiety. Considering only impulsiveness, the high-impulsive *S*s have higher amplitude and longer latency peaks in the sequence of posterior–anterior changes across the cortex. For example, in a reaction-time task, once a cognitive set is established by the warning signal, information processing as evidenced by dipole shifts procedes more slowly. These results are consistent with a neurological model involving frontal (cognitive) preplanning and premotor differences in information processing. We propose, in a modification of our earlier model, that limbic output via the anterior thalamic nucleus is gated in the cingulum bundle. Our research with squirrel monkeys indicates a direct relationship between the electrical activity of the cingulum bundle and the hippocampus during the performance of 'timed' behaviors. This suggests a 'time-locking' of the activity in the hippocampus and cingulum bundle in the processing of information from the hippocampal to cortical levels. That is, the rate of information processing is possibly 'gated' at the level of the anterior thalamic nucleus and subsequent activity in the cingulum bundle and cingulum cortex. Holsheimer (1982, p. 309) has recently noted that:

> "Unit activity recorded from the cingulate cortex during theta rhythm shows periodic trains of spikes which are phase-locked to the local theta field potential waves. These cortical theta units were also shown to be correlated with hippocampal theta units. These findings, along with the fact that theta field potentials show a phase reversal within the cingulate cortex, lead to the conclusion that this cortical area is a source of theta activity."

Also, within this context, Pandya, Van Hoesen and Mesulam (1981) noted:

> "The results described herein allow for some speculations as to the role of the cingulate gyrus in certain complex behaviors. By virtue of its connections with the premotor cortices, the cingulate gyrus is in a position to exert 'limbic' influences in motor behavior. By its extensive projections to the prefrontal cortex and amygdala, it may also exert an influence on a wide variety of motivational mechanisms which govern not only the immediate responses to the environment, but more long range consequences as well. Lastly, the extensive interconnections between the cingulate gyrus and the inferior parietal lobule may provide a basis for limbic influences in attentional and spatial timing mechanisms." (pp. 328–329)

In conclusion, we propose that at this point in the search for biological correlates of personality traits, the most fruitful approach will result from relating broad clusters of higher-order personality measures to profiles of cognitive, psychophysiological, behavioral and environmental (stimulus) measures. To the extent that this is an accurate observation, the need is obvious for researchers to attempt to agree upon a personality model that allows for a comparison across laboratories of these four classes of variables.

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