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BRAINSTEM RESPONSE AND STATE-TRAIT VARIABLES

Kirby Gilliland*
Department of Psychology
University of Oklahoma
Norman, Oklahoma

Φ5 473598

INTRODUCTION

The purpose of this paper is to summarize a series of investigations from our personality research program that have relevance for mental state estimation. For several years, we have been conducting research at the interface between the areas of personality, human performance, and psychophysiology. Of particular concern have been those personality variables that are believed to have either a biological or perceptual basis and their relationship to human task performance and psychophysiology. These variables are among the most robust personality measures and include such dimensions as extraversion-introversion, sensation seeking, and impulsiveness. These dimensions also have the most distinct link to performance and psychophysiology. Through the course of many of these investigations two issues have emerged repeatedly: a) these personality dimensions appear to mediate mental state, and b) mental state appears to influence measures of performance or psychophysiology.

This paper will provide a selective review of some of those studies that have highlighted these issues. Of particular concern will be those studies that offer specific insight into these issues or possible mechanisms for exploring them.

SOME FUNDAMENTAL DISTINCTIONS

To better understand the influence of personality variables or mental states it is important to understand the distinction between trait and state variables. Both are theoretical in nature, and both are believed to influence behavior. Traditionally, personality *trait* variables have been viewed as relatively permanent internal dispositions. That is, traits are evidenced regularly, are internal in origin, and are enduring in their nature. *States*, on the other hand, have been viewed as characteristics that are irregular and short-lived, and are usually viewed as responses to external social or environmental factors (ref. 1). While this distinction is generally accepted, it has not had universal support (ref. 1,2,3,4,5).¹

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1 Allen and Potkay (ref. 2) have suggested that the distinction between traits and states is arbitrary. They argue that rather than being two separate types of dimensions, traits and states are simply ends on a continuum. Further, (ref. 3) they argue that the delineation of trait or state measures is unnecessary and that researchers should simply "...adopt a more neutral, operational approach to predicting behavior."

It is also important to establish the relationship between traditional personality states and more general mental states. Personality states have typically referred to characteristics that have parallel trait measures, for example, state and trait anxiety and state and trait arousal. The term mental states refers to a much broader range of mental phenomena including such states as confusion, disorientation, boredom, and even fatigue. In this sense, personality states could be viewed as a subgroup of the broader category of mental states. Therefore, much of our research has been an exploration of a special category of mental states and its relationship to performance and psychophysiology. The remainder of this paper will concentrate on one state-trait dimension, that of arousal.

TRAIT-STATE MEASURES OF AROUSAL, PERFORMANCE, AND PSYCHOPHYSIOLOGY

Recent interest in the biological bases of personality has centered on a group of personality dimensions that are believed to share the common underlying dimension of arousal. The most intensely researched arousal-based dimension, extraversion-introversion (ref. 6), is believed to be the result of differential ascending reticular activating system (ARAS) arousal. It is believed that introverts have higher ARAS arousal levels as compared to extraverts and seek to restrict environmental stimulation in order to maintain a more comfortable overall level of arousal. Conversely, extraverts have a lower ARAS arousal level and seek higher levels of environmental stimulation to provide a more comfortable overall level of neural activity. The extraversion-introversion dimension and construct of arousal have been so closely linked they have often been viewed as synonymous. In fact, it is not unusual to find extraversion-introversion scales being used as a trait arousal measurement instrument, or as a method to "manipulate" arousal.

Typically, studies of extraversion-introversion are cast within an arousal framework and the results of these studies are also interpreted within the context of arousal dynamics. It was during these types of investigations that we began to realize that not only were introverts and extraverts performing differently, but also they were experiencing quite different mental states. For example, during a study of simple visual reaction time before, during, and after noise stress (ref. 7), extraverts and introverts not only performed quite differently but also reported quite different mental states. In this study, groups of introverts and extraverts performed simple visual reaction time during three seven-minute periods. One group of extraverts and one group of introverts simply performed reaction time throughout the overall 21-minute period. The remaining group of introverts and the remaining group of extraverts also performed simple visual reaction time throughout the 21-minute period. However, during the second seven-minute period, both of these groups were exposed to 75dB intermittent, cafeteria-type noise.

Figure 1 shows the results from this experiment. It should be noted that introverts showed an overall faster reaction time as compared to extraverts. This finding is typically explained within the context of an arousal model, and such results are viewed as supportive of the arousal-based nature of the extraversion-introversion trait. Noise exposure caused a similar degradation in reaction time performance for both extrovert and introvert groups. What was surprising was that during the post noise period, the last

seven-minute period of reaction time, introverts exposed to noise returned to a level of RT performance not unlike that of introverts not exposed to noise. Extraverts who were exposed to noise appeared to show continued degradation in performance over that resulting from noise exposure.

It is possible to construct a number of post hoc explanations for these results based on arousal theory. What is interesting about this particular study is that there is a much simpler explanation for these results. Following the completion of the first seven-minute reaction time period, each subject filled out a post-test questionnaire. Included in this questionnaire were a number of questions regarding mental state; for example, subjects were asked to rate their level of interest, boredom, and frustration. They were also asked to rate the amount of time they performed the simple visual reaction time task. In analyzing the results of this post-test questionnaire it was learned that extraverts were significantly more bored and frustrated with the task as compared to introverts. In addition, extraverts rated the task as lasting twice as long as the introverts. Thus, introverts and extraverts appeared to experience quite different mental states during the performance of this experiment.

This study, as well as many others, have shown what appear to be important trait arousal differences between introverts and extraverts. In the present study this can be seen in the overall faster reaction times of introverts as compared to extraverts. However, this study also demonstrates that environmental variables (in this case a lack of stimulation) can differentially influence the mental states of introverts and extraverts leading to quite different performance.

In subsequent investigations^{#,+} (ref. 8), we attempted to explore more directly a link between extraversion-introversion and neural activity. These studies have utilized the brainstem auditory evoked response (BAER), a sensory evoked response reflecting the activity in the auditory pathway--a neural pathway that transverses the ARAS. The BAER provides an exceptionally stable measure of neural functioning in the auditory pathway. The BAER is derived by averaging the first ten msec of multiple (1000 or more) auditory pathway evoked potentials, elicited by short-latency click or tone stimuli. This average evoked potential results in seven vertex-positive waves believed to reflect sequential neural activity at successively higher levels of the brainstem auditory pathway (ref. 9, 10). The putative generators of wave I through wave VII are the acoustic nerve, the cochlear nuclei, the superior olives, the lateral lemniscus, the inferior colliculus, the medial geniculate, and the thalamocortical radiations, respectively (ref. 11, 12). It was believed that the stability of this measure and its close neural approximation to the ARAS made it a viable possibility for exploring differences between introverts and extraverts.

[#] Andress, D.: Individual Differences in Brainstem Auditory Evoked Responses. Unpublished Master's thesis, University of Oklahoma, 1981.

⁺ Bullock, W.: A Converging Measures Test of Eysenck's Biologically-based Theory of Introversion-extraversion. Unpublished doctoral dissertation, University of Oklahoma, 1984.

The results of a series of studies of the BAER in introverts and extraverts^{#,+} (ref. 8, 9) can be summarized in Figure 2. Introverts have been shown consistently to have wave V latencies that are significantly faster than those of extraverts. This has been the major and most consistent finding across the studies performed in our laboratory. This finding suggests that introverts have greater neural responsivity in the area of the lateral lemniscus and inferior colliculus. It is interesting to note that this area corresponds closely to the hypothalamic region that Eysenck views as the seat of arousal differences between introverts and extraverts. Thus, these studies seem to support the view that a personality dimension based primarily on arousal differences can be demonstrated by a physiological measure.

Another avenue in our research has been the exploration of BAER differences in relation to cognitive workload, or alternatively the exploration of state arousal (ref. 13, 14). In one study, BAERs were recorded during a pretest baseline period, during three (low, moderate, high) workload sessions, and during a post-test baseline period (ref. 13). The major results of this study revealed that longer latencies were produced at wave VI for all workload conditions as compared to the pretest baseline period. The BAER differences that were observed did not systematically differentiate the workload conditions represented in this study. Nor did the post-test baseline return to the pretest baseline level. However, the BAER was shown to be sensitive to state arousal manipulation when contrasting baseline and workload conditions.

These findings were replicated in a followup study of the post-test baseline recovery period (ref. 14). Subject's BAERs were recorded during a pretest baseline period, during the same three workload conditions, and during a post-test baseline period just as in the previous experiment. In addition, BAERs were recorded at five-minute intervals for forty minutes following the workload trials. Finally, BAERs were recorded during an additional trial at the high workload level in ABAB design fashion. The results of this study are illustrated in Figure 3. These data suggest that wave VI of the BAER is affected by cognitive workload in comparison to prior resting conditions (just as in the previous study). Wave VI latency does not fully recover under passive baseline measurement until after approximately 35-40 minutes. The final BAER under high workload conditions was comparable to those obtained under the earlier workload trials. Thus, the apparent covariation of wave VI latency of the BAER with cognitive workload suggests that this measure may be a responsive index of state arousal, albeit in a discrete rather than continuous fashion.

The results of these studies of BAER activity in relationship to extraversion-introversion and cognitive workload suggest an interesting possibility. One component, wave V latency, appears to differentiate reliably the construct of arousal as a trait. Wave VI latency has been shown to differentiate reliably state alterations in arousal. Thus, it is possible that the BAER may be useful as a method for assessing neural activity related to both trait and state forms of arousal.

SUGGESTIONS FOR IMPROVED TECHNOLOGY

It is unlikely that any single dependent measure will prove sufficient to capture and portray mental states. More likely complex multivariate

procedures will be needed to more fully explain the relationship between mental states, human performance, and psychophysiology. Our past research has suggested candidate behavioral and psychophysiological measures with the potential for aiding in the exploration of this complex relationship, but multivariate measurement alone will probably be insufficient to advance our understanding.

Major new advances in our knowledge of the relationship between mental state and task performance will probably be made through research integrating current advances in cognitive science, human factors, individual differences, and psychophysiology. For example, our laboratory is currently moving toward procedures that utilize careful laboratory control of environmental and task variables combined with real time multivariate data acquisition and analysis to provide a time-series based method for exploring these types of relationships. This technique will require the recording of multiple performance measures along with selected psychophysiological and subjective ratings, and displaying these outputs in real time. Using time-series based techniques one can then explore the interrelatedness of these measures and attempt to identify those measures that may be the most efficient in predicting such critical operator factors as performance efficiency, resource recruitment ability, and performance failure.

The distinguishing characteristic of this approach is one of modeling the performance "dynamically" rather than the usual static method associated with traditional experimental methodology. By using a more dynamic procedure one can explore not only the effect of some variable during a baseline and experimental phase (as is common in experimental techniques), but also the initial reaction, the long-term recruitment or compensation ability, the additive effects of stressors or drugs, and the rate of decline in performance ability. These characteristics are sometimes lost in standard experimental formats, but are often critical elements in defining the capability of human operators. Through multivariate, time-series-based techniques and the advent of high speed/capacity, real-time computer technology, we may be able to learn more about many of the operator variables, such as mental state, that significantly influence system performance.

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Figure 1: Simple Visual Reaction Time of Extraverts and Introverts Before, During, and After Noise

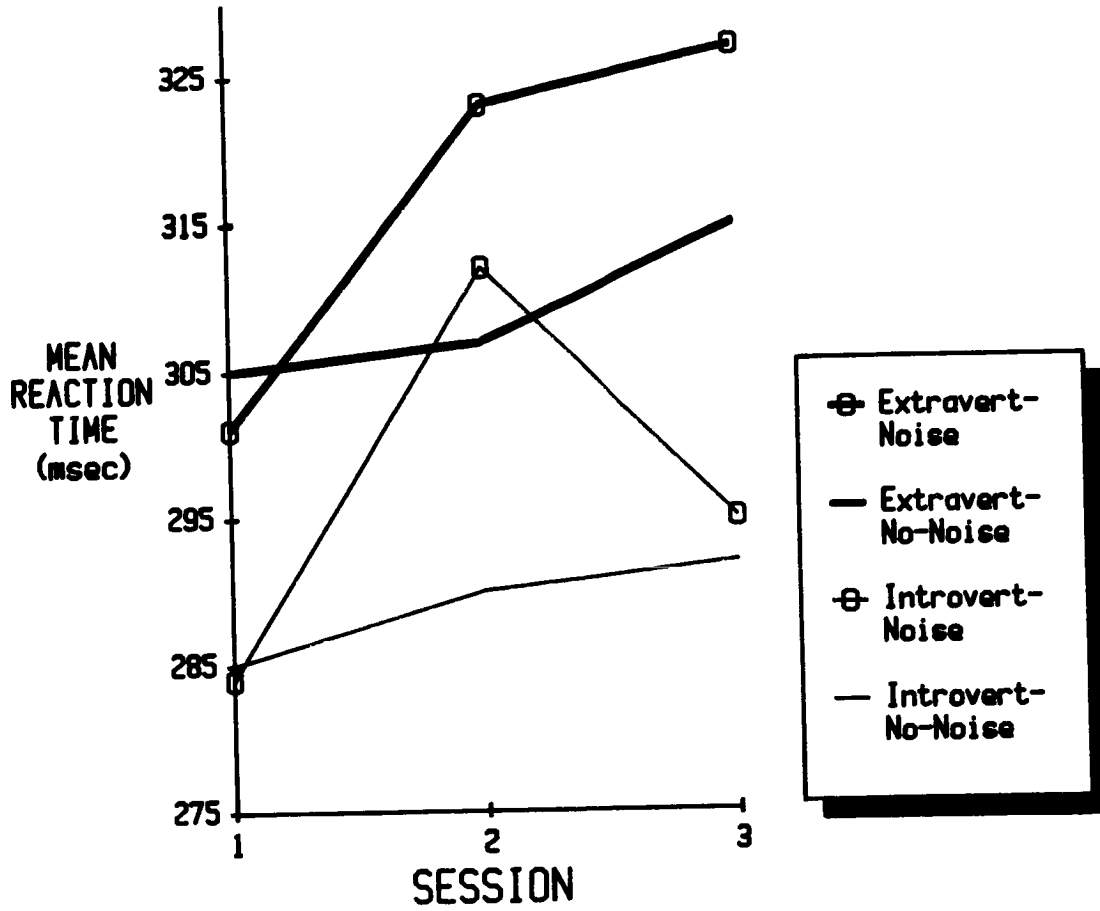


Figure 2: Mean BAER Wave V Latency for Introverts and Extraverts

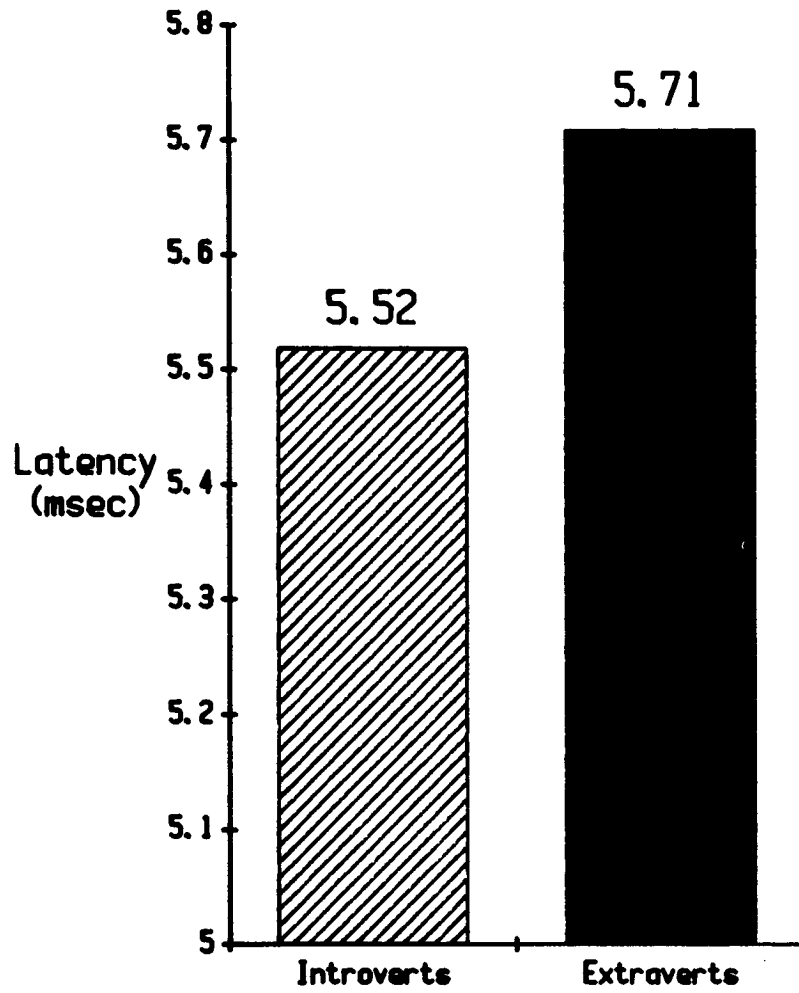


Figure 3: Mean BAER Wave VI Latency for Baseline, Workload, and Recovery Conditions

