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SHIFTS OF TONIC AROUSAL WITHIN AND BETWEEN TASKS THAT VARY IN COGNITIVE DEMAND

Introduction

Physiological data, such as respiration and electrodermal activity, can reveal significant details about a person's thought process. These measures can be used in conjunction with a series of questions to evaluate credibility as in a lie detector test (Honts, 1994). Electrical conductance under the skin, referred to as electrodermal activity (EDA), occurs because of sympathetic neuronal activity, and is sensitive to changes in autonomic sympathetic arousal (i.e. – an underlying mechanism of the “fight or flight” response) (Critchley, 2002). Sweat glands contain the “fight or flight” hormone which is called cortisol. This hormone becomes innervated by the sympathetic neuronal activity, and can be a good indicator of a person's automatic response. Since cortisol carries a weak electrical charge, this response is measured by recording micro-fluctuations of cortisol from the skin's surface. Generally, EDA responses, or skin conductance responses (SCRs), measure arousal and have been used to look at the role of information processing, attention, emotion and even abnormal behavior on responding to a single controlled stimulus (Dawson, Schell & Filion, 2000). In other words, besides questions that may or may not be responded to truthfully, responses can be matched with stimuli, like a picture, word, or sound, to analyze correlations in shifting patterns of arousal, like in the case of studying emotional impact. One study looked at SCRs of participants who engaged in an attentional task involving positive, negative, and neutral stimuli, and found that for anxious and avoidant groups of people,

negative pictures elicited larger SCRs (Silva, Ferreira, Soares & Esteves, 2015). The more arousal associated with a stimuli, the more changes in skin conductance.

SCRs can be stunted in nature when stimuli are presented quickly. If the participant does not have time to recover to a baseline, or his/her resting SCR, these responses tend to overlap making it difficult to measure arousal in regards to more rapidly presented stimuli. So, one way to measure an overall arousal response is by looking at tonic baseline shifts, or averaged responses over the duration of the task containing all of the presented stimuli. Basically, rather than looking at individual responses, skin conductance levels (SCLs) look at overall arousal level, and if that level is changing throughout the duration of the presented task. Cook, Hawk and Davis (1991) found during a study of valence, or positive and negative emotion-provoking stimuli, that arousal was linked with how much an image provoked a positive or negative reaction. Higher SCLs, were associated with higher arousal level imagery “joy, fear and anger”, and lower SCLs were associated with low arousal level imagery “pleasant, relaxation and sadness” (Cook, Hawk, Davis & Stevenson, 1991, p. 10). By looking at these changing patterns of SCLs, one can analyze arousal for conditions including imagery with rapidly presented startle stimuli.

Skin conductance levels can be used to analyze the overall relationship of arousal with regards to tasks that vary in cognitive demand, or mental demand, and where stimuli seemingly void of emotional content, are presented rapidly. Research indicates that SCLs are related to performance and anticipation of performance, which reveals a relationship with “energy regulation and mobilization” (Dawson, Schell & Filion, 2000, p. 215). Because of this, it would make sense that arousal can be shown to vary with perceived sleep quality, fatigue, and mood as well as the cognitive performance demands the individual requires to complete the task.

The present study examined the changing patterns in SCLs during a test of cognitive flexibility in which a participant is analyzed on how well they adapt and detect changing patterns, sustained attention, and attentional filtering, all considered to be

neutral in valence. It was hypothesized that SCLs would reflect the type of task demand and that changing arousal levels within each test reflect an adaptive response over the course of the test. Follow up analysis included measuring sleep and fatigue, the results of which were used to examine the effect of these variables on the pattern of changing SCL data.

Methods

Participants

Participants (N = 51) were University of Missouri – Kansas City (UMKC) students whose mean age was 23.8235 with a standard deviation of 5.96559 ranging from 18 – 42 with normal hearing and normal or corrected vision. There were 37 females and 14 males. Students were recruited via an online recruiting and scheduling system (PsychPool), and course credit, with instructor permission, was used as compensation following participation. All participation was voluntary, and a signed copy of informed consent was filed separately from all other participant data and materials.

Measures

Participants were asked to complete a series of self-report questionnaires, including the Modified Fatigue Impact Scale, which determines self-perceived cognitive and physical fatigue; the Perceived Stress Scale, which measures an individual's perception of his/her stress; and the Pittsburgh Sleep Quality Index (PSQI), which measures an individual's perceived sleep and sleep quality.

The participant was prepared for electromyography (EMG) electrode placement on the lower eyelid group (orbicularis oculi) by cleaning and swabbing electrode gel under the participant's left eye and temple, according to established practices (Blumenthal et al., 2005). He/she was asked to go on break to wash the non-dominant hand to prepare for pulse rate and EDA electrode placement. Skin conductance electrode paste was applied to the index and middle finger of the participant as well as to 6mm EDA electrodes, which were then placed on the two fingers according to established practices (Boucsein, 2012). Biometric data obtained consisted of heart rate, SCL, along with the muscle activity of the eyeblink in response to a presented startle noise. Signals were amplified using a Biopac bio-

amplification module and recorded using Acqknowledge software. During the psychophysiological recording portion of the study, the participant was seated comfortably in a sound-attenuated chamber where he/she underwent the Wisconsin Card Sorting Task (WCST), a measure of cognitive flexibility with no time limit or outside stimulus, and Conner's Continuous Performance Test II (CPT), a measure of dimensions of focused/sustained attention lasting approximately 14 minutes introducing letters at varying speeds requiring the participant to hit the spacebar as fast as he/she can for every letter presentation except the letter "X".

Following these tests, the participant underwent the startle eyeblink modification portion of the study called Words-As-Prepulses (WAP). The sound-attenuated chamber was darkened from low light to nonexistent light, and headphones were placed over both ears. The participant was then shown a total of 60 words that included both 15 words from a participant's "to-be-remembered" list, along with 15 words that were similar but not on the list, each to be presented twice. The words were presented randomly, and at random intervals between words, ranging from 2.5 to 5.5 seconds. Each word appeared for 1000ms and startle sounds eliciting a "baseline" eyeblink response were presented in between word trials. During the word trials, the startle noise was presented at 30ms, 120ms, 240ms, and 970ms following word onset in pseudo-random order, and counterbalanced during the duration of the study. The participant was then asked to keep their attention on the screen and to press the spacebar as soon as any word appeared. This test assessed, among other aspects, how well the individual was able to filter out a loud, abrasive stimulus while concentrating on responding to a target stimuli (the words).

At the conclusion of the tests, the participant was disconnected from the electrode recording equipment, debriefed, and thanked for his/her participation. SCLs were analyzed over the course of early, late and middle portions of each test to determine variability of arousal patterns in relation to the respective portion during the duration of the test. Afterwards, a post-hoc analysis of perceived sleep and fatigue was used to assess other factors modulating patterns of arousal during each of these tests.

Results

A 3 (test type) X 3 (time) repeated measures ANOVA of SCL revealed a significant main effect of test type: $F(2, 100) = 59.07$, $p < .001$, while the main effect of time was not significant. However, the interaction of time by test type was also significant [$F(4, 200) = 19.27$, $p < .001$] indicating that arousal level, as measured by SCL changed differently, but not in the same way, see Figure 1.

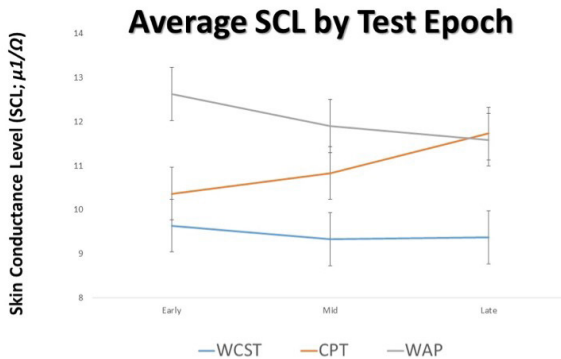


Figure 1

In order to assess other measures coinciding with these changing arousal patterns, first participants were divided among two groups: self-perceived “poor” sleepers and self-perceived “good” sleepers as determined by the PSQI. When these two groups were analyzed by the variability of skin conductance levels from early – late portions of the WCST by the total correct answers given, it was determined that self-perceived “poor” sleepers who had more SCL change throughout the test had less correct answers whereas self-perceived “good” sleepers who had more SCL change throughout the test had more correct answers, see Figure 2. When these same variables were analyzed with reaction times on the CPT, it was found that both “poor” and “good” self-perceived sleepers had longer reaction times with higher levels of arousal changes,

see Figure 3. However, when looking at reaction time consistency, or how much they changed from shorter to longer reaction times throughout the test, self-perceived “poor” sleepers with higher levels of SCL change tended to have less consistency, and self-perceived “good” sleepers with higher levels of SCL change tended to have more consistency, see Figure 4.

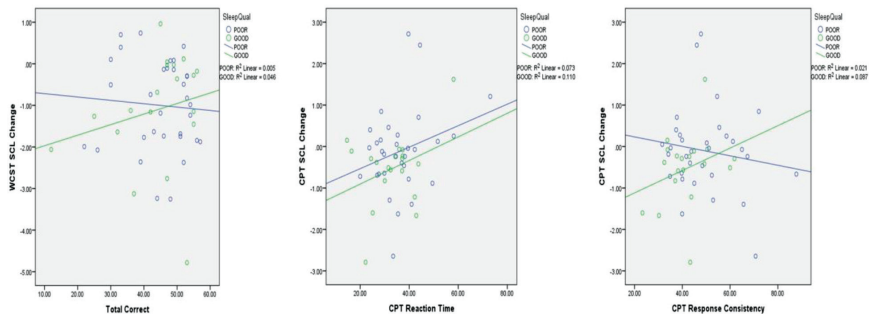


Figure 2-4

Average SCL over the course of these tests was then compared with self-perceived mental and physical fatigue. In all 3 tests there was little to no change among self-perceived “good” sleepers, but self-perceived “poor” sleepers who also perceived themselves to be more mentally and/or physically fatigued had significantly lower average SCLs. So, it appears that those who considered themselves to be “poor” sleepers, who were more fatigued either mentally or physically, had significantly less average arousal over the course of all three tests, see Figures 5-10.

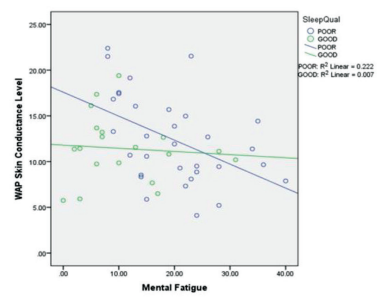
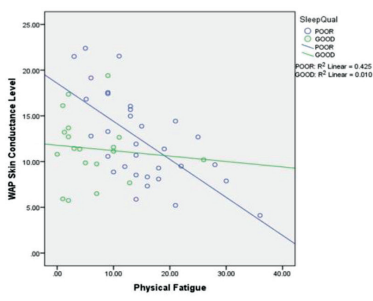
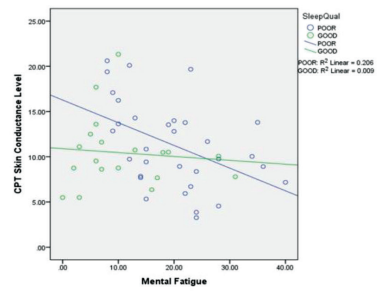
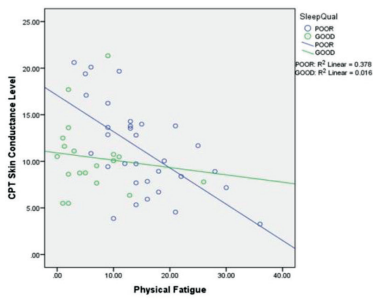
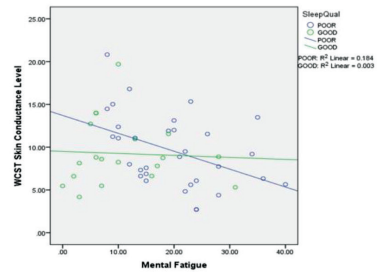
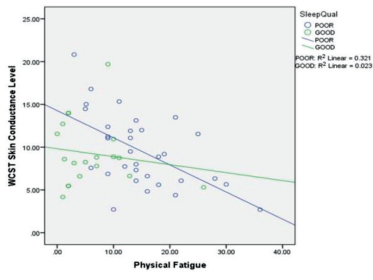


Figure 5-10

Discussion

The main effects results support the hypothesis as they suggest that baseline arousal is affected by the demands of the specific test as well as showing a type of adaptive response to the demands of test as well. Because the stimuli were neutral in nature, it can be safe to assume these changes were due, in some ways, to the cognitive demands of the test. If the stimuli were not neutral, it could not be certain that the changing arousal patterns were not due to strength from an emotional response. When looking at the overall changes in arousal patterns of the WCST, it is revealed that there is a slight dip in arousal from the early to middle portion of the test, but a slight increase from the middle to late portion of test indicating that there was not much in the way of arousing stimuli presented over the course of the test, nor was there much cognitive demand placed on the participant. When looking at the changes in the pattern of arousal from early to middle and middle to late portions of the CPT, it is shown that over the course of this longer, more exhausting test, arousal tends to increase. It may be inferred by watching arousal levels increase over the course of this test, that participants may be becoming increasingly tired, and need the extra levels of arousal to keep themselves awake in order to complete the task at hand. Conversely, when looking at the WAP where a startle noise is elicited throughout, the participants tend to start out with higher levels of arousal, which tends to decrease over the course of this much shorter test. When assessing the results from the WAP, it may be that the startle eliciting noise is abrasive enough to jump start this mechanism involved in the “fight or flight” because of seeing those high levels of SCLs early on. Over time, the participant tends to habituate to the noise and becomes less aroused as the test continues. It may be inferred that it is some kind of anxiety-producing aspect occurring within these tests causing these increases and decreases in arousal over time.

The results from this study reveal that arousal levels are dependent not only on the type of test that’s given, but the duration of the test as well. When looking at sleep, it is shown that during the WCST, “poor” sleepers have a harder time performing

well on tests of cognitive flexibility the more aroused they become, but “good” sleepers actually perform better as they become more aroused, perhaps indicating that sleep quality has something to do with task demands when a person is confronted with an alerting response. For both groups of sleepers it was clear that the more varied their SCLs were, the longer their reaction times tended to be, indicating that the ability to have stable arousal patterns has to do with how quickly a person is performing a task, but, when looking at how consistent each type of sleeper was in reacting, it was clear that “poor” sleepers were less consistent in reaction times the more varied their skin conductance level was, and “good” sleepers were more consistent the more varied their skin conductance was inferring that “good” sleepers had a tendency to adapt to changing arousal patterns better than “poor” sleepers.

When looking at mental and physical fatigue in relation to sleep and average skin conductance levels, the results suggested that “good” sleepers who perceived themselves to be more mentally and/or physically fatigued had little change in skin conductance levels from those that perceived themselves to be less fatigued, however those who considered themselves to be “poor” sleepers who were more mentally and/or physically fatigued had overall lower average skin conductance levels in all three test conditions emphasizing that self-perceived “poor” sleepers may have less of an ability to become physiologically aroused when introduced to an outside stimuli intended to evoke anxiety.

This study is not without several limitations. While analysis of self-perceived sleep and fatigue may be relevant in regards to the physiological data received in this study, there is no guarantee that it is an individual’s actual fatigue and sleep being reflected. Follow up research using actual physiological sleep and fatigue data in regards to SCLs in relation to tasks varying in cognitive demand may yield more conclusive results about what is occurring when these different patterns emerge.

The significance of these results provides better understanding of the physiological mechanisms behind tests and tasks that are undertaken every day. These data suggest there is a significant

relationship between arousal, performance, perceived mental and physical fatigue, and perceived sleep. It is important to take all of these qualities into consideration when determining capabilities in larger aspects of achievements in life.

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