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Trait Arousability And Its Impact On Adaptive Multimedia Training

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AND ITS IMPACT ON ADAPTIVE MULTIMEDIA TRAINING

by

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ABSTRACT

Today's best intelligent, adaptive, multimedia trainers have shown excellent performance; however, their results still fall far-short of what good human tutors can achieve. The overarching thesis of this paper is that future intelligent, adaptive systems will be improved by taking into account relevant, consistent, and meaningful individual differences. Specifically, responding to individual differences among trainees will (a) form more accurate individual baselines within a training system, and (b) better inform system responses (so that they interpret and respond to observable data more appropriately). One variable to consider is trait arousability, which describes individual differences in sensitivity to stimuli. Individuals' arousability interacts with the arousal inherent to a task/environment to create a person's arousal state. An individual's arousal state affects his/her attentional capacity, working memory function, and depth of processing.

In this paper, two studies are presented. The purpose of the first study was to evaluate existing subjective measures of trait arousability and then develop a new measure by factor analyzing existing apparatus. From this well-populated (N = 622) study, a new reliable (α = .91) 35-item scale was developed. This scale includes two factors, negative emotionality and orienting sensitivity, which have been previously theorized but not yet so reliably measured. The purposes of the second study were to (a) validate the measure developed in the first investigation and (b) demonstrate the applied value of the arousability construct in the context of training. Results from the second study (N=45) demonstrated significant main effects, but the interaction effects were inconclusive. They neither clearly confirm nor invalidate the hypotheses, but they do raise further questions.

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CHAPTER ONE: INTRODUCTION

Statement of the Problem

Training is an immense and important industry in modern society. Each year billions of dollars are spent on training, and millions of lives are affected by it. Corporate training, for example, accounts for about $55.8 billion (O'Leonard, 2007) a year in the U.S. alone, and U.S. military training enrolls more than a million new- and continuing-trainees, annually (Department of Defense, 2007). In the last 40 years, training has dramatically progressed and expanded, due to cultural, technological, economic, and political influences, as well as new philosophies regarding the importance of human capital (e.g., Salas & Cannon-Bowers, 2001). As society continues to progress in this fashion—becoming ever more technologically complex and culturally diverse—training will likely continue to play a significant role in most private, public, and governmental institutions.

Despite its importance, many training endeavors fail, while others are only partially successful. For instance, Banfield and his colleagues (Banfield, Jennings, & Beaver, 1996) describe two common corporate-training failure scenarios. The first is that staff with the lowest skills—and therefore greatest need to receive training—are able to avoid training or otherwise restrict their participation in it, so that the training rarely affects the way they actually carry out their jobs. Second, among the rest of the corporate population, motivation to impact organizational performance remains low, and the few individuals who become enthusiastic about corporate training (and corporate enhancement) remain isolated and fail to gain 'critical mass.'

As Banfield et al.'s examples imply, many different factors contribute to the success (or failure) of training, and many relevant issues fall outside the scope of the training itself. These outside factors include individual differences among the trainees, such as cognitive ability, locus of control, self-efficacy, organizational commitment, expectations, pre-training motivation, and so on (see Cannon-Bowers et al., 1995). Although, these influences cannot be changed or controlled by the trainer; they can be diagnosed and (potentially) compensated for. This, in turn, may lead to greater training success.

With the diversity of available training approaches and the accessibility of computers, it is plausible that individualized training could be effectively delivered via computer-based training programs. However, considering individual differences for training purposes has met with some resistance.

Practically, individual differences can be difficult and expensive to design for. Numerous cognitive styles, personality variants, and learning styles have been identified, and the interplay of these variables adds further complexity (e.g., Jonassen, 1993). Even when a manageable quantity of individual variables are examined, it is often not practical to redesign training to accommodate variables that include many different categories, variables that only affect a small portion of the population, or variables that are difficult to measure. Most individual differences fall into these categories, and consequently, they have not received much consideration in teaching or applied design.

Ideal individual characteristics to consider would have only a few categorical levels, affect a considerable portion of the population, be easily and reliably measured, and meaningfully influence training outcomes. Further, individualized training solutions should be practical to create and quick/easy to distribute to different learner groups.

Purpose of the Current Studies

This dissertation will review one variable (i.e., trait arousability) that may satisfy these criteria. After trait arousability and its potential to influence computer-based training are reviewed, two studies will then be conducted to explore the viability of using the variable for differentiated computer-based training. If trait arousability proves to be a useful individual difference to consider, then general guidelines of how to apply it will be drafted.

Arousability describes an individual's emotional and physiological reactivity to novel events (Mehrabian & Ross, 1977; Mehrabian, 1994). While every person experiences a range of high- and low-arousal states, research suggests that stable individual differences in *trait arousability* exist. In other words, some individuals are believed to be particularly sensitive to stimuli, and consequently, they are likely to experience high-arousal states more often and for longer durations. Categorically, it appears that most of the population (about 75-80%) is comprised of less-sensitive individuals. While about 20-25% of the population is made-up of highly-sensitive people who are easily over-stimulated and consequently perform more poorly in certain situations (e.g., achievement-based or distraction-filled environments; see Yermolayeva–Tomina, 1964; Mehrabian & Ross, 1979).

Trait arousability is typically measured using a Likert-style survey. Several different surveys exist, including Mehrabian's (1994) *Trait Arousability Scale*, Aron and Aron's (1997) *Highly Sensitive Person* scale, Coren's (1988) *Arousal Predisposition Scale,* and Satow's (1987) *Environmental Sensory Stimuli* scale. Each of the surveys require only a few minutes to complete, and they are easily scored. However, there is no de facto trait arousability measurement apparatus. Thus, the first part of the experimental research is dedicated to comparing results from the various scales, and if appropriate, combining items from different scales to create a single, more robust device. If appropriate, factor analytical methods will be used to divide the items into theoretically solid sub-constructs.

Once a unified measure has been compiled, it will be used to classify participants in a subsequent study that explores the impact of arousability on training. In this study, training material will be presented in either a high-stimulation or low-stimulation format. Participants will receive the training, and then its effectiveness will be judged. Outcome measures of performance will certainly be used, and measures of workload, anxiety, distraction, and concept-map formation may also be employed (depending upon the results of the pilot studies).

Finally, if (as hypothesized) arousability exerts a meaningful influence on training, then guidelines for practically applying mitigation strategies for it will be created. Specifically, the guidelines will answer questions such as: (a) What are the ideal levels of stimulation for high- or low-arousability groups? (b) How can the 'stimulation level' of a training system be reliably calculated? (c) And what degree of performance improvement might be expected, if arousability is accounted for? (Mehrabian and his colleagues have already developed an approach to numerically categorize stimuli. Their work would be used to inform these specific, applied questions.)

If arousability proves to be a significant, meaningful individual difference then exploring it could be important in a number of ways. First, this work could show that individualized training, in general, is both possible *and* practical. Second, arousability could be found to meaningfully affect training performance, and thus compensating for it might improve training effectiveness. And finally, this work could help inform the future of computer-based training, where systems will likely will exploit dynamic, adaptive solutions and respond to their individual users in ways we are only starting to explore.

CHAPTER TWO: EDUCATION AND TRAINING REVIEW

Individual Differences and Adaptive Training

Today, most training is still carried out in a traditional manner, where some number of learners are exposed, often as a group, to the same training regime. Along these lines, training facilities may create guidelines for trainers' behavior and curriculum activities, with the goal of establishing equal treatment and uniform measures for all learners. From one perspective, the attempt to deemphasize learners' differences makes training more egalitarian. However, from another, pretending learners are a homogonous group is unrealistic and may be detrimental to individuals' performance.

For instance, about 25% of military pilot-trainees fail the training program, despite having passed a rigorous select process, and presumably, having the capacity to succeed; each failure costs the US Air Force between $50,000 to $80,000 (Hunter & Burke, 1989). Failures, such as this, may be prevented if the training were more effective for those 25% of learners—if it adapted to their individual needs. Nonetheless, making effective use of adaptive training remains difficult and controversial (e.g., Crozier, 2002); the science associated with adaptive training is sometimes faddish, and empirical results are often mixed. However, by exploring individual characteristics rooted in core cognitive processes (such as arousal), adapting training may become more realistic and effective.

In this section, a review of individual differences and adaptive training is presented, and popular trends in adaptive instruction, including learning styles and differentiated training, are discussed and critiqued. At the end of the section, approaches to adaptive training rooted in cognitive theory are presented.

A Brief Overview of Individual Differences

The phrase 'individual differences' describes the diverse psychological characteristics exhibited by distinct persons, including differing personalities, motivations, intelligence levels, abilities, interests, values, and self-concepts. Definitively, individual differences are the objective and quantitative variations of individuals' behaviors (Anastasi, 1958). These variations may stem from heritable or environmental factors, or be the results of experiential calibration of evolved mechanisms (i.e., genetic inputs being filtered through environmental encounters; called the behavior-genetic hypothesis) (Buss & Greiling, 1999).

Many individual characteristics display stability in longitudinal studies. For example, individuals' mean intelligence scores remain stable (relative to normal age-related decline) for intervals of 45 years or more, and individual differences in personality traits display uniformly-high consistency after childhood (Stokes-Hendriks, 2002). These and similar findings suggest, first, that many individual differences stem from genetic predispositions and, second, that most meaningful environment influences occur early in life, and thus, the behavioral outcomes are 'set' early on (Alwin, 1994). (Although this is a simplified view, it is a fair conceptualization of most individual traits; for a more robust explanation see Buss & Greiling, 1999.)

For the purposes of training, the etiology of individual differences is not necessarily important; however, the stability of individual traits is key. Because many individual differences show temporal stability, they can serve as valid predictors for future performance. Hence, individual traits can be—and have been—used for a variety of purposes, though most often for selection and categorization.

Although recognition of individual differences dates back to Plato's time (Anastasi, 1958), Sir Francis Galton's work in the late 1800's formed the foundation of differential psychology. Galton was motivated by the work of Charles Darwin and strove to explore Darwin's theories amongst the human population. Initially, Galton examined intellectual and ability traits, looking for genetic causes for eminence in society (Galton, 1869; Buss & Poley, 1979).

Before Galton, scientists typically viewed individual variations as statistical 'noise.' Thus, Galton not only brought fresh theories and new statistical methods to psychology, but he also impelled differential psychology in to being. The science of individual differences grew steadily after Galton's contributions but was notably propelled by World War I. In 1917, American Psychological Association (APA) President Robert M. Yerkes called on psychologists to help the war effort, and they responded by developing measures of individual differences for the military. More than 1.7 million American soldiers were evaluated for selection and classification purposes by the Army Alpha and Beta intelligence tests (Furnham, 1992; Anastasi, 1958), and shortly after the tests' development, the first standardized personality inventory was created: The Woodworth Test of Emotional Stability (Furnham, 1992). These military studies marked a significant milestone for individual measurement—and for psychology as a whole. After the studies, the APA grew 14-times over, and psychology began to be accepted as a legitimate science, worldwide (Marks, 1976-77)

Today, individual differences such as intelligence and personality are still recognized as important indicators of job fit and performance, and they continue to be used for military and industrial selection (Stokes-Hendriks, 2002). However, differential psychology is marred by its early discriminatory misuses. During the field's early years, racism and sexism were widely-held beliefs, and the techniques offered by individual differences testing were well-suited for 'scientifically' demonstrating the superiority of one race/sex over the others. As Lieberman says of the time: “Although slavery was in the past, Jim Crow segregation provided a context in which the exploited status of ‘Negroes’ still needed justification” (2001:71).

Biased measures of individual differences—often of intelligence—were used to justify African-American’s social challenges, segregation, or slavery (see Herrnstein and Murray, 1994; Gould, 1996; Brace, 1997:865). Even today, prominent scientists, most notably J. Philippe Rushton, continue to generate controversy by exploring connections (arguably, biased or unbiased) between individual characteristics and race or gender (Lieberman, 2001; see Rushton, 1995). Hence, although the field of differential psychology has steadily advanced, and has been successfully applied to numerous areas, including learning (e.g., Gilliland & Clark, 1939), individual measurement remains somewhat controversial.

Learning Styles

Beginning in earnest around 40 years ago, educationalists attempted to bypass some of the controversy by identifying individual differences that were not necessarily connected to performance (e.g., Crozier, 2002; Messick, 1984). By doing this, they hoped to remove the stigma that certain individual characteristics (e.g., I.Q.), and therefore certain individuals (e.g., Caucasian children), were superior to others. These educationalists theorized that each person has their own approach to learning, or a *learning style*, and that all approaches have the potential to achieve the same levels of performance.

One of the departures, compared to other forms of individual difference measures at the time, was that learning styles were not used for selection or categorization. Rather, they were used to inform instructors, so that learning could be adapted to the learner. Hence they were used to adapt the system rather than select for it. Today, learning styles remain one of the predominantly studied form of adaptive instruction.

Although learning styles are often-studied and quite popular among some practitioners, they nonetheless garner extreme criticism. First, the learning styles literature is highly fragmented. For example, competing terms are often used interchangeably, including ‘learning styles,’ ‘learning strategies’, ‘approaches to learning’, ‘cognitive styles’, ‘conative styles’, ‘cognitive structures’, ‘thinking styles’, ‘teaching styles’, ‘motivational styles’, ‘learning orientations’, and ‘learning conditions’ (Coffield et al., 2004). The inconsistent vocabulary is presented here as an indicator of the field’s disunity. Many other examples can be found, including the investigators’ disagreement about the stability of learning styles, the variety of research approaches to studying learning styles, and disagreement about how to use this knowledge for pedagogical purposes (Coffield et al., 2004; Curry, 1990). Further, there are nearly 100 competing models of learning styles. Nearly all of the models are comprised of dichotomous descriptions of learners such as field-dependent vs. field-independent learners, common-sense vs. dynamic learners, or random vs. sequential learners. In their extensive review of learning styles, Coffield and his colleagues (2004) conclude:

> The sheer number of dichotomies betokens a serious failure of accumulated theoretical coherence and an absence of well-grounded findings, tested through replication. Or to put the point differently: there is some overlap among the concepts used, but no direct or easy comparability between approaches; there is no agreed ‘core’ technical vocabulary. The outcome – the constant generation of new approaches, each with its own language – is both bewildering and off-putting to practitioners and to other academics who do not specialise in this field. (p. 136).

Yet, despite these “significant difficulties in the bewildering confusion of definitions,” learning styles research has zealously continued (Curry, 1987, p. 3). Which leads to the second problem: Much of the research lacks rigor (e.g., Messick 1984; Coffield et al., 2004). In Coffield et al.'s review, many critical examples of this are offered. For instance almost all of the influential models of learning styles suffer from psychometric weaknesses; only three (out of the approximately 100 total models) "could be said to even come close" to meeting minimum psychometric standards (p. 139).

Further, unsubstantiated (and occasionally outlandish) claims are sometimes made. For example, Gregorc bases his Mind Styles™ model on his own 'metaphysical' experiences, and despite lacking theoretical bases and receiving unsupportive empirical evaluations (see Coffield et al., 2004; Joniak & Isaksen, 1988; and O'Brien, 1990), he continues to make strong statements about his model's veracity and usefulness (Gregorc, 2008). In another example, Dunn makes the extravagant claim that endemic low achievement and poor motivation are created by ignoring students' learning preferences (see Dunn, 2003), and that "the research shows that every single time you use learning styles, children learn better, they achieve better, they like school better" (as quoted by O'Neil, 1990, p. 7). Meanwhile, Fielding argues learning styles "should be a student entitlement and an institutional necessity" (1994, p. 393). Overall, Coffield et al. (2004) describe this trend by saying, for some "the absence of sound evidence provides no barrier to basing their arguments on either anecdotal evidence or 'implicit' suggestions in the research" (p. 118).

Yet, despite its shaky foundations, the notion of learning styles has become popularly commercialized by consultants and the media. This leads to a third problem: That is, commercialization has caused the science behind learning styles to become further diluted (for mass consumption), meanwhile popularizing the construct to a segment of eager practitioners who seem to have accepted it as dogmatic truth. "In many ways, the use of different inventories of learning styles has acquired an unexamined life of its own, where the notion of learning styles itself and the various means to measure it are accepted without question” (Coffield et al., 2004, p. 8), and that for learning styles enthusiasts “…learning styles are the central doctrine in a quasi-evangelical crusade to transform all levels of education” (p. 125).

With these complications, it is not surprising that the use of learning styles is rejected by many academics and practitioners (albeit, not the dogmatic ones mentioned above). Furthermore, in addition to the confusing science, questionable measures, and negative impact of commercialism, opponents of learning styles question their real influence on the process of learning. In their extensive review, Coffield et al. (2004) were only able to find one study that explored the percentage of variance attributed to learning styles: Furnham, Jackson, and Miller (1999) looked at the variance explained by personality and learning styles, together, and found that it only accounted for about 8% of the total effect on learning performance of telephone sales staff.

In summary, learning styles represent one of the most popular channels for the study and application of individual difference research for education and training. However, despite its popularity, this research suffers from (a) a disjointed scientific core, (b) poor psychometric support, (c) over-commercialization, and (d) an apparently modest impact on actual learning outcomes. Further, its greatest problem might be laid at the feet of overzealous researchers and dogmatic practitioners, whose dogged (over-)support for the learning styles has turned many other scientists and practitioners firmly against this research.

Differentiated Instruction

Differentiated instruction is another commercialized approach for utilizing individual differences in education and training. It is more philosophy than theory, and it typically includes and extends the application of learning styles. The vision of differentiated instruction is a learning environment where the learners are each engaging in their own, preferred learning experiences while still attaining the same knowledge and skills. More specifically, the goal of differentiated instruction is to deliver various levels of instructor support, task complexity, pacing, and learning methods to different learners, many of whom may have differing ability levels (Tomlinson, 2000).

> In differentiated classrooms, teachers are leaders who establish learning goals for their learners. Always, however, because they understand their students' individuality and trust their insights, they invite learners to participate in shaping classroom procedures, making choices that work best for them and thinking of ways to make the classroom more effective (Tomlinson, 2000:27).

Differentiated instruction receives similar criticisms as learning styles approaches. First, the field lacks a suitable operationalized definition. For instance, Adams & Pierce (2006) offer this explanation: "Instruction may be differentiated in content, process, or product according to the students' readiness, interest, or learning profiled" (p. 2). Other proponents offer similarly vague definitions (see for example, Hall, 2002; Tomlinson, 2004; Tomlinson, 2001; Tomlinson & Kalbfleisch, 1998)

Second, there are very few major studies on the effectiveness of differentiated instruction (Burns, 2005; see also Subban, 2006 for a review). Most empirical studies in this area focus on instructor/learner motivation, instructors' self-efficacy for using differentiated techniques, or instructors' subjective beliefs about differentiated instruction's effectiveness (Subban, 2006). However, a few empirical investigations on performance have been conducted. For instance, McAdamis (2001) found low-scoring students made statistically-significant improvement after they received differentiated instruction. However, the McAdamis study also included an entire-school change in philosophy, which included professional development, mentoring, intensive planning sessions, teacher support groups, and so on. Consequently, it is difficult to determine what, in particular, affected students' scores. In a different large-scale deployment of the concept, Burns (2005) found that differentiated instruction had no positive influence on middle or high school students' academic achievement or standardized test scores; although, middle school teachers (subjectively) felt that the differentiated instruction aided their students' understanding.

Third, putting differentiated instruction into practice is impractical. It requires that instructors have the time and ability to diagnose individual students' needs and then create uniquely-tailored learning processes for each. As Moll (2003) explains, "No two students in any classroom learn the same way. The teacher must vary, in a purposeful way, the methods, materials, procedures, and environment of learning to reach every student in the classroom." Although, as other proponents explain, differentiated instruction does not necessarily mean individualized instruction—because similar students can be grouped (e.g., Tomlinson, 1999)—it nonetheless seems difficult to effectively implement and does prove time consuming (e.g., Ernst & Ernst, 2005). While some instructors may excel at diagnosing learners and developing unique curricula for them, others will likely lack the skills or motivation to do so. Furthermore, in any large-scale training operation (such as a multinational business or for the military), consistency across instructors would be difficult to ensure. As Burns (2005) discovered in practice: (a) implementing differentiated instruction on a large scale affects completion of the standard curriculum, (b) different instructors will implement the differentiated instruction model to varying degrees, and (c) instructors' beliefs about differentiated instruction significantly affect their willingness to use it.

In summary, differentiated instruction offers an utopist paradigm in which curriculum and the classroom environment are uniquely tailored to each individual's needs. While the ideals of differentiated instruction are respectable; fully achieving this paradigm in reality is impractical. As a philosophy, differentiated instruction seems to encourage instructors to think about their individual students needs—which is good! However, trying to formalize differentiated instruction into a procedural learning strategy is untenable, and the empirical data suggest that in the end, differentiated instruction hardly affects how much individuals learn.

Adaptive-Intelligent Tutoring Systems

The adaptive learning approaches discussed so far can be considered human-human, or learner-instructor, focused paradigms (e.g., Moore, 1989). In the 1950's, Pask and McKinnon-Wood introduced the first adaptive instruction machine, therefore inventing a new learner-machine (or learner-interface) interaction (e.g., Hillman, Willis & Gunawardena, 1994). Pask and McKinnon-Wood's Self Adaptive Keyboard Instructor (SAKI; Pask, 1960; 1982) modified typing exercises based upon the learners' performance. Using SAKI, training times were typically shortened by one-half to two-thirds, compared to conventional instruction methods of the time.

Since SAKI's time, intelligent tutoring systems have continued to evolve. Today, there are two broad categories of systems:

> Speaking about *adaptive systems* we stress that these systems attempt to be different for different students and groups of students by taking into account information accumulated in the individual or group student models. Speaking about *intelligent systems* we stress that these systems apply techniques from the field of Artificial Intelligence (AI) to provide broader and better support for the users… (Brusilovsky & Peylo, 2003: 156-157).

While many intelligent tutoring systems are both *adaptive* and *intelligent*, some systems fall into only one category.

Purely *intelligent* (i.e., non-adaptive) systems will always provide the same diagnosis in response to the same stimuli, regardless of a learner's previous actions. For example, intelligent language tutoring systems (such as German Tutor by Heift & Nicholson, 2001) are typically only intelligent. They perform complex analyses on learners' immediate performance in order to optimize the education material and approach. However, these systems rarely include any student modeling component; thus, the systems do not incorporate dynamic models of learners (e.g., Heift & Schulze, 2003).

In contrast, purely *adaptive* (i.e., non-intelligent) systems will select different diagnoses based upon learners' past actions; these systems can be effective using simple state-machine models and do not necessarily require artificial intelligence. For instance, computer-based adaptive tests select test items, in real time, according to the examinee's ability level. These adaptive (non-intelligent) systems are quite common and are similar to widespread testing systems such as the Graduate Management Admission Test (GMAT), Test of English as a Foreign Language (TOEFL), Graduate Records Examination (GRE), Armed Sciences Vocational Aptitude Battery (ASVAB), and Microsoft Certified Professional exams (Lilley & Barker, 2004). While these adaptive systems are effective, they are certainly not 'intelligent.'

Today, nearly all intelligent, adaptive, or adaptive-and-intelligent tutoring systems are performance-focused; that is, they analyze learners' performance and then execute performance-focused mitigations (e.g., 'coaching students or diagnosing their misconceptions' Brusilovsky & Peylo, 2003: 156). Only very recently have a few investigators begun to examine learners' processes that are not observable. These researchers are developing ways to analyze, interpret, and then somehow manipulate learners internal socio-psychological states (e.g., mood or motivation-level). For instance in 2004, Chaffar and Frasson proposed the ESTEL architecture, most likely the first published architecture for intelligent tutoring systems that offered a clear strategy for assessing learners' states and inducing 'optimal emotional states' for learning. Around the same time, the Tutoring Research Group (TRG) at the University of Memphis developed AutoTutor, an intelligent tutoring system that can respond to learners' emotions by using inputs such as a video of the learner's face or a posture detector (D'Mello et al., 2005). Other investigators are also beginning to contribute to this new approach (see Porayska-Pomsta et al., 2008); however, the science of affective-adaptive-intelligent tutoring systems is still in its infancy.

Adaptive-intelligent tutoring systems can be very effective. For instance, learners who use AutoTutor (discussed above) show test-score improvements of 0.4 to 1.0 standard deviations, which is the average improvement achieved when learners use effective systems (Graesser et al., 2002). Consequently, these systems certainly will continue to play a role in the future of education and training. As Sarrafzadeh et al. (2003) succinctly explain:

> [Adaptive-intelligent tutoring systems] offer many advantages over the traditional classroom scenario: they are always available, non-judgmental and provide tailored feedback. They have proved to be effective, resulting in increased learning (p. 501).

However, adaptive-intelligent tutoring systems are still only half as effective as human tutors (e.g., Porayska-Pomsta et al., 2008). Proponents of the *affective*-adaptive-intelligent paradigm explain the discrepancy by pointing out tutoring systems' inability to attend to non-performance cues. They suggest that system designers study effective human tutors' abilities to support learning, and analyze the non-performance cues and socio-psychological inferences that the human tutors make (Porayska-Pomsta et al., 2008). They also recommend using alternative input devices, such as physiological sensors (e.g., EEGs, eye-tracking), in order to access more meaningful non-performance data.

A second problem of adaptive-intelligent tutoring systems is that they rarely account—*a priori*—for learners' individual differences. Instead, these differences are discovered and mapped only after repeated interactions with the system.

In conclusion, adaptive-intelligent tutoring systems are effective learning tools. Despite their high degree of success, they can still be improved upon: Specifically by incorporating additional cognitive theories to expand their focus beyond performance measures and interventions, incorporating psycho-physiological measures that can help identify cognitive states, and integrating meaningful data from individual differences research to help establish baseline parameters and interpret non-performance data.

Summary

In conclusion, as this brief review indicates, adaptive training approaches range from the highly-successful to the highly-unsupported. The least successful approaches (e.g., learning styles) fail due to their shaky scientific bases or impracticality to implement (e.g., differentiated instruction). The most successful approaches (e.g., adaptive-intelligent tutors) rely primarily upon strict performance measures to diagnose and respond to learners, and therefore, despite their effectiveness they are still somewhat limited.

Practically-speaking, the next generation of adaptive learning systems will likely be computer-based. They will respond to learners' performance, as well as other cues (either observable or psycho-physiological data) that indicate learners' socio-psychological states. These systems will also utilize models regarding individual differences, which will help establish system baselines for individual learners and enable the system to better interpret learners' actions or cognitive-state data. In the next subsection, a case will be made for using cognitive psychological and individual differences research to improve upon contemporary adaptive instruction approaches.

Individual Differences and Adaptive Training: A Cognitive Approach

"There is an intertwined and reciprocal relation between cognitive theory and educational practice—a relation that benefits both fields" (Mayer, 2002: 55). As Mayer's quotation exemplifies, the study of cognitive psychology can provide a significant benefit to the practice of education, and conversely, the practical educational problems educators face can inform cognitive theorists and guide their research. Cognitive psychology can bring theory structure, operational hypotheses, and a framework for experimental analysis to education. The adaptive instruction approaches discussed in the previous subsections each can be improved upon, via the application of cognitive psychology.

Education and training that incorporates the study of individual differences can particularly benefit from the decades of analyses into differential psychology. Potentially, the most meaningful individual variables can be discovered by examining individual differences that are predicted based-upon models of cognition. In this way, the study of adaptive training progresses from theory, to analysis, to application—rather than the converse. This traditional approach to theoretical analyses also ensures the greatest likelihood of success.

So, if practitioners are serious about *effective* individualize training what can they do? The answer is to first turn to science, and identify individual variables that have predicted, meaningful influences on the desired outcomes (particularly performance). Look for variables that are stable and based in core cognitive functions, that affect a large portion of the population, and have few dimensional categories. Once these target variables are identified, they must next be rigorously tested, and outcome gains must be sufficiently large to warrant the investment of time and energy. Finally, when applications using this research are developed, they must be practical and deployable. For instance, valid measures and clear recommendations for individuals must be available, so that instructors are not left guessing.

Through reliance upon the scientific approach and cognitive research, rigor and better outcome monitoring can be brought to the applications of learning styles/differentiated instruction. And, through the application of cognitive science, intelligent-adaptive tutoring systems can progress to their next stage of development, looking past basic performance and into the minds of the learners.

Definitions

Thus far, this report has included literature from the learning and training fields, and made little distinction between the terms. For the purposes of this chapter's broad overview, the difference between these fields was not relevant. However, their definitions should now be noted. In research and industry, the distinction between 'learning' and 'training' is up for debate. Sweller (2005: 20) suggests that "learning is defined as an alteration in long-term memory." Training can be considered a more discrete, performance-measured component of learning. As Vince Eugenio, chief learning officer of Randstad US, explains:

> Training is a series of very specific, structured activities that are related to the achievement of clearly stated performance objectives that are typically related to doing a job. (quoted in Whitney, 2006).

Hence *training* is an intentionally-constructed process designed to transfer specific knowledge, skills, and/or attitudes to others. While *learning* may take place in a training setting, it may also occur in more incidental ways or involve knowledge, skills, or attitudes unnecessary for attaining specific performance outcomes.

The term *pedagogy* is often used in conjunction with learning. It stems from the Greek words *paid* ('child') and *agogus* ('leading'), and literally refers to the science of teaching children (Knowles, 1980). Since this report is interested in adult training, pedagogical theories are not specifically applicable; although, the term pedagogy is sometimes applied to adult education.

The term *andragogy* was coined to distinguish adult education approaches from child-centric strategies. *Andragogy* uses the Greek word *anēr* ("man, not boy," or adult). It is a contrast to pedagogy in that andragogy assumes that the learners 1) are self-directed rather than depended, 2) have accumulated a reservoir of experience that can be accessed for learning, 3) that their motivation to learn stems, increasingly, from the developmental tasks of their social roles, and 4) that their perspective of the learning is one of performance- rather than subject-centeredness (i.e., a focus on immediate use, rather than postponed usefulness) (Knowles, 1980:44-45).

Finally, *adaptive instruction* is a general term that refers to the use of alternative instructional strategies based upon individual differences. As this review has demonstrated, adaptive instruction can take many forms: From computer-based adaptive testing to classroom-based differentiated curricula. The remainder of this report will focus on adaptive instruction (of adults) for training outcomes. More specifically, it will examine the impact of an individual difference—arousability—in the context of adaptive multimedia training.

CHAPTER THREE: AROUSAL REVIEW

General Arousal

Before arousability is explored in the context of adaptive multimedia training, the concept of arousal must be introduced. Arousal is the most fundamental mechanism of the nervous system, affecting many downstream processes such as alertness, attention, mood, and temperament. Because arousal influences so many other mechanisms, there are different ways to conceptualize it. For instance, arousal is often considered in the context of basic stimulus-response behaviors as a reflexive reaction to environmental stimuli: As an individual encounters "novel, intense, unusual, complex, or unpredictable stimuli" (Sokolov, 1960, 1963; as quoted by Mehrabian, 1977b) his/her cognitive processes are leveraged to attend to, interpret, and categorize the incoming information. Thus, as more stimuli are encountered, individuals becomes more *aroused*. Similarly, arousal is often emphasized in the context of the sleep-wake cycle where it refers to the state of responsiveness of an organism. Thus, arousal "moves the animal toward readiness for action from a state of inactivity " (Immelman & Beer, 1989). While these sorts of definitions are true, they are somewhat limiting. For instance, these examples deemphasize the role of internal stimuli, as well as voluntary motor activity and emotional responses. Pfaff (2006) offers a broader operational definition:

> "Generalized arousal" is higher in an animal or human being who is: (S) more alert to sensory stimuli of all sorts, and (M) more motorically active, and (E) more reactive emotionally (p. 5).

Thus, the broad definition of arousal refers to a person's levels of mental alertness, physical activity, and emotionality.

Heuristically, it is useful to imagine arousal varying on a continuum from under-aroused (e.g., deep sleep, boredom, unengaged) to hyper-aroused (e.g., extremely wakeful, stressed, strongly emotional) (e.g., Hebb, 1955). However, this unidimensional conceptualization of arousal is not universally accepted.

Unidimensional vs. Multidimensional Arousal

The unidimensional perspective sees arousal as an undifferentiated, global psycho-physiological mechanism: a single continuum ranging from low- to high-arousal. This is perhaps best described by the well-known Yerkes-Dodson (1908) law, which models unidimensional arousal–performance as a curvilinear (inverted-U) relationship (see Figure 1). The Yerkes-Dodson model describes a person's optimum stimulation level (Hebb, 1955; Leuba, 1955). The optimum level of arousal theory makes three assumptions: (a) individual differences in arousability exist, (b) there is an optimum level of arousal (or 'stimulation'), (c) individuals develop strategies to make their actual arousal level match more closely with their optimum level. Thus, individuals who are experiencing low levels of arousal seek excitement, while individuals who are experiencing overly-high levels of arousal will try to escape or avoid stimulation (e.g., Werre, 1987).

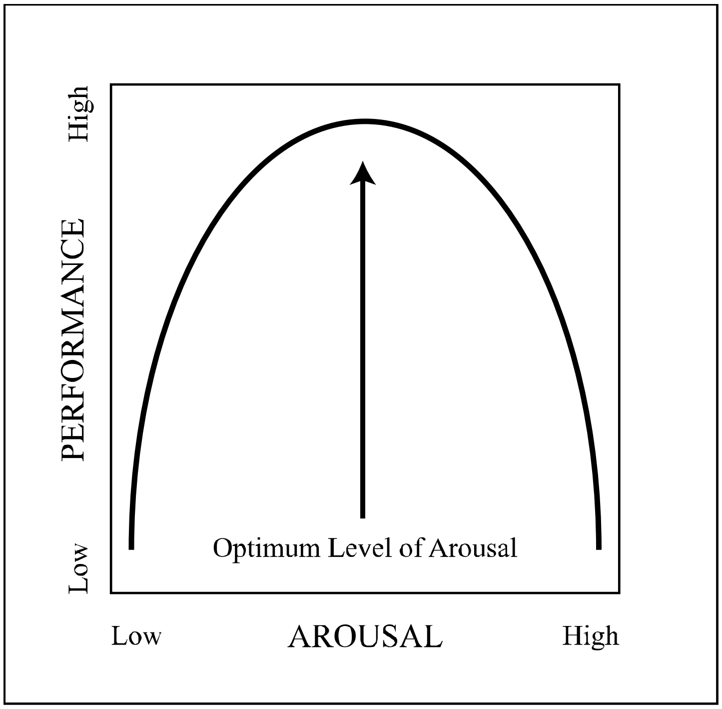


Figure 1. Graphical representation of the unidimensional relationship between arousal and performance, as initially proposed by Yerkes and Dodson (1908).

While the inverted-U relationship and the theory of optimum arousal are useful rules-of-thumb, most contemporary arousal investigators believe the construct is more complex than these perspectives suggest. Since the mid-1980s, researchers have seriously questioned the unidimensional model of arousal for a myriad of reasons (Deffenbacher, 1994), including its lack of empirical support (e.g., Robbins, 1997; Hockey, Coles & Gaillard, 1986; Näätänen, 1973; Neiss, 1988) and inability to account for differentiated patterns of arousal–stress–motivation–performance (e.g., Hockey et al., 1986; Posner & Rothbart, 1986; Fazey & Hardy, 1988).

Also, as Thayer (1967) colloquially points out: Individuals may describe themselves as generally alert in a certain situation without necessarily experiencing the negative emotionality associated with unidimensional high arousal (e.g., jittery, intense, anxious, or fearful feelings). Consequently, Thayer suggests a two-factor model of arousal that separates the construct into *tense arousal* (or *preparatory-emergency activation*) and *energetic arousal* (or *general activation*) (Thayer, 1967; 1989).

Tense arousal includes negative emotionality and occurs in response to danger (real or imagined); it manifests emotions such as anxiety, tension, or fear. Energetic arousal represents the general alertness that drives vigor and readiness. Tense arousal is associated with avoidance behaviors, and it ranges from calm to anxious; while energetic arousal is associated with approach behaviors, and it varies from tired to energetic. These two systems interact to create four poles of arousal: 'tense-energy,' 'tense-tiredness,' 'calm-energy,' and 'calm-tiredness' (Thayer, 1989; see also Matthews et al. (1990) for a similar three-factor model).

Tucker and Williamson (1984) propose a different two-factor model where one neural system maintains readiness for action (i.e., *activation*) and another responds to novel stimuli (i.e., *arousal*). They base their theory on neuroanatomical research showing distinct pathways that respond independently to either continued stimulation or repetitive stimuli (see Pribram & McGuinness, 1975).

However, critics complain that some arousal theories—such as those just discussed—neglect the role of cognitive effort. They believe that arousal can be mitigated to some extent by the individual experiencing it (e.g., Kahneman, 1973). Thus, arousal models including neural control mechanisms have appeared.

For instance, Hockey (1986a; Hockey & Hamilton, 1983) extends the two-factor model of arousal to include a state control mechanism. He contends that combined responses to stimuli produce unique arousal states, and that the affects of these states can be mitigated via conscious control. Hockey asserts that a *central control system* makes cognitive resource-management decisions in order to offset the negative affects of suboptimal or supraoptimal arousal. Individual differences in this resource management mechanism equate to different degrees of success when coping with nonoptimal arousal. Hockey's control state model makes several assumptions. First, he assumes that behavior is goal directed, and that the control of goal states is a self-regulating process. Second, he assumes that there is a comparison mechanism that discerns differences between optimal and nonoptimal arousal. Third, he assumes that the central control system can respond to mismatches in desired/actual arousal and leverage resources (if it so chooses) to overcome the mismatched state (e.g., Beauducel, Brocke & Leue, 2006).

Yet, critics continue to raise concerns. Notably, Hardy and Fazey (Hardy, 1996; Hardy & Fazey, 1987; Fazey & Hardy 1988; Hardy & Parfitt 1991) question the curvilinear relationship between (unitary or multidimensional) arousal and performance. They suggest that under low cognitive anxiety the inverted-U may hold true, but when a person experiences high anxiety *and* supraoptimal arousal then the degradation in performance is often sudden and dramatic (i.e., a catastrophe). Furthermore, once someone has 'fallen off the cliff,' small reductions in arousal are no longer able to improve performance. Figure 2 depicts the relationship between arousal and performance as per the *catastrophe model*.

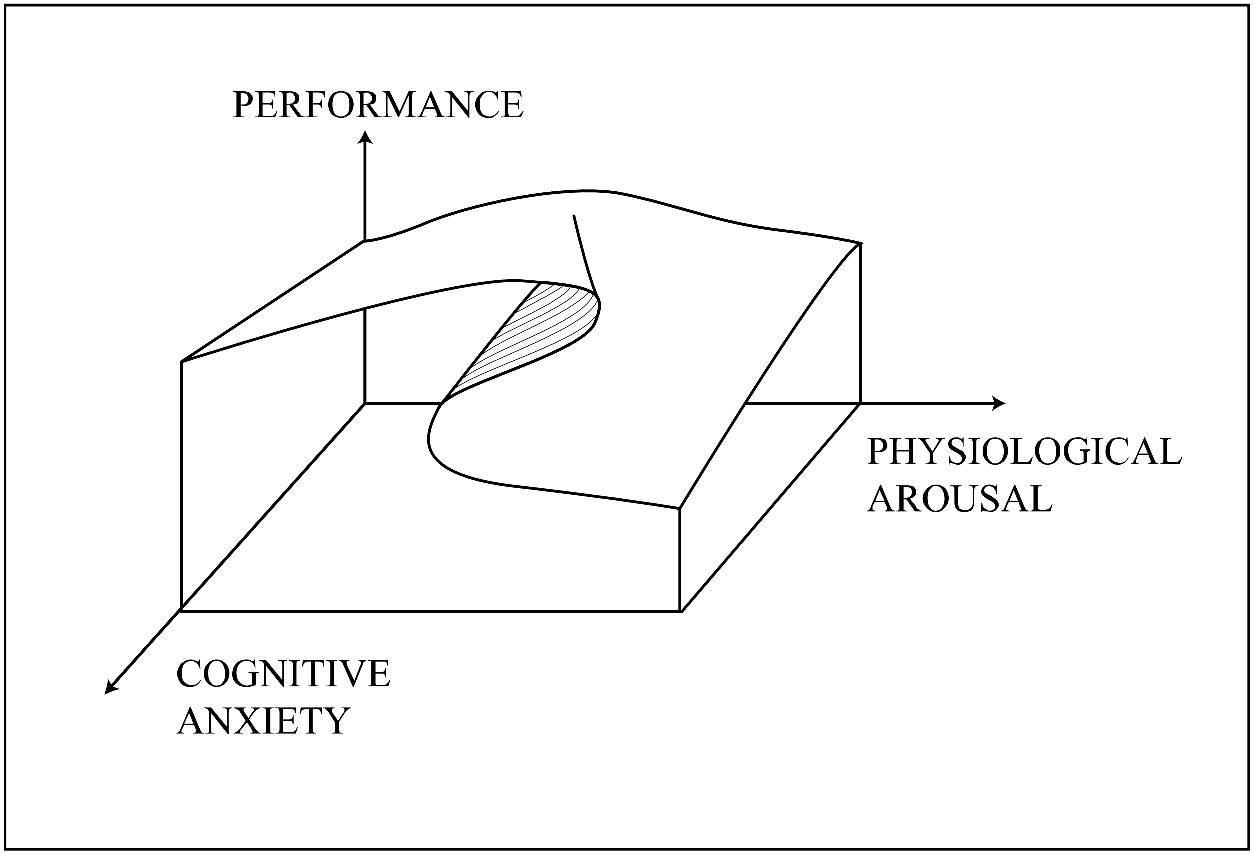


Figure 2. Hardy & Parfitt's (1991) catastrophe model. Reproduced with permission from the British Psychology, © The British Psychological Society.

At this point, it may appear that multidimensional arousal theories have definitively trumped unidimensional perspectives. However, the case is not yet closed. Certainly, most contemporary investigators gravitate toward multidimensional paradigms, but Muse, Harris, & Feild (2003) suggest that these investigators are biased against unitary theories. In a review of the literature, they conclude that unitary arousal has not received a "fair test":

> First, it was already clear that there was little representation among the body of research of results that supported the inverted-U. If, in fact, the bulk of studies were designed in such a way to be biased against a true test of the inverted-U, meta-analysis based on those designs and results would tell us little about the "true" relation between stress and performance. Because the inverted-U encompasses the negative linear model (the negative linear is the right side of the U), support for the negative linear model does not necessarily imply lack of

> support for the inverted-U if the positive linear side of the U is not addressed in the study. Second and similarly, the bulk of the studies report correlational, linear-based results. Such results do not allow us to look for nonlinear effects as suggested by the inverted-U; access to the original data would be required (p. 352).

Finally, Pfaff (2006) offers a middle ground, calling the distinction between the two paradigms a “false dichotomy” (p. 7). He suggests that arousal is ultimately comprised of generalized arousal *and* specific forms (e.g., hunger, sex, fear). As evidence of this, Pfaff references his own empirical work, showing that generalized arousal contributes from 29.7% to 45% to overall arousal functions across different experimental situations. He also cites a number of other studies (e.g., Campbell & Sheffield, 1953; Barfield & Sachs, 1968; Antelman & Szechtman, 1975; Brown, 1953; and Richter, 1922) showing how one form of arousal (e.g., hunger) can influence another (e.g., emotion), and he offers compelling neuroanatomical evidence in support of his theory (see Pfaff, 2006, for supporting explanations and numerous references).

Pfaff does not reject the various dimensions of multidimensional arousal outright; instead, he contends that “teamwork, not identity, among autonomic responses fosters information flow and cooperation” (p. 71). In other words, he believes that the many components of arousal work in concert to produce the arousal state. Although the various aspects of generalized arousal are not correlated, Pfaff explains, they are nonetheless coordinated:

> What we have, therefore, are autonomic functions that are physiologically coordinated to “do the job,” but that are not correlated with each other at time *t*. By analogy, consider a football team. Even though the players are following agreed-upon plays and are moving effectively with respect to each other, attempts at correlating their responses statistically at any given time would yield no correlations. Their movements are cooperative, but not identical (p. 79).

Unidimensional vs. Multidimensional Arousal: Summary

Looking across the many arousal theories, a few generalizations can be rather safely assumed. From the multidimensional perspectives, three conclusions can be drawn. First, general arousal is likely moderated by other cognitive factors, notably anxiety (or a valenced assessment of the arousal source). Whether investigators (such as Thayer) choose to include anxious activation as part of the arousal construct or (like Hardy and Fazey) they choose to see it as a separate force, it is clear that an individual's assessment of stimuli (e.g., reward/punishment) can produce different behavioral outcomes (e.g., glee/sorrow). Second, coping mechanisms probably mitigate degradation in performance due to sub- or supraoptimal arousal. These coping mechanisms may be learned strategies (e.g., Kohn, 1996) or (as Hockey suggests) they may be neurological mechanisms. Either way, individuals likely possess some way to mitigate arousal-based performance loss—at least to some extent. And third, the arousal–performance curve is most likely not a simple inverted-U in all situations. When other moderators are considered (i.e., anxiety) the relationship among the factors must consequently become more complex.

Muse et al. (2003) remind investigators not to prematurely reject the unitary hypothesis. Further, empirical studies and theoretical positions (e.g., Anderson 1994; Eysenck, 1967; Humphreys & Revelle, 1984) continue to show the usefulness of the unitary arousal hypotheses—at least as a functional heuristic, if not absolute truth.

Finally, Pfaff (2006) dedicates an entire book to explaining a unique approach to the unidimensional/multidimensional arousal debate. His theories help unify the findings from both perspectives, and he restores the legitimacy of generalized arousal as part of the overall arousal phenomenon—this time as a genuine mechanism, rather than just a heuristic.

Arousal and Information Theory

Understanding arousal depends, in large part, upon understanding the basic premise of information theory, a scientific perspective credited to Claude Shannon (see Shannon, 1948). One of the fundamental theories within this science is *information entropy*, which states that more information is conveyed when more uncertainty is present. (Shannon uses the term *entropy* to denote uncertainty.) Pfaff (2006) offers a commonsense explanation:

> If any event is perfectly regular, say the ticking of a metronome, the next event (the next tick) does not tell us anything new. It has an extremely high probability (*p*) of occurrence in exactly that time bin. Likewise, in the time bins between ticks, silence has an extremely high probability of occurring. We have no *un*certainty about whether, in any given time bin, the tick will occur. According to Shannon's equation, the information in an event is in inverse proportion to its probability. Put another way, the more uncertain we are about the occurrence of that event, the more information is transmitted, inherently, when it does happen (p. 13).

The crux of information entropy is that information rates are highest when uncertainty is greatest. Conversely, information rates are lowest when uncertainty is minimized. The important distinction, here, is that *information delivery*—and not *quantity*—determines the information rate. From this, two important observations follow. First, the greater the surprise, uncertainty, or novelty associated with a stimulus, the greater arousal "spike" (i.e., *arousal amplitude*) it will cause. Second, the amount of information conveyed by a continuous or repeated stimulus declines over time; thus, individuals habituate to an repeated/repetitive stimulus because each successive moment of it conveys less information (i.e., each moment contains less uncertainty, even though the information content remains fixed).

Orientating Reflex

The arousal "spike" caused by the presentation of unexpected stimuli is called the *orienting reflex*. Specifically, the orienting reflex triggers in response to changes in stimulus quality and intensity, and it extinguishes as the same stimulus is presented repeatedly (Mehrabian, 1995). The time it takes for arousal to gradually return to baseline is called the *duration of habituation*. Mehrabian (1995: 4) presents another way to conceptualize this:

Information Rate = (Information Content) / (Duration of Exposure)

Additionally, Mehrabian and Russell (1974) exemplify the instances when orienting reflex is greatest; of course, orienting reflex is strongest when greater uncertainty (i.e., entropy) is present (see Table 1):

Table 1: Low/High Entropy Situations*

Lower Information Rate / Weaker Orienting Reflex	Higher Information Rate / Stronger Orienting Reflex
Redundant	Varied
Simple	Complex
Familiar	Novel
Sparse	Dense
Usual	Surprising
Patterned	Random
Static	Moving

* From Mehrabian & Russell (1974)

In summary, the critical contribution from information theory is that arousal is a reaction to the *information rate* of stimuli, and not necessarily their content. Thus, individual differences in arousability (discussed in the following subsection) "only manifest in response to a limited class of stimuli, with such differences being attenuated over time because of adaptation. What then is the special class of stimuli that is likely to highlight individual differences in patterns of arousal response? These are the novel, intense, unusual, complex, or unpredictable stimuli which elicit higher arousal responses from people in general" (Mehrabian 1977b: 238).

Individual Differences in Arousability

Most everyone has comparable baseline arousal levels (i.e., resting arousal levels), and everyone experiences wide fluctuations in arousal throughout any given day. Universally, high-information situations elicit higher levels of arousal, and low-information situations elicit lower levels (see Mehrabian & Russell, 1974; Duffy, 1962; Humphreys & Revelle, 1984). Within-subject fluctuations in arousal level describe an individual's arousal state.

Psychological states, such as a person's arousal state, derive from the interaction between situational characteristics and an individual's psychological traits. Psychological traits are stable individual characteristics are believed to reflect differences in genetic, biological, temperamental, or learned bases for behavior (see Humphreys & Revelle, 1984). Psychological traits are nearly impossible for adults to alter (although coping strategies can be learned).

Trait-based differences in arousability describe individuals' sensitivity to the intense or unexpected stimuli mentioned above. Individuals with high trait arousability are more easily aroused and return to their baseline arousal levels (i.e., habituate) more slowly. Highly arousable individuals experience both positive and negative stimuli more strongly than other people do (Mehrabian, 1994).

Individual differences in trait arousal have been studied from many different angles and under a variety of monikers. This construct has been called general arousability (Gray, 1964), introversion/extraversion (e.g., Eysenck, 1967), nervous system strength (e.g., Pavlov, 1955), sensitivity (e.g., Aron & Aron, 1997), reactivity (Strelau, 1984), augmenting–reducing (Petrie, 1967), stimulus screening (e.g., Mehrabian, 1977b), and trait arousability (e.g., Mehrabian, 1994). The various names generally reflect differences in approach, scientific focus, or time period. However, these constructs are comparable (e.g., Kohn, 1987). For the purposes of this report, individual differences in arousal response are labeled 'arousability.' In the following subsections, each arousability construct is briefly described, in alphabetical order; Table 2 also includes a summary of these approaches.

Table 2: Summary of Arousability Constructs (Alphabetical)

Name	Description	Selected Sources
Augmenting–reducing	Some individuals neurologically augment sensations, while others reduce them. A neurophysiological stimulus intensity control mechanism causes these differences.	Petrie, 1967 Buchsbaum et al., 1986
General arousability	Individual differences in arousability are considered from two factors: sensitivity to reward (i.e., impulsivity) and sensitivity to punishment (i.e., anxiety).	Gray, 1964 Gray, 1987
Introversion/Extraversion	Introverts and extraverts differ in the sensitivity of their arousal system and the thresholds of their ARAS. Introverts have lower response thresholds and, in general, higher cortical arousal.	Eysenck, 1967
Nervous system strength	Individuals' resilience to intense stimulation varies along a "strength–weakness" dimension. 'Strong' nervous systems are able to endure a greater amount/duration of stimulation than to 'weak' nervous systems. Once a certain threshold is crossed, the nervous system shuts down (in whole or part); this is called 'transmarginal inhibition.'	Pavlov, 1955 Rokhin, Pavlov, & Popov, 1963
Reactivity	Individuals' reactivity to stimuli varies on a continuum from sensitivity to extreme endurance under stimulation. Strelau has identified six factors in reactivity to stimuli: briskness, perseverance, sensory sensitivity, emotional reactivity, endurance, and activity.	Kohn 1985 Strelau, 1984
Sensitivity	Arousable individuals possess increased nervous-system sensitivity to subtleties, and they process stimuli more deeply.	Aron & Aron, 1997 Aron, 1996
Stimulus Screening	Screening is an individual difference that describes a person's ability to prioritize, and then selectively attend to, distracting stimuli.	Mehrabian 1977a Mehrabian, 1977b
Trait Arousability	Trait arousability describes an individual's emotional and physiological reactivity to novel events. It is covarying and complementary to stimulus screening ability.	Mehrabian & Ross, 1977 Mehrabian, 1994

Augmenting–Reducing

The augmenting-reducing, or stimulus-intensity modulation, perspective suggests that individuals vary in their subjective experience of stimulation (Barnes, 1976; Petrie, 1967; Sales, 1971, 1972). 'Augmenters' subjectively amplify stimulus intensity, while 'reducers' subjectively attenuate it (and 'moderates' neither augment nor reduce). However, all people have approximately the same optimal-level of (subjective) stimulation. Therefore, augmenters typically avoid intense stimuli, while reducers are generally sensation-seekers (Sales 1971, 1972). [Note, while Zuckerman (e.g., Zuckerman, 1979) contends that the converse is true (i.e., augmenters are high, and reducers low, sensation-seekers) this paradox has been clearly explained by considering transmarginal inhibition (see Davis, Cowles, & Kohn, 1983).]

General Arousability

Gray's (1964) concept of general arousability describes stable individual differences in arousal by examining the dimensions of anxiety and impulsivity. Gray (1987) suggests that three systems work in concert to contribute to arousal. First, the behavioral activation system (BAS) initiates goal-directed behavior, including approach–avoidance behaviors (e.g., response to rewards). Second, the behavioral inhibition system (BIS) responds to threatening or unexpected stimuli (e.g., response to punishments). And finally, the nonspecific arousal system (NAS) is influenced by both the BAS and BIS, and it ultimately affects the speed and magnitude of a person's responses. The BAS system represents 'impulsivity,' while the BIS system represents 'anxiety.'

There is considerable, ongoing debate about Gray's factors, as well as the relationship between sensitivity to reward and sensitivity to punishment, in general (e.g., Franken & Muris, 2006). However, what this approach does clearly show is that stimuli's valence (i.e., whether they are regarded positively or negatively) does influence individuals responses to them at the physiological level.

Introversion/Extraversion

Significant quantities of research have examined the arousability differences between extraverts and introverts. Some of the earliest arousal-related investigations carried out individually by Gross, McDougall, and Jung sought to explain these basic personality differences by way of their arousal responses (Strelau & Eysenck, 1978). However, Eysenck is likely the best-known proponent of this approach. He defined introversion/extroversion in terms of differences in cortical arousability, suggesting that introverts and extraverts have different arousal system sensitivity levels and that introverts' ARAS (ascending reticulocortical activating system) sensory stimulation thresholds are lower. Consequently, introverts have lower response thresholds and, in general, higher cortical arousal (Eysenck, 1967).

However, extraversion does not always show a one-to-one relationship with other models of arousability. While some arousability investigators (e.g., Aron, 2004; Gunnar, 1994; Gray, 1981; Strelau, 1986) have found a high degree of similarity between their measures of arousability and extraversion, others (e.g., Mehrabian 1977b; Corulla, 1989; Stelmack et al., 1985) have found no significant correlations. Most likely, this discrepancy reflects the degree to which sociability is considered a component in extraversion (Corr et al., 1995). Eysenck's introversion/extraversion conceptualization comprises impulsiveness and sociability, whereas Jung's approach reflects physical sensitivity and an individual's preference to reflect upon a situation before acting (Aron, 2004; 2006).

> Eysenck's (1967) theory does not make a theoretical distinction between the power of sociability and impulsivity components of extraversion to influence performance. Although these two traits are correlated (= 0.50), some authors (e.g. Carrigan, 1960) have suggested that they represent independent factors, combined together by a 'shot gun wedding' (Guilford, 1975) of concepts (Corr et al., 1995: 713).

Aron, who found that about 70% of introverts are also highly arousable (Aron, 2004), attempts to explain the relationship between arousability and sociability. She asserts that it is partially causal. She argues that since arousability is an inherent trait, evidence of it is manifest in infants and children (e.g., Aron, 2002; Liss et al., 2005; Kagan, 1994), and because arousable individuals become easily over-stimulated, arousable children may learn to withdraw from stimuli. Thus, children who experience over-stimulation may develop strategies for coping with it, and these strategies develop into behaviors that are labeled as "shy" (e.g., Aron, Aron, & Davies, 2005; Kagan, 1994) or "inhibited" (e.g., Gray, 1981) once the children mature.

However, Aron notes that arousable children, if raised in an appropriate environment, may actually exhibit socially-extraverted behavior as adults (Aron & Aron, 1997). She therefore concludes that arousability only partially correlated with measures of low-sociability, a major component of many introversion–extroversion scales (Humphreys & Revelle 1984). However, the original Jungian conceptualization of introversion still correlates highly with measures of arousability. Consequently, when considering arousability from the introversion/extraversion perspective, it is important to examine the measurement approaches and critical factors that are used to define extraversion.

Reactivity

In general, the reactivity paradigm describes an individual's reactivity to nervous system arousal. Strelau defines reactivity as:

> …a property that determines the intensity (magnitude) of reaction that is characteristic for a given individual and is relatively stable. Reactivity constitutes a dimension that runs from (sensory or emotional) sensitivity at one pole to extreme endurance under strong stimulation at the other (Strelau, 1983: 204).

The definition of reactivity adds little to the other constructs; however, the concept of reactivity has been significantly extended by Strelau's research, who examines arousal and arousability's meaningful affects on temperament and behavior. Strelau's Regulative Theory of Temperament (RTT) model (e.g., Strelau, 1996) describes temperament using six arousal-based traits: briskness, perseverance, sensory sensitivity, emotional reactivity, endurance, and activity. *Briskness* describes the tendency to react quickly. *Perseverance* is the tendency to continue reacting after the stimulus has ended. *Sensory sensitivity* describes an individual's ability to react to low stimulative value sensory stimuli. *Emotional reactivity* describes the intensity of emotional reactions, including emotional sensitivity and emotional endurance. *Endurance* describes reactions to long-lasting or extremely intense stimulation. Finally, *activity* is the tendency to initiate arousal by engaging in behavior that provides stimulation.

> Of special significance in this regulatory process are two temperamental traits—reactivity and activity. They play a significant role in regulating the stimulative value of the surroundings and the person's own action, in accordance with the individual's need of stimulation. Temperamental traits codetermine the individual's style of action, the choice of situations and behaviors of given stimulative value, as well as the psychophysiological costs inherent in performing activity under highly stimulating demands (Strelau, 1996: 131).

Consequently, one of most valuable aspects of this approach is its careful factoring of arousal responses, and its correlation of arousability, temperament, and behavior.

Sensitivity

Aron labels arousability as 'sensory-processing sensitivity,' and defines it as increased nervous-system sensitivity to subtleties:

> And this greater sensitivity and its physiological correlates are found at all levels of the nervous system, from measures of skin conductance, reaction times, and evoked potential (Stelmack, 1990) to subcortical areas (Fischer et al., 1997) to differences in cortical processing (generally more right hemisphere activity, e.g. Berenbaum & Williams, 1994) (Aron, 2004, p. 338).

Aron asserts that highly-sensitive people actually process stimuli more deeply (Aron, 1996). Thus, in addition to a propensity for arousal, highly-sensitive people possess "a talent for retrospective and prospective reflection about consequences" (Aron & Aron, 1997, p.349). The key differences between Aron's work and other arousability approaches are that (a) she more greatly emphasizes the positive aspects of high arousability, and (b) her work tends to focus on developing coping strategies for highly-sensitive (i.e., arousable) adults and children.

Nervous System Strength and Transmarginal Inhibition

Russian psychologists carried out some of the earliest arousal research. They developed the notion that individuals' resilience to intense stimulation varied along a "strength–weakness" dimension (Pavlov, 1955; Rokhin, Pavlov, & Popov, 1963). Pavlov initiated this theory after observing differences in dogs' reactions to extreme stimulation (i.e., pain). Organisms with 'strong' nervous systems are able to endure a greater amount/duration of stimulation as compared to organisms with 'weak' nervous systems. However, once a certain threshold is crossed, arousal-response and stimulation are no longer correlated. Instead, the organism's nervous system shuts down (e.g., becomes fatigued, loses concentration, loses consciousness, etc.), which effectively reduces its arousal. Pavlov labeled this phenomenon 'transmarginal inhibition,' and it is often abbreviated TMI.

Highly arousable people experience TMI sooner than less arousable ones who are exposed to the same supraoptimal stimulation. This suggests that while highly arousable individuals experience greater arousal at low/medium levels of stimulation, they may actually experience lower levels of arousal when very high stimulation occurs (Corr et al., 1995). Hence, this research differs from other work on arousability because of its focus on reactions to over-stimulation.

Stimulus Screening Ability

Mehrabian theorizes that individuals who are not highly arousable must screen-out irrelevant stimuli before they are physiologically affected by it. He believes that these “screeners” apply a hierarchical approach to information processing and focus their attention on higher-priority information, which effectively reduces the perceived complexity of their context. Conversely, he argues, nonscreeners are less able to ignore intrusive stimuli and consequently perceive their environments as more complex and random. This causes nonscreeners to experience more intense spikes in arousal (i.e., arousal amplitude) and less rapid declines to their baseline levels (i.e., duration of habituation; Mehrabian, 1977b). Thus, stimulus screening theory implies that arousability is an individual difference in peoples’ ability to prioritize, and then selectively attend to, distracting stimuli.

Stimulus screening differs from other arousability perspectives because it uses an information-processing perspective and suggests that arousable people are less effective information parsers. Mehrabian’s approach to arousability effectively operationalizes it; however, his tone has been criticized. For instance, Aron suggests that the stimuli that Mehrabian labels ‘irreverent’ should be considered ‘subtitles’ and that these may be quite important:

> The only difficulties are, first, the assumption that low screeners can not filter out what is irrelevant, which seems to imply that there is some means, probably by taking the viewpoint of a high screener, for determining what is relevant. Low

screeners may find all the subtle aspects of a situation very relevant (Aron & Aron, 1997: 360).

Trait Arousability

Mehrabian also developed the theory of trait arousability. Trait arousability describes an individual's emotional and physiological reactivity to novel events (Mehrabian & Ross, 1977; Mehrabian, 1994). It is covarying and complementary to stimulus screening ability (Mehrabian, 1995). In other words, where screening ability is the cognitive process, trait arousability is the emotional/physiological outcome of that process. Mehrabian uses trait arousability as one of the three critical traits that define a person's personality; it is part of his three factor PAD temperament model (e.g., Mehrabian, 1996b), which consists of pleasure-displeasure (P), arousal-nonarousal (A), and dominance-submissiveness (D).

Arousability Constructs: Summary

Consider lessons-learned from across the spectrum of related arousability theories. The augmenting–reducing paradigm suggests that arousal is a subjective reaction to stimuli; hence, the same stimuli may elicit different arousal responses from different individuals. Gray's general arousability approach clearly applies a multidimensional definition of arousal to the study of arousability, and general arousability suggests that the interpretation of stimuli (e.g., as reward or punishment) can affect arousal reactions down to the physiological level. The introversion–extraversion perspective shows that individual differences in arousability influence core personality traits, and that low sociability may be partially caused by high arousability. The reactivity perspective, as extended by Strelau, describes six components in arousal responses: briskness, perseverance, sensory sensitivity, emotional reactivity, endurance, and activity. The sensitivity approach reminds researchers that hypersensitivity is not necessarily a negative phenomenon, and that highly-sensitive people may use their arousability to detect subtleties in the environment. The Russian psychologists' strength–weakness approach to arousability contributes the theory of transmarginal inhibition (TMI), which explains why individuals' nervous systems 'shut down' when they reaches a certain amount of over-stimulation and that highly-arousable individuals have lower thresholds for TMI. Finally, the stimulus-screening and trait arousability approaches help operationalize arousability using the information processing paradigm. These eight conceptualizations each contribute to the overall understanding of individual differences in arousal, and taken together, they effectively define contemporary understanding of arousability.

Effects of Extreme Arousability

Regardless of the name or nuances of the construct, each of the arousability approaches discussed above can be considered to include three broad categories: hypersensitive, hyposensitive, and moderate (i.e., 'normal'). Because hypersensitives are very responsive to stimulation, they are likely to experience chronic over-arousal. Conversely, because hyposensitives are particularly insensitive, they are likely to be chronically under-aroused. In both cases, problems (and sometimes unique benefits) can occur. Below, some commonly studied effects are briefly discussed.

High Arousability and Illness

Selye's (1956) concept of general adaptation syndrome states that "more arousable persons are more likely to evidence physiological imbalances and illnesses in response to environmental stresses" (Mehrabian, 1995: 6). In accordance with this, many arousability researchers' investigations have found greater incidences of physical, psychosomatic, and psychological dysfunctions highly-arousability individuals (Mehrabian, 1995). For instance, Moosman (2002) discovered that highly-arousable therapists are more susceptible to vicarious traumatization (i.e., trauma induced by experiencing their patients' trauma by-proxy). Coren correlates high arousability and sleeping disorders, particularly insomnia (Coren, 1988). Gray (1964) connects high arousability with a greater likelihood of developing PTSD (post-traumatic stress disorder), and Aron links childhood stress, high arousability, and adult manifestations of anxiety, depression, and shyness. She explains: "When sensitive children are raised under stress at home and at school, they are more prone to illness and injury than non-sensitive children; but if raised without undue stress, sensitive children are slightly less prone to illness or injury than the non-sensitive" (Aron, 2004: 352).

The medical literature also reports correlations between arousability and physical illness. For example, several researchers (e.g., Dembroski et al., 1978; Dorado & Fernández, 1997; Furnham, 1984; Lafreniere, 1986) suggest that 'Type-A' behavior—a predictor of health problems such as heart disease—is connected with excessive arousability, and Lambert-Nehr reports a link between susceptibility to migraines and high sensitivity: "It is probable that [their] nervous system is overreactive . . . and responds rapidly to any intense bombardment of the brain by sensory impulses" (Lambert-Nehr, 2003).

Some research finds that highly-arousable people are more likely to suffer from alcoholism, substance abuse, smoking, obesity, and compulsive gambling. After reviewing the literature, Adams (1988) concludes that highly-arousable individuals may attempt to cope with their arousability—and the stressful stimulation it causes—by seeking out mitigations, such as drugs or alcohol.

Finally, in extreme cases, arousability may contribute to mental illnesses like schizophrenia, which is characterized by a lack of focus and high distractibility. Several empirical investigations have verified a correlation between schizophrenia and arousability (e.g., Mehrabian, 1977b; DePalma & Nideffer, 1977). For instance, Dinzeo et. al. (2004) found schizophrenics are more highly arousable than controls, and Ludwig and Stark (1973) suggest that schizophrenia may be caused by chronic sensory overload, which would be facilitated by high arousability.

Overall, it appears that the general adaptation syndrome theory (i.e., that high arousability leads to stress and illness) is supported in a variety of contexts. High arousability appears to contribute to numerous health conditions, from stress-related health problems (e.g., a greater risk of heart disease reported by Mehrabian, 1995) to instances of extreme mental illness (e.g., Dinzeo et. al., 2004). Although anyone who becomes overly stressed can develop these conditions, highly arousable people are predisposed to become overly, negatively stimulated; hence, their higher incidences of physical and mental maladies.

High Arousability and Environmental Preference

Arousability (typically under the stimulus screening paradigm) has been often-studied in the environmental-behavior literature—particularly in the area of workplace design. Many common workplace variables are moderated by the effects of arousability. For instance, Oldham and his colleagues demonstrated that job performance and satisfaction are significantly affected by the interaction of individuals' arousability and the characteristics of the workspace: "Employees exhibited the lowest performance and satisfaction when their jobs were low in complexity, their screening skills were weak, and they worked in dense areas, areas with few enclosures, or close to other employees” (Oldham, Kulik, & Stepina, 1991, p.929). Oldham (1988) has also shown that hypersensitives benefit more greatly than hyposensitives from partitioned or low-density office layouts. Fried (2006) contends that the physical features of the work environment lead to nonspecific arousal, which in turn can lead to many detrimental behaviors, depending upon individuals’ levels of screening ability.

Similarly, Mehrabian (Mehrabian & Russell, 1975; Mehrabian, 1976) asserts that approach-avoidance behaviors to work are moderated by a person’s reactions to and perceptions of an environment. Hines and Mehrabian (1979) applied this theory to workplace design and demonstrated that individuals’ motivation to work was affected their level of arousal (higher arousal limited motivation) and the perceived pleasantness of the environment. Specifically, they found that the pleasantness of an environment interacted with a person’s screening ability, and that this affected individuals’ desire to work. The effect was much more pronounced in hypersensitive individuals.

The basis for these, and many other articles in this vein or research, is that over-stimulation, caused by intrusions and distractions, leads to negative behavioral and affective responses (e.g., Oldham, Kulik, & Stepina, 1991; Maher & von Hippel, 2005). Less-arousable individuals are simply better able to perform in distracting environments (e.g., Belojevic, Jakovljevic & Slepcevic, 2003; Yermolayeva-Tomina, 1964). Consequently, hypersensitive individuals prefer less sensory-stimulating environments (e.g., workplaces that are quieter, include more visual privacy, and so on). Hypersensitives may also *require* these preferred settings in order to achieve optimal performance.

High Arousability and Emotional Sensitivity

Arousability, by definition (assuming the cross-disciplinary definition constructed in this paper), includes increased emotionality. Although, the previous subsections have focused on hypersensitives' increased *negative* sensitivity (e.g., reactions to stress, impact of negative workplaces), highly-arousable individuals are also more sensitive to the positive aspects of emotionality, namely emotional empathy and creativity (e.g., Mehrabian & Epstein, 1972).

Mehrabian & Russell (1974) have demonstrated that emotionally empathic individuals experience higher arousability, and from the other direction, Mehrabian (1977b) demonstrates that highly arousable individuals experience greater affiliative tendency and sensitivity to rejection. Kagan et al. (1999) report that highly-sensitive individuals are also more reflective, and Aron (2004) adds that hypersensitives show evidence of rapid emotional learning. Extending these findings, Kasof (1997) suggests artistic creativity is connected to arousability, since creativity is linked with openness to subtlety and emotional empathy (like high arousability). Aron & Aron's (1997) finding that arousable individuals also have vivid dreams and more active imaginations helps support this assertion (see also Hicks, Fortin, & Brassington, 2002). Aron summarizes:

> …most sensitive persons are highly conscientious in all matters, being aware of the consequences of a lapse in their behaviour. They are often highly creative, intuitive, empathic, and able to grasp non-verbal cues (for example, the intentions of animals, the condition of bodies or plants), appreciative of beauty, and spiritual or philosophical rather than material and hedonistic in their orientation to life (Aron, 2004: 358).

In conclusion, it is important to realize that high arousability includes increased sensitivity to both positive and negative stimuli. Consequently, while highly-sensitive individuals may suffer from information overload, anxiety, or depression their sensitivity may also lead to greater emotional empathy, creativity, and imagination.

High Arousability and Improved Vigilance Performance

Based upon the inverted-U arousal–performance curve, one might expect hypersensitive individuals to perform better at vigilance tasks (since they will be able to maintain higher arousal during the inherently low-stimulation task). However, empirical investigations into this are inconclusive. While some studies support the conclusion (e.g., Rose et al., 2002; Schmidt et al., 2004; see Matthews, 1999, for a supportive review) others reject it (e.g., Bakan, 1959, Bullock and Gilliland, 1993, Davies & Hockey, 1966; Keister & McLaughlin, 1972; see Koelega, 1992, for an unsupportive review). In a meta-analysis, Koelega (1992) found no support for the notion that group differences in arousability (specifically extraversion–introversion) contributed to performance decrement on vigilance tasks. However, Koelega's analytic methods were criticized, so it is unclear what conclusions can be drawn from his work (see Schmidt et al., 2004).

Further, taking into account the complexities of arousal (discussed in the "Unidimensional vs. Multidimensional Arousal" subsection of this report), it seems likely that different circumstances encourage or inhibit the predicted decrement. Schmidt et al. (2004) drive towards this conclusion. Specifically, they explain the inconclusive performance-based results are a function of coping strategies or the neurological central control system. Schmidt et al. call on researchers to look at outcome differences between groups that are not directly connected to performance. For instance, in their specific study, Schmidt et al. successfully used reaction time (RT) measures to differentiate between introverts/extroverts on vigilance tasks:

> The present results can be also interpreted with respect to this control theory of arousal. According to the theory extraverts show larger performance decrements although they invest more effort than introverts in compensating sub-optimal arousal levels. Bearing this in mind, it is interesting to consider the results for different performance parameters. It may be that, even after 40 min of time-on-task, the effort mechanism in extraverts is still effective enough to detect hits, though they cannot compensate their performance decrement in RT. Thus, differential effort and arousal deficits of extraverts may be detected by some more sensitive parameters, even if differential performance deficits do not show up in hits (p. 1344).

In summary, differences between arousability groups can be identified in vigilance tasks to some extent. However, because hyposensitive individuals can mitigate the negative affect of under-arousal (to some extent), direct performance measures may not be sufficiently sensitive to detect the group differences in laboratory conditions. Ultimately, it is unclear whether the differences in vigilance task performance translate to *meaningful* performance differences outside the laboratory setting.

Low Arousability and Stimulus Seeking

According to the optimal level of arousal hypothesis, hyposensitive individuals may attempt to mitigate their chronic low arousal by seeking stimulating environments or activities. In a variety of settings, researchers have found that people with intrinsically low arousal demonstrate stimulus-seeking behaviors. Some stimulus-seeking activities include thrill-seeking, such as attraction to dangerous professions (e.g., military pilot) or participation in extreme sports (e.g., skydiving); engagement in uninhibited behaviors (particularly for men), such as a propensity to drink or engage in alternative sexual behaviors (e.g., Zuckerman, 1971); or stimulus-seeking may manifest in antisocial ways. For instance, a significant quantity of research has investigated the link between low arousability and criminal (e.g. Farley & Farley, 1972) or bullying (e.g., Woods & White, 2005) behavior.

While stimulus-seeking tendencies do correlate with low arousability, Mehrabian cautions researchers not to assume complete correlation. First, anyone (regardless of their trait arousability) can become under-aroused, and consequently, seek stimulation. Second, in addition to low intrinsic arousal, other factors contribute to whether a person engages in stimulus-seeking behaviors and the specific type of behaviors that are preferred (e.g., Mehrabian 1995). Thus, the conclusion is that, heuristically, hyposensitives tend to exhibit stimulus-seeking behaviors; however at a deeper level of analysis, this rule-of-thumb is moderated by several caveats.

Low Arousability and Achievement Task Performance

Hyposensitive individuals tend to excel over hypersensitives in complex, achievement-based tasks (e.g., Eysenck & Levey, 1972). As Mehrabian (1977b) explains: “Achievement situations involve uncertainty and therefore elicit high levels of arousal” (p. 245). “Higher achievers are consequently less aroused while performing high risk (high information rate) tasks and are thus likely to outperform low achievers in these situations when the unpleasant consequences of failure are especially salient” (p. 245), and “higher achievers tend to screen more, which is consistent with their ability to process the higher information rates of achievement tasks” (248). Although, Mehrabian (1977b) notes that degradations in the performance of highly-arousable individuals are only expected if distractions surface during moderately- or highly-complex tasks. This assertion makes sense, given that highly-arousable individuals are predicted to perform equally well (or better) on less stimulating jobs, such as vigilance tasks (discussed above).

From the perspective of a hypersensitive person, Jaeger (2004) explains that highly-arousable individuals can feel overwhelmed and over-stimulated by the pressures of traditional workplaces, and that these feelings may lead to low self-confidence and "a nagging sense of being not cut out for the real world."

Empirically, this has been well demonstrated by Gilliland et al. (1986). In an analysis of the selection criterion for the U.S. Air Force, they reported "Stimulus Screening, Thrill and Adventure Seeking, Neuroticism, Type-A Behavior, and General Intelligence showed the most promising relationships to [U.S. Air Force Criterion Task Set] performance variables" (p.64). Considering that stimulus screening (i.e., arousability), adventure seeking (i.e., sensation-seeking), neuroticism, and Type-A behavior are all highly inter-correlated and based upon general arousability, Gilliland et al.'s work strongly suggests that intelligence and arousability are key individual differences related to achievement in high-performance environments.

Effects of Extreme Arousability: Summary

Arousal, and by extension arousability, represent foundational cognitive functions. As this brief review demonstrates: Numerous outcome differences can be linked to variations in arousability. The research reviewed in this chapter shows that hypersensitive people are at a greater risk to suffer illness, particularly stress-related illnesses. Hypersensitives are more anxious, more neurotic, and more likely to be negatively affected by workplace distractions. Positively, hypersensitives also demonstrate more empathy and creativity, and a greater affiliative tendency. On the other hand, hyposensitives may engage in stimulus-seeking behaviors, which could manifest in many different ways, including a higher likelihood to engage in criminal behavior. Hyposensitives also perform better than hypersensitives in achievement-based environments—where the stress inherent to these settings overwhelms more sensitive people. Table 3 further summarizes the findings included in this section.

Table 3: Summary of Common Arousability Effects

Name	Description	Selected Sources
Stress and Illness	Highly-arousable individuals tend to experience more stress and over-stimulation, as well as the by-products of these states including greater likelihood of developing physical illnesses, psychological disorders, insomnia, and drug/alcohol abuse.	Adams (1988) Aron (2004) Aron, Aron, & Davies (2005) Benham (2006) Coren (1988) Mehrabian (1995) Moosman (2002) Myin-Germeys & van Os (2007)
Workplace Preferences	Highly-arousable people prefer to work in less stimulating places, (e.g., fewer distraction and greater visual privacy). Hypersensitives' performance and motivation degrades when they are exposed to negative workplace conditions.	Fried (2006) Hines and Mehrabian (1979) Maher & von Hippel (2005) Oldham (1988) Oldham, Kulik, & Stepina (1991)
Empathy and Creativity	Hypersensitive people tend to exhibit more empathy and creativity, and more rapid emotional learning than hyposensitive individuals.	Aron, 2004 Kagan et al. (1999) Kasof (1997) Mehrabian (1977b) Mehrabian & Epstein, 1972). Mehrabian & Russell (1974)
Vigilance Task Performance	There are mixed results regarding arousability and vigilance task performance. A logical hypothesis is that while highly-arousable individuals are naturally better able to perform vigilance tasks, less-arousable individuals are nonetheless able to exert sufficient effort to overcome the affects of suboptimal arousal.	Matthews, 1999 Rose et al., 2002 Schmidt et al., 2004 c.f., Davies and Hockey, 1966 c.f., Keister & McLaughlin, 1972 c.f., Koelega, 1992
Stimulus Seeking	Hyposensitive individuals may attempt to mitigate their chronic low arousal by seeking out stimulating environments or activities. These activities could include extreme sports, dangerous professions, or criminal behaviors.	Zuckerman, 1994
Achievement Task Performance	Highly-arousable individuals tend to perform more poorly in achievement-based (i.e., stressful, complex, uncertain) workplaces.	Eysenck & Levey, 1972 Gilliland et al. (1986) Jaeger (2004) Mehrabian (1977b)

CHAPTER FOUR: AROUSAL, AROUSABILITY, AND TRAINING

Significant research has explored the affects of (state) arousal on the learning process. State arousal derives from the interaction of individuals' arousability and the task/environment. Various characterizations of arousal (e.g., unidimensional, emotionality, reward/punishment valenced) have been examined in the context of numerous learning tasks (e.g., classical conditioning, vicarious conditioning, recall) and using animal or human populations. For instance, well-established research on rats suggests that increasing their arousal (via injected hormones) improves their memory retention (e.g., Roozendaal, Carmi, & McGaugh, 1996). In regard to human populations the findings are more complex. For humans, investigators have typically explored the affects of arousal on three cognitive mechanisms related to learning: attention, working memory (WM), and long-term memory (LTM).

Arousal–Attention Relationship

Attention represents a complex cognitive process responsible for "(a) orienting to sensory events; (b) detecting signals for focal (conscious) processing, and (c) maintaining a vigilant or alert state" (Posner & Peterson, 1990: 26). Attention can be focused consciously or unconsciously, and an executive control mechanism resolves conflicting demands on attention allocation and response tendencies (Posner & Peterson, 1990).

The first relationship between arousal and attention is straightforward: Arousing stimuli garner more attention. People spend more time looking at arousing stimuli (e.g., Lang et al., 1993), and arousing stimuli produce more cortical activity (e.g., Bradley et al., 2003). Arousing stimuli are also distracting. A considerable number of investigations demonstrate that arousing, non-task stimuli interfere with primary tasks and compete for attentional resources (Anderson, 2005; Schimmack & Derryberry, 2005; MacKay et al. 2004; Gronau et al., 2003, Buodo et al., 2002; Pratto & John, 1991). Many of these studies presented participants with simple tasks (e.g., math problems or basic reaction-time measures) while displaying arousing or neutral photographs in the periphery. Then, these investigators measured the interference effects of the imagery. Other studies used the Emotional Stroop task, in which participants are shown two color-coded words. Each word is presented for 100ms, one after another. Typically, participants are unable to report the second word if it is presented 200-500ms after the first; however, Anderson (2005) demonstrated that if the second word was inherently arousing, then participants were more likely to encode it. Further, Anderson found that this effect was related to the arousal-level—and not the emotional valence—of the word.

The second relationship to consider is how attentional resources are affected by a person's arousal state. In general, it appears that attentional capacity and arousal form an inverted-U relationship, where moderate arousal leads to the greatest attentional capacity (Kahneman, 1973; Mandler, 1975). Both sustained and selective attention are affected by a person's arousal state (Das et al., 1994), and under both high and low arousal conditions, attentional capacity is attenuated.

In high-arousal states, a person's autonomic nervous system activity increases. Mandler (1975) suggests that this increase in internal feedback interferes with external cues and competes for limited attentional resources. Thus, when individuals experience supraoptimal arousal states, their attention narrows and becomes more selective (Easterbrook, 1959). In other words, a highly-aroused system focuses more on dominant sources than does a less-aroused system (Broadbent, 1971). This is often demonstrated using a dual-task paradigm. Participants are asked to perform two simultaneous tasks, but when their arousal becomes too great they begin to ignore the secondary task, which is called “task shedding” (Tsang & Wilson, 1997). When this occurs, performance on the secondary tasks, naturally, deteriorates; performance on the primary task may remain constant or even improve (Humphreys and Revelle 1984; Anderson and Revelle 1982; Eysenck 1982). However, performance on the primary task will eventually deteriorate if unavailable attentional resources are required.

Low-arousal states, per se, receive less academic attention. Partially, it is difficult to induce low arousal directly, since active tasks (such as experimental procedures) inherently contain some arousing stimuli. One approach is to use sleep deprivation. Similar to sustained vigilance tasks, low arousal induced by sleep depravation decrements performance; however, attentional lapses can be mitigated by internal control. For instance, Drummond and his colleagues asked participants to perform arithmetic and verbal learning tasks, with or without total sleep deprivation. Although sleep deprivation only modestly inhibited performance, functional magnetic resonance imaging (fMRI) revealed significantly more cognitive activation under the sleep deprivation condition. In other words, participants used many more cognitive resources to maintain sufficient attention while under the low-arousal, sleep-deprivation state (Drummond, Gillin & Brown, 2001). This is consistent with colloquial and subjective reports that maintaining attention while experiencing suboptimal arousal requires significant “mental effort” (e.g., Kahneman, 1973). However, individuals experiencing low arousal (from sleep deprivation) can only sustain their mental effort for a time. Eventually, their performance will become unstable as lapses in cognitive function occur. This describes the “state instability” hypothesis, which suggests that sleep deprivation hinders performance because sleep-initiating mechanisms compete for attentional capacity, consequently impacting mood, cognitive performance, and motor function (Doran, Van Dongen, Dinges, 2001).

Another way to conceptualize low arousal is as boredom (Mikulas & Vodanovich, 1993). Specifically, boredom is a state of low arousal combined with dissatisfaction. Sustaining attention while experiencing boredom requires individuals to exert "effort" (O'Hanlon, 1981). However, as with the sleep deprivation studies, sustained attention under boring conditions can only be maintained for a time. The higher "cost of attention" (Portas et al., 1998) eventually induces mental fatigue and drowsiness (Babkoff et al., 1991), which inevitably impact performance.

Arousal–WM Relationship

Working memory (WM) is where incoming information is temporarily stored and manipulated before it passes to long-term memory (or else is forgotten). WM suffers from two major limitations: capacity and duration. Its capacity, initially defined by Miller's (1956) classic article, is around seven items, and without rehearsal WM's duration is only about 20-seconds long (Peterson & Peterson, 1959). However, as individuals develop expertise, they "chunk" bits of information together to form cognitive schema, which are stored in long-term memory. Cognitive schema essentially act as a central executive for WM and make its limitations irrelevant (Sweller, 2005). Thus, with greater levels of understanding, the processing demands of WM reduce.

Arousal affects WM in predictable ways. First, high arousal diminishes WM's capabilities, most likely because the cognitive activation caused by high arousal places an increased processing load on WM (Lupien, Gillin, & Hauger, 1999). The implication of this is that any information processing that requires the use of WM becomes disrupted under supraoptimal arousal conditions (Berlyne, 1960; Zajonc, 1965). “Automatic” tasks (i.e., tasks in which a person has expertise) do not require WM processing, and are consequently not significantly hindered by high arousal (Hasher & Zacks, 1979; Humphreys and Revelle; 1984). Almost by definition, individuals engaged in training are non-experts; thus, high-arousal levels significantly impact training effectiveness by reducing trainees’ abilities to transform the incoming information into relevant knowledge structures.

In low-arousal situations, WM may also be impaired. As discussed in the previous subsection; low-arousal conditions require individuals to exert greater mental effort in order to maintain average performance. This mental effort interferes with attentional resources, and it also places demands on WM processing. More specifically, neurological studies have demonstrated that both inherent low arousal, and low arousal caused by sustained attention, lead to activation of the thalamus, which in turn, intrudes on WM capabilities (Barch et al., 1997; Callicott et al., 1999; Manoach et al., 2003; Kinomura et al., 1996; Coull, 1998) .

Arousal–LTM Relationship

Arousal’s influence on memory encoding

Encoding is the act of creating new memories in long-term memory (LTM); it is sensitive to arousal affects both during, and immediately after, the encoding process. Significant quantities of research continue to support the notion that emotionally-charged (positive or negative) events are remembered longer than emotionally-neutral ones (e.g., McGaugh, 2000; Safer et al., 1998; Cahill, 2000; Schafe et al., 2001; McGaugh & Roozendaal, 2002; Bradley et al., 2002). This finding makes logical sense and is supported theoretically. Specifically, the *action decrement* *theory* (Walker, 1958) suggests that high-arousal situations induce (a) longer-lasting memories but (b) also initially produce greater inhibition of retrieval (see Eysenck, 1976, for a review and explanation of the neurophysiological basis of this theory). Consequently, low-arousal stimuli are better retained for short retention periods (15-20 minutes) while high-arousal stimuli are better retained for longer periods.

Numerous investigations have explored this theory with mixed results. In an attempt to clarify the findings, Schwartz (1975) reexamined the results and differentiated *verbatim* (e.g., the position of a word on a word list) versus *semantic* (e.g., the meaning of a word from a list) recall. He reports that high-arousal may facilitate long-term verbatim recall, but that it inhibits long-term semantic recall. Eysenck (1976) further adds that "at short retention intervals, high arousal may facilitate the retrieval of responses but hinder the retrieval of appropriate associative links. The hypothesis that high levels of arousal may have an enhancing effect on retention at short retention intervals, provided that subjects do not have to retrieve associative links, is further supported by those studies of short-term recognition memory already discussed in which high arousal led to superior recognition performance" (p. 393).

Although the above-cited studies are decades old, contemporary research has continued to support (and argue about) the action decrement theory and its moderators. For instance, Steidl, Mohi-uddin, & Anderson (2006) recently evaluated the affects of arousal during learning tasks, and found that for procedural tasks higher arousal during encoding (a) impairs initial acquisition, (b) has no effect on medium-term recall (i.e., one-week later), and yet (c) enhances long-term recall (i.e., 3-months later). However, these findings only hold true for dominant information or "easy" learning tasks. Complex (i.e., semantic) learning remains inhibited by high arousal.

Another case where arousal may affect memory is when arousal is induced *after* a learning event. If an extremely strong, *negative* emotional experience (i.e., stressful arousal) is created, it may impair the retrieval of information unrelated to the arousing event, producing retrograde amnesia (e.g., Loftus & Burns, 1982; Kirschbaum et al., 1996; de Quervain et al., 1998; Wolf et al., 2001; Payne et al., 2002). In the context of learning this implies that if a stressful educational event follows some other educational event, then the learning that transpired during the first event may be "overwritten" by memories created in the second. For example, Diamond et al. (1996) show this empirically. Diamond and his colleagues trained rats to find their food in a maze, and immediately following this, trained the rats to perform a water-maze task. After the rats learned the water-maze, their original spatial memory of their food's location was significantly impaired. However, this effect only occurred if the rats were naïve to immersion in water; after the rats became accustomed to water exposure, training in the water-maze no longer interfered with their original spatial memories. Thus, the stressful (i.e., high arousal) nature of the second learning experience caused the rats to "forget" some of their recently-encoded memories. Diamond et al. suggest that this phenomenon helps the memory processing center of the brain (i.e., the hippocampus) "reset" in order to focus on the new information being experienced.

Arousal's influence on memory recall

Arousal experienced at the time of recall can influence how effectively memories are accessed. Consider the tip-of-the-tongue phenomenon where specific information is unreachable when a person is highly motivated to access it; yet, as soon as he/she abandons the recall attempt, the information appears (Schacter, 2001). Or consider how frequently individuals report retrieval failures when experiencing the supraoptimal arousal caused by test anxiety (Eysenck, 1976).

Like memory encoding, semantic memory (versus verbatim memory) recall appears most affected by supraoptimal arousal. While high levels of arousal may actually facilitate high-dominance recall (i.e., verbatim recall), high arousal inhibits low-dominance recall (i.e., secondary or semantic recall) (Eysenck, 1976; 1975; 1974). Thus, at short retention intervals, high arousal facilitates recognition (Archer & Margolin, 1970; Schwarz, 1974; Wesner, 1972) and free recall (Corteen, 1969; Kaplan, Kaplan, & Sampson, 1968; Maltzman et al., 1966; Sampson, 1969; Schönpflug & Beike, 1964; Schwartz, 1975), but it inhibits deeper learning (Howarth & H. Eysenck, 1968; Kleinsmith & Kaplan, 1963, 1964; McLean, 1969; Osborne, 1972). For example, Eysenck (1976) demonstrated that high arousal inhibits search processes, causing participants to focus only on the most readily-accessible sources of information. Downstream, this not only leads to reduced recall of semantic memories, but also affects complex processes that require "deep" information, such as decision-making or creative problem solving.

Supraoptimal arousal induced sometime before a recall task may also affect retrieval. For instance, de Quervain et al. (1998) found that the rats' performance in a water maze became impaired if they were subjected to stress (i.e., a foot shock) 30 minutes before testing. However, the rats' performance was not impaired if the stress was induced two minutes, or four hours, before the test.

Arousal and Learning Summary

Following the inverted-U pattern, it appears that moderate arousal (created via the interaction of external stimuli and a person's internal state) is most ideal for most training settings. Under supraoptimal arousal conditions, individuals' attention narrows, their ability to process incoming information is inhibited, and their depth of processing is reduced (Eysenck, 1976). During acquisition, high arousal focuses individuals' attention on physical characteristics of the presented information (i.e., dominant and verbatim processing), causing semantic and peripheral information to be ignored. Consequently, memories associated with high-arousal situations may be strongly remembered, for a long duration; however, these memories are often less accurate, include far fewer contextual details, and may even become confused with other memories (e.g., Schmolck, Buffalo, & Squire, 2000; Christianson & Loftus, 1991; Kensinger, Piguet, Krendl, Corkin, 2005). During recall, individuals experiencing high arousal are more likely to access "easy" information (i.e., readily accessible stored information). Thus, limiting their recall of deeper (e.g., unusual or semantic) information, and inhibiting their problem-solving capabilities. Under suboptimal arousal conditions, individuals must exert "mental effort" to sustain their attention. This eventually leads to performance decrements both because sleep-inducing mechanisms compete for attentional resources and because thalamic activation caused by the mental effort uses some of WM's capacity. Consequently, optimum cognitive functioning, which should lead to the most favorable training conditions, occurs when individuals are only moderately aroused. Arousal and its relationship to training effectiveness appears to form the classic, inverted-U relationship.

CHAPTER FIVE: HYPOTHESES AND METHODS

As discussed in Chapter 2, contemporary and future adaptive training systems are likely to be computer-based and incorporate both models of behavior/cognitive states and performance data. Thus far, adaptive multimedia systems have failed to account for individual differences *a priori*. At best, individual differences are indirectly "teased out" based upon observed performance measures, or in rare cases they are inferred from measures of neuro-physiology. Is it possible that ignoring the influence of individual differences contributes to the attenuation of performance observed with contemporary intelligent/adaptive training systems? It seems plausible that using individual difference information to (a) form individual baselines and (b) inform system responses (so that they interpret and respond to observable data more appropriately) will lead to improved system performance.

Before this notion can be tested, though, system designers need a reliable way to measure arousability. Currently, the measurement of this arousability is confusing. As the last chapter demonstrated, the arousability construct has been identified in many different social-science areas, under a number of different monikers, and using many diverse measurement approaches. It remains unclear if the construct is unidimensional or multidimensional, and if it is multidimensional which factors it includes. Further, it is unclear which measurement device(s) is(are) best suited to this application. This drives the need to first examine existing measures of arousability more closely. By looking across constructs and measures, a more robust, better factored apparatus may be created. Thus:

> *Hypothesis 1:* By factor analyzing existing measures of arousability a more reliable, more valid apparatus can be created. This apparatus will also help clarify

the factor structure of arousability, which will make it more suitable for use in applied training systems.

Based upon the literature review found in previous chapters, it is clear that a person's inherent arousability, combined with task demands, generates his/her arousal state. It is also plain that arousal states significantly affect individuals' cognitive functioning, including their receptivity for training. Consequently, optimum training occurs when trainees experience the most favorable (i.e., median) arousal states; however, if all trainees experience the same tasks demands, but they have different inherent arousal levels, then some of the population must experience nonoptimal arousal.

In regard to multimedia (including simulation-based) training, supraoptimal arousal is more likely to be an issue than suboptimal arousal, because of the inherently high-information design of most multimedia systems. As the last chapter outlined, supraoptimal arousal leads to narrowed attention, limited working memory capacity, and a focus on verbatim (rather than semantic) information. In short, supraoptimal arousal limits individuals' depth of processing. In the context of training, this most likely means that highly-arousable individuals will appear to learn training material, but have a shallower understanding of it than less-arousable individuals. For instance, consider a situation where people undergo a training exercise, such as military warfighters learning new operations. Following the training, individuals' understanding will most likely be tested using standardized exams, structured field exercises, or other measures of verbatim (i.e., recall, procedural, or rules-base) knowledge. Thus, individuals across all arousability-levels will likely pass these evaluations, and under normal field conditions, all trainees are likely to maintain sufficient performance. However, when field conditions change and the trainees are forced to make difficult decisions or exercise creative problems solving, then highly-arousable individuals' deficiency of understanding will become clear. Consequently, this leads to the second hypothesis:

> *Hypothesis 2:* Highly-arousable individuals will demonstrate poorer semantic understanding of (highly-arousing) multimedia-based training, as compared to less-arousable individuals. However, all participants will likely show equal verbatim understanding of the training.

Two studies will be conducted to test the above hypotheses. First, existing survey-based measures of arousability will be researched and comparatively analyzed, and a factor analysis across relevant existing measures will be conducted. Second, the measurement device developed from the first study will be used to test the second hypothesis in an experimental training setting.

CHAPTER SIX: ANALYSIS OF EXISTING MEASURES (STUDY 1)

Subjective Measures of Arousability

Individual differences in arousability have been theorized for as long as arousal has been studied (Mehrabian, 1977b); however, measuring trait arousal initially proved challenging because most methods were unable to separate confounding state variables. Early measures of general (state) arousal used physiological (e.g., galvanic skin response) measures, but as Mehrabian (1977) points out, these techniques lacked widespread support and were cumbersome to use. Fortunately, subjective measures of arousal are quite effective. [Although today's physiological measures have advanced and are often used in the service of arousal-related research, a discussion of these methods is outside the scope of this report.] In fact, Thayer (1989) has argued that subjective estimates of energetic arousal are the most likely to be associated with performance—more so than even psycho-physiological measures.

In 1967, Thayer developed the Activation Deactivation-Adjective Check List (AD-ACL), a verbal-response measure of (state) arousal that correlated with the then-current physiological measures (Thayer, 1967; see also Thayer, 1989). This was one of the first self-report, survey-based measures of arousal. Shortly thereafter, Mehrabian and Russell began developing a subjective measure of (trait) arousability.

Mehrabian's Trait Arousability Scale

Mehrabian and Russell (Mehrabian & Russell 1973; Mehrabian, 1977a) first created an apparatus to detect individual differences in stimulus screening ability (i.e., the ability to screen-out low priority stimuli, which is the direct opposite of high trait arousability). The Stimulus Screening Questionnaire (SSQ) is a 40-item, 9-point scale that measures individual differences in the degree of screening-out irrelevant stimuli in the environment. Individual's scores are summed across all items, and scores above 25 indicate high screening ability (i.e., low trait arousability). Items in the scale are all highly inter-correlated, even though they describe several different aspects of stimulus sensitive (e.g., thermal screening, arousability to novel settings, habituation rate). The Kuder–Richardson (1937) reliability coefficient for this scale is 0.92 (Mehrabian, 1977a).

As Mehrabian's research progressed, he incorporated trait arousability into his Pleasantness-Arousability-Dominance (PAD) temperament model of personality, and he refined and transformed the SSQ measure into the Trait Arousability Scale (TAS) (Mehrabian, 1996a, 1996b). The current TAS is a completely reworked version of the original SSQ. (But since stimulus screening ability is the direct opposite of trait arousability, the scale still measures both constructs.)

The full-length TAS is a reliable 34-item, 9-point survey ($\alpha = .90$; Mehrabian, 1995). It incorporates both positively- and negatively-worded statements, which controls for response bias (i.e., where some individuals to tend to agree, or disagree, with all statements). To calculate an individual's score, the negative statements are recoded, and then all the responses are summed. The norm mean score on the survey is 30, with a standard deviation of 33. However, statistically-significant sex differences do exist: As a whole, women tend to exhibit greater arousability ($m = 43$; $\sigma = 32$) than men ($m = 18$; $\sigma = 34$) (Mehrabian, 1994).

Both the SSQ and the TAS have been well-received by academic investigators. These measures have been used in the service of diverse research, including predicting job performance (e.g., Gilliland, Schlegel, & Dannels, 1986; Mehrabian, 1977b), investigating workplace design (e.g., Fried, 2006; Oldham, Kulik, & Stepina, 1991; Oldham, 1988; Hines & Mehrabian, 1979), predicting fear responses (e.g., Sparks, 1989), understanding eating disorders (e.g., Craig, Hollis, & Dess, 2003; Mehrabian & Riccioni, 1986) and analyzing mental illnesses (e.g., Dinzeo et. al., 2004; Mehrabian, 1977b; DePalma & Nideffer, 1977).

The TAS is protected by copyright and can be purchased for a small fee from Mehrabian, directly. His web site, including ordering information, is located www.kaaj.com/psych.

Vando's Reducer–Augmenter Scale

Vando developed the Reducer–Augmenter Scale (RAS) to study sensory stimulation in the context of pain tolerance (Vando, 1969, 1974). The RAS correlates moderately with other measures of arousability, such as extraversion (Dragutinovich, 1987a, 1987b; Kohn et al., 1987; Kohn, Hunt, Cowles & Davis, 1986), strength of the nervous system (Dragutinovich, 1987a, 1987b; Kohn et al., 1987), and sensation-seeking (Dragutinovich, 1987a, 1987b; Kohn et al., 1987). More recently, Clapper (1990) revised the RAS and named the updated version the Revised Reducer–Augmenter Scale (RRAS; $\alpha = 0.79$). The RRAS adds a six-pointed scale and includes updated wording for some items.

The RAS (or RRAS) has been criticized because it assumes that arousability is inherently linked with stimulus seeking tendencies (Kohn, 1987.) More specifically, the scale is worded in such a way that agreement with high sensation-seeking items is always scored as a reducing response and vice versa. As Kohn asserts, "the RAS is an alternative measure of sensation seeking" (p. 237).

Kohn further argues that the RAS includes a puzzling factor structure, consisting of three partially-correlated scales interpreted as Musical Augmenting–Reducing, General Life-style Augmenting–Reducing, and Physical Thrill Seeking. Due to these problems with the RAS, "notably its built-in sensation-seeking content and its overrepresentation of content parochially relevant to music" (Kohn, 1987: 238), it has not become a highly-used measure. However, the reducer–augmenter paradigm (presented in the previous chapter) has been accepted in a variety of fields.

Kohn's Reactivity Scale

The Kohn's (1985) Reactivity Scale (RS) consists of 24 items (α = .73 to .83) that assess an individual's level of 'reactivity' or central nervous system arousability. It uses a 5-point Likert format. The RS has been mainly used to determine individual differences in response to pain (e.g., Fillingim et al., 2005; Edwards & Fillingim, 1999; Dubreuil & Kohn, 1986), and as one might expect, high scores on the RS (i.e., high arousability) correlate negatively with pain tolerance (Dubreuil & Kohn, 1986). The RS has been used in studies of hypervigilance (e.g., Ness et al., 2005; McDermid et al., 1996), with which it is also correlated. However, even the hypervigilance studies have been conducted within the larger context of pain and medical research. Outside of these fields, the RS has received very little attention, most likely because the RS fails to add value beyond the use of already-established measures (such as the TAS and HSP). The RS is available to researchers in Kohn (1985).

Satow's Environmental Stimulus Screening scale

Satow (1987) created a 60-item questionnaire that divides sensitivity to stimuli into four categories: lower sensory threshold, more rapid perception of a stimulus, and lower tolerance for intense or prolonged stimulation. The development of this apparatus followed Satow's theory of stimulus preference, which outline four preferences-types across a continuum, ranging from high threshold for stimulation but poor perception of subtly, to low threshold for stimulation but high perception of subtly. While Satow reports that the total ESS accounts for 15-18% of total variance observed, its factor structure remains questionable. Each orthogonal factor accounted for less than 2-4% of the variance, which is generally considered statistically insignificant. Additionally, Satow appears to create the factors somewhat pell-mell, rather than using theoretically-sound rationale.

Most likely because its psychometric failings, the ESS has not been highly used by other researchers. Satow and her colleagues have used the scale in the research of pain sensitivity, though (e.g., Satow & Taniguchi, 1989). The ESS is freely available to researchers, and can be found in Satow (1987).

Coren's Arousal Predisposition Scale

Coren's (1988) Arousal Predisposition Scale (APS) was originally designed to predict individuals' likelihood to experience disrupted sleep, based upon the theory that some instances of insomnia stem from cognitive hyper-arousal. The APS is a 12-item, five-point questionnaire. It has reasonably high internal consistency (α = .83) and moderate correlations with various indicators of sleep difficulty, such as restlessness and delayed sleep onset. Overall, the APS accounts for about 20% of the predicative variance of sleep difficulty (Coren, 1988). Also, like the TAS, APS results are moderated by sex, with women tending to be more highly arousable (Deane, Henderson, Mahar, & Saliba, 1998).

Since its inception, investigators have used the APS to successfully measure individual differences in arousability (e.g., Coren & Mah, 1993; Dorado & Fernández, 1997), as well as predict differences in cognitive performance while being distracted (e.g., Coren & Aks, 1991), antisocial behavior (e.g., Coren, 1999; Woods & White, 2004), and impulse aggression (e.g., Houston & Stanford, 2001). Primarily, the APS has been most utilized in the sleep disorders and antisocial behavior literatures. However, the scale has yet to achieve real prominence, and as a whole researchers seem reluctant to use of the APS for arousability studies. Deane et al. (1998) suggest that the scale has not been sufficiently empirically validated, and that this lack discourages researchers from using it (see also Roy & Viveiros, 2003). The APS is available for researchers and can be found in Coren (1988).

Aron and Aron's Highly Sensitive Person scale

Aron and Aron's (1997) Highly Sensitive Person (HSP) survey is a 27-item, 7-point questionnaire that measures individuals' sensitivity to subtle stimuli and their ability to become distracted. Reliability measures of the scale are between $\alpha = .85$ and $\alpha = .87$ (Aron & Aron, 1997). The HSP scale includes items related to sensory over-stimulation, nervousness in social settings, and response to distractions; however, like the TAS and SSQ, the HSP appears to be a unidimensional measure despite its diversity of items. All items on the HSP are positively worded, and individuals' scores are calculated by finding the mean of their responses. Norm mean scores are around 4.38, with standard deviations of around 0.74. Unlike the TAS, sex and gender differences do not significantly impact the HSP scoring (Aron & Aron, 1997).

The HSP scale has been used in several areas of research, including Aron and Aron's own investigations into introversion and shyness (e.g., Aron, Aron, & Davies, 2005; Aron, 2004a; Aron & Aron, 1997), highly-sensitive people and love (e.g., Aron, 2004b; Aron, 2001), and highly-sensitive children (e.g., Aron, 2002). Other researchers have built-upon the Aron's research and explored high-sensitivity and work (e.g., Jaeger, 2004), gifted children (e.g., Mendaglio, 2003; Fornia & Frame, 2001), social anxiety (e.g., Hofmann & Bitran, 2007), eating disorders (e.g., Shapiro, 2006), and anxiety and stress (e.g., Benham, 2006; Shapiro, 2005).

The HSP survey is freely available for researchers. The Arons present an abbreviated version of the scale on their web site (www.hsperson.com), and the complete survey can be found in Aron and Aron (1997), as well as a reprint in Aron (2006).

Some Related Measures

The following measures are each partially related to arousability and, to some extent, can be used to assess it. They are provided here as examples of related constructs and measurement approaches but are not recommended for the sole evaluation of trait arousability.

Arousal Seeking (or Avoidance)

Measures of arousal seeking/avoidance have been used to measure trait arousability. Based upon the theory of optimal arousal, individuals who are easily over-aroused (i.e., high arousability) should display arousal-avoidance behaviors, while individuals who are perpetually under-aroused (i.e., low arousability) should display stimulus-seeking behaviors. Thus, measures of stimulus-seeking should be able to identify high and low arousability. Several arousal-seeking questionnaires exist, including Zuckerman's Sensation Seeking Scale (Zuckerman et al., 1978; Zuckerman, 1994), Mehrabian's Arousal Seeking Tendency (Mehrabian & Russell, 1973; Mehrabian, 1978), Pearson's (1970) Novelty Experiencing Scale, the Arnett Inventory of Sensation Seeking (Arnett, 1994), Change Seeker Index (Garlington & Shimota, 1964), and the Brief Sensation Seeking Scale (Hoyle et al., 2002). Components of other popular measures sometimes also include arousal-seeking scales, such as the impulsive sensation seeking subscale from the Zuckerman–Kuhlman Personality Questionnaire (Zuckerman et al., 1993), the novelty seeking subscale from Cloninger's (1987) factor-7 model, or the arousal avoidance subscale of the Telic-Dominance Scale (Morgatroyd et al., 1978).

Zuckerman and his colleagues' work has been highly influential in the science of sensation seeking. They developed the Sensation Seeking Scale (Zuckerman et al., 1978; Zuckerman, 1994), an extensively-used device now in its fifth iteration (SSS-V). The SSS-V (α = 0.83 to 0.86) includes 40-items in forced-choice format. In addition to producing a general sensation-seeking score, the SSS-V includes four subscales: thrill and adventure seeking, experience seeking, disinhibition, and boredom susceptibility. Stimulus seeking tendencies are linked to many outcomes, such as extraversion, psychopathy, need for change, and hypomania (Zuckerman, 1972). The SSS-V is freely available to researchers from Zuckerman (1994).

However, as mentioned in the previous chapter, sensation seeking and arousability are not correlated one-hundred percent. Other factors influence an individual's sensation-seeking tendency, and it not appropriate to assume that all sensation-seekers (or avoiders) have low (or high) arousability.

Distractibility and Attentional Style

Siddle and Mangan (1971) showed that distractibility was correlated with initial amplitude of the orienting response, slower speed of habituation, and neuroticism. Consequently, self-report measures of distractibility (a key characteristic of high arousability) could also be used to study arousability. Many different measures of distractibility exist; for instance, Weinstein (1978) developed the noise sensitivity survey; Bowsher, Johnson, and Robinson (1966) developed a scale to measure intrusion; and Aks (1988) created a measure of perceived distractibility. (Later Aks contributed to the Arousal Predisposition Scale; Paulhus, Aks, & Coren, 1990.)

Similarly, measures of attentional style could be employed to assess arousability, such as the Tellegen Absorption Scale (TAS; Tellegen, 1982; Tellegen & Atkinson, 1974); the Differential Attentional Processes Inventory (DAPI; Yanchar, 1983; Crawford et al., 1993), and the Test of Attentional and Interpersonal Style (TAIS; Nideffer, 1976).

The Tellegen Absorption Scale (α = .88) consists of 34 true/false statements about individuals' involvement in activities, and it is included as one of the 11 subscales of the Multidimensional Personality Questionnaire (Tellegen, 1982). The Differential Attentional Processes Inventory (α = 0.88, Yanchar, 1983) is comprised of 40 items related to focused attention, split-attention, and distractibility; it includes four subscales: moderately focused attention, extremely focused attention, dual attention cognitive-physical, and dual attention cognitive-physical.

Nideffer's (1976) Test of Attentional and Interpersonal Style (TAIS) assesses attention and arousal, and their direct relationships with performance. The TAIS consists of 144 items broken into 17 subscales, including measures of internal and external overload. The median correlation within and across scales is .53 (Nideffer, 1976). Although, some have questioned the sensitivity or factor analytical methods of the TAIS (e.g., Van Schoyck & Grasha, 1981; Vallerand, 1983), it has shown predictive validity for describing athletes behaviors (e.g., 'choking' or finding the 'zone') while under pressure (e.g., Nideffer, 1976). However, the TAIS is very broad, and includes many factors unrelated to arousability (e.g., self-esteem, intellectual expression, physical orientation, and so on). Also, since it was developed for athletes, its immediate usefulness seems primarily confined to sports psychology (e.g., Abernethy, Summers,

& Ford, 1998), although Enhanced Performance Systems who market and distribute the TAIS, claim it has been successfully used business, military, and education as well (see EPSystemsCanada, 2008).

Personality

Some personality measures include subscales related to arousability. Notably, these measures include the strength of excitation subscale of the Strelau (1972) Temperament Inventory, the extraversion subscale from either the Eysenck Personality Inventory (EPI-E; Eysenck & Eysenck, 1968) or the Eysenck Personality Questionnaire (EPQ-E; Eysenck & Eysenck, 1975), Mehrabian (1978) Pavlovian Temperament Survey (PTS), Mehrabian PAD temperament inventory, Cloninger's (1987) factor-7 model, the Adult Temperament Questionnaire (ATQ Evans & Rothbart, 2007),

However, some of these alternative measures are poor arousability analyses. First, the temperament scales' focus is broader than arousal, and individual subscales may not be validated to 'stand on their own.' Additionally, concerns have been raised about individual subscales. For instance, Strelau's inventory suffers from questionable validity, and specific studies related to arousability have failed to statistically support relationships between measures of arousal and scores on the inventory (Kohn, 1987; e.g., Carlier, 1985; Gilliland, 1985; and Strelau & Terelak, 1974). As another example, the Eysenck measures split extraversion into two components: impulsivity and sociability; however, as discussed in previous chapters, it is unclear whether arousability is adequately correlated with sociability.

Trait Anxiety

Measures of trait anxiety may seem like viable apparatus for analyzing trait arousability. Certainly, arousable individuals often exhibit persistently high anxiety, and conversely, patients who suffer from pathological anxiety typically complain that stimulation causes tension (Cameron, 1944). Anxiety is a disease of over-arousal (Malmo, 1957). People who are predisposed toward hyper-reactivity may more easily suffer from pathological anxiety; however, anyone (regardless of their arousability characteristics) has the capacity to become over-stimulated, and thus suffer from anxiety.

Consequently, there is a partial correlation between trait arousability and *trait anxiety* (Spielberger, Gorsuch, & Lushene, 1970). Lafreniere and her colleagues (1993) suggest that the interaction between arousability and telic-dominance interact to create trait anxiety; thus, while it is likely that trait arousability and trait anxiety are related and often observed together, measures of trait anxiety are not completely predictive of arousability (and vice versa).

Subjective Measures of Arousability: Summary

Many different self-response apparatus exist to measure trait arousability. It appears that the most suitable questionnaires are the Trait Arousability Scale (TAS; Mehrabian, 1995) and the Highly Sensitive Person scale (HSP; Aron & Aron, 1997). Some scales, such as the Environmental Sensory Stimuli questionnaire (Satow, 1986) or the Arousal Predisposition Scale (APS; Coren, 1988) fall a little short, psychometrically. Meanwhile, other validated measures, such as the Sensation Seeking Scale (Zuckerman, 1994), only partially assess the arousability construct. Table 4 summarizes the most useful primary and partially-related self-response measures of arousability.

Table 4: Summary of Arousability Questionnaires (Alphabetical)*

Scale	Description	Reliability	Availability
Arousal Predisposition Scale (APS)	12-item, 5-point scale that measures individuals' trait cognitive arousal	α = .83	Freely available from Coren (1988)
Arousal Seeking Tendency (AST-II)	32-item, 9-point scale that measures individuals' preferred arousal level	α = .93	Mehrabian (1978; AST-II)
Brief Sensation Seeking Scale (BSSS)	10-item, 5-point scale that was derived from the SSS-V; it is suitable for use with adolescents	α = .74	Freely available from Hoyle et al. (2002)
Change Seeker Index (CSI)	95-item, true/false style scale that measures individuals' need for variation stimulus inputs	α = .80 to .85	Garlington & Shimota (1964)
Differential Attentional Processes Inventory (DAPI)	40-item, 7-point scale that measures moderately focused attention, extremely focused attention, dual attention cognitive-physical, and dual attention cognitive-physical.	α = .88	Yanchar (1983) Crawford et al. (1993)
Environmental Sensory Stimuli scale	60-item, 7-point scale that measures sensory threshold, rapidity of perception, and tolerance for intense or prolonged stimulation	Not given	Freely available from Satow (1986)
Highly Sensitive Person (HSP)	27-item, 7-point scale that measures individuals' sensitivity to subtle stimuli and their ability to become distracted	α = .85 to .87	Freely available from Aron & Aron (1997); reprinted in Aron (2006)
Novelty Experiencing Scale (NES)	80-item, like/dislike-response scale that measures assesses a approach-avoidance to novel experiences	α = .87	Pearson (1970)
Reactivity Scale (RS)	24-item, 5-point scale that measures individuals' central nervous system arousability	α = .73 to .83	Freely available from Kohn (1985)

Revised Reducer–Augmenter Scale (RRAS)	34-item, forced-choice style scale that measures sensory stimulation in the context of pain tolerance	α = .79	Clapper (1990) (Original form from Vando, 1969, 1974)
Sensation Seeking Scale (SSS-V)	40-item, forced choice style scale that measures individual’s need for varied, novel, and complex sensations	α = .83 to .86	Freely available from Zuckerman (1994)
Stimulus Screening Questionnaire (SSQ)	40-item, 9-point scale that measures individuals’ abilities to screening-out irrelevant stimuli	α = 0.92	This scale has been updated and replaced by the TAS
Telic-Dominance Scale	42-item measure of a number of serious-minded, planning, and arousal-seeking	α = .84	Freely available from Morgatroyd et al. (1978)
Tellegen Absorption Scale (TAS)	34-item true/false scale that measures individuals’ involvement in activities	α = .88	Tellegen (1982)
Test of Attentional and Interpersonal Style (TAIS)	144-item, 17-subscale measure of attentional processes, physiological arousal, and performance (designed for athletes)	α = .53	Available for purchase from Enhanced Performance Systems at www.enhanced-performance.ca
Trait Arousability Scale (TAS)	34-item, 9-point survey measures individuals’ patterns of arousal response to high-information events	α = .90	Available for purchase from Mehrabian at www.kaaj.com/psych
Zuckerman–Kuhlman Personality Questionnaire (ZKPQ)	5-point, 5-factor personality scale that includes a measure of impulsive sensation seeking (ImpSS)	α = .82 to .87 (Zuckerman & Kuhlman, 2000).	Zuckerman et al. (1993)

* Details and citations related to each measures’ reliability and availably are presented earlier in this chapter.

Study 1: Factor Analysis Across Existing Measures

The purpose of this study is to address Hypothesis 1, which suggests that by looking across various existing constructs and measures of arousability, a more robust, better factored apparatus may be created. Two of the best subjective measures of arousability appear to be Mehrabian and the Arons' surveys. While their two lines of similar research have uncovered comparable results, their work has been applied to very different fields. Thus, these two measures were selected for inclusion in this study. Further, some items from Satow's (1987) Environmental Sensory Stimuli Scale were selected. Even though Satow's scale failed to achieve psychometric validity, the items from her survey do appear to analyze sensory sensitivity for the environment stimuli, directly—a component less emphasized in the other measures. As such, it was hypothesized that items from this measure might make a useful addition to the optimized measurement instrument.

Method

Participants were recruited from the University of Central Florida's undergraduate classes (N = 622) and asked to complete the HSP scale (Aron & Aron, 1997), the TAS (Mehrabian, 1995), and a portion of Satow's Environmental Sensory Stimuli Scale (1986). As mentioned above, the ESS factors were included because they more directly question reactions caused by diverse environmental stimuli. However, the complete ESS was not used for several reasons. First, the overall scale failed to achieve sufficient reliability. Second, many items on the scale are highly redundant; for instance, one item reads "I like vivid colors," while the following item says "I like somber colors." Third, some of the items seem strange and/or are not clearly related to arousability; translating the scale from its original Japanese into English might be to blame.

Consider these items, for instance: “I like working to the rhythm of stamping feet, clapping hands or whistling,” “I like Hawaiian music,” or “I like to look down at rapids from a bridge.” The preceding items most likely would not clearly relate to the conceptualization of arousability used in this investigation. Finally, for practical reasons (i.e., to minimize the time required to complete the experiment), it seemed most practical to include only a relevant subset of questions. Redundant or theoretically less-relevant items were excluded, and in the end, ten items were selected. These items are listed in Table 5.

Table 5: Selected items from the Environmental Sensory Stimuli Scale (Satow, 1987)

Item 1	I like working in an office where background music is playing.
Item 2	I have no trouble in reading in noisy surroundings, e.g., when a radio or loud music is playing.
Item 3	I am sensitive to sounds, even the smallest noises annoy me.
Item 4	I can’t sleep in a room unless it is pitch-black.
Item 5	I am sensitive to pain.
Item 6	I am sensitive to small changes in temperature.
Item 7	I am sensitive to small changes in humidity.
Item 8	I am sensitive to small differences in the touch of clothes.
Item 9	I am sensitive to odors.
Item 10	I can detect even the smallest movement of air.

Participation in the experiment was entirely voluntary, and participants were empowered to quit at anytime without penalty. Some students completed the surveys in person, on paper, follow a class meeting. Other students completed the surveys online, outside of a class setting. Depending upon their major, some students received psychology experimental participation credit for their efforts, while other students (i.e., non-psychology students) did not. Overall, participations from one cohort (i.e., those who received psychology participation credit) did not know that participations from a different cohort (i.e., students from a different major, who did not need psychology participation credit) were involved. Also, no significant differences were found between participants who replied in person, participants who replied online, or participants who received participation credit.

Analysis

Data was not used for participants who failed to respond to all questions in a given analysis. Consequently, N ranges between 606 and 619 for the following analyses. First, the reliability of each, individual measure was analyzed. For the TAS and HSP the results ($\alpha = .89$ for the TAS, and $\alpha = .88$ for the HSP) were equivalent those reported by other researchers. The internal reliability of the select ESS questions was $\alpha = .64$. Next, the total reliability of all items combined was evaluated. Cronbach's alpha for the total pool of items was very high ($\alpha = .93$).

Next, a (rotated) Varimax factor analysis with Kaiser Normalization was applied, in order to divide the items into empirically-derived sub-constructs. Although both Mehrabian and the Aron's scales are considered unidimensional, this analysis yielded two orthogonal factors. The first accounted for 18.06% of the variance, and the second accounted for 6.73%. See Table 6 for the individual item loadings.

The highest loading items for the first factor are TAS questions 21, 13, and 10. These items are each concerned with emotionality (e.g., "I am emotionally low key" or "I have continued, intense feelings"). The internal consistency of the 17 items that comprise this factor is .88. The highest loading items for the second factor are HSP questions 7, 25, and 9. These questions deal with immediate responses to sudden sensory stimuli (e.g., "Are you made uncomfortable by loud noises" or "Are you easily overwhelmed by things like bright lights").

The internal consistency of the 18 items that comprise this factor is .88. Finally, the alpha for the new, 35-item composite scale is .91.

If the overall data are reanalyzed using these factors, the following normative values emerge. For factor 1 (negative emotionality), the possible range of scores fell between -68 to +68. The mean in this dataset occurred at 12.3 with a standard deviation of 20.2. For factor 2 (sensory sensitivity), the possible range of scores fell between 0 and +126. The mean in this dataset occurred at 67.8 with a standard deviation of 16.9.

Table 6: Rotated Component Matrix: Factor Loadings*

Trait Arousability Scale (Mehrabian, 1995)

	Factor 1	Factor 2
Item 1	.167	-.040
Item 2	**.386**	.131
Item 3	-.049	.133
Item 4	.195	.147
Item 5	.169	.118
Item 6	**.427**	.066
Item 7	.095	.078
Item 8	.096	.068
Item 9	**.601**	.021
Item 10	**.768**	.004
Item 11	-.007	.138
Item 12	.002	.072
Item 13	**.770**	.086
Item 14	**.669**	.117
Item 15	.028	.071
Item 16	**.372**	.204
Item 17	**.269**	-.052
Item 18	**.379**	.006
Item 19	**.622**	.002
Item 20	.069	.118
Item 21	**.711**	.079
Item 22	**.275**	.085
Item 23	-.002	-.052
Item 24	.195	.107
Item 25	**.276**	.111
Item 26	.138	.199
Item 27	.140	.179
Item 28	**.468**	.035
Item 29	**.657**	-.081
Item 30	**.375**	.065
Item 31	.216	.016
Item 32	**.296**	.063
Item 33	-.007	.052
Item 34	**.525**	.002

Highly Sensitive Person scale (Aron & Aron, 1997)

	Factor 1	Factor 2
Item 1	.033	**.355**
Item 2	-.120	.014
Item 3	.148	**.250**
Item 4	.126	.182
Item 5	-.021	**.405**
Item 6	.061	**.413**
Item 7	.018	**.644**
Item 8	-.016	.182
Item 9	.086	**.763**
Item 10	.129	.059
Item 11	.024	**.464**
Item 12	.089	.074
Item 13	.194	**.370**
Item 14	.230	**.254**
Item 15	.077	-.028
Item 16	.051	.244
Item 17	.120	.054
Item 18	.075	**.277**
Item 19	.103	**.541**
Item 20	.139	**.254**
Item 21	.241	**.330**
Item 22	.108	.025
Item 23	.056	**.365**
Item 24	-.045	.167
Item 25	.073	**.729**
Item 26	.085	**.418**
Item 27	-.062	**.330**

Environmental Sensory Stimuli Scale (Satow, 1987)

	Factor 1	Factor 2
Item 1	.008	.044
Item 2	-.037	-.102
Item 3	.016	**.412**
Item 4	-.035	.164
Item 5	.140	.154
Item 6	-.023	.120
Item 7	-.031	.089
Item 8	-.033	.207
Item 9	.039	.219
Item 10	-.104	.133

* Items scoring above .25 were included in each factor.

Discussion

In this analysis, the TAS (Mehrabian, 1995), HSP (Aron & Aron, 1997), and a portion of the ESS (Satow, 1987) were compared and combined. Together these scales showed an exceptionally high internal consistency measure (α = .91), and when the items were factor analyzed, two subscales resulted: negative emotionality and orienting sensitivity.

The first factor, negative emotionality, is defined by a propensity to experience negative emotions such as fear, sadness, frustration, and sensory discomfort (i.e., unpleasant affect resulting from sensory stimulation, such as pain or irritation). The second factor is defined by an increased orienting sensitivity; that is, a person's threshold for perceptual stimuli. These two subscales were originally proposed by Evans and Rothbart (2008; Derryberry & Rothbart, 1988; Evans & Rothbart, 2007); although, Smolewska et al. (2006) first suggested that the HSP (specifically) may be comprised of multiple factors.

In 2006, Smolewska, McCabe, and Woody analyzed the HSP. Even though it (and the TAS) are supposedly unidimensional measures, Smolewska et al. extracted three factors, which they labeled excitation, aesthetic sensitivity, and low-sensory threshold. Later, Evans and Rothbart (2008) renamed the factors negative affect, orienting sensitivity, and distress to over-stimulation, respectively.

Evans and Rothbart (2008) then conducted their own analysis of the Arons' apparatus. In their discussion, they complained that the HSP items were not written to fit with precise definitions of sensory discomfort or negative emotionality. Nonetheless, they "roughly" (p. 110) sorted the items into categories. Through factor analysis and comparison to the Adult Temperament Questionnaire (ATQ; Evans & Rothbart, 2007), they were able to narrow the HSP into two factors: propensity for negative affect and orienting sensitivity. However, Evans and

Rothbart (2008) were dissatisfied with the scarcity of items that fit with the sensory sensitivity subscale, saying: "According to our conception of sensory sensitivity, there is only a single sensory sensitivity item in the HSP" (p. 117).

In contrast, this analysis leveraged the TAS, HSP, and a portion of the ESS. Thus, it was able to overcome the dearth of adequate measures associated with each factor—the problem Evans and Rothbart identified with the HSP, alone.

This analysis further diverges from Evans and Rothbart's conceptualization of the underlying constructs of the two subscales. Specifically, Evans and Rothbart theorized that the negative emotionality and orienting sensitivity constructs were only modestly correlated, because the two "roughly" constructed subscales, which they devised from the HSP, correlated at $r = .25$. This led Evans and Rothbart to conclude that there is no support "for Aron and Aron's (1997) contention that self-reported sensitivity and susceptibility to sensory discomfort were strongly related constructs" (p. 116).

In spite of Evans and Rothbart's claim, it does appear that psychometric and theoretical evidence (the former, from this study) support the notion that negative affect and orienting sensitivity are related. First, in this study, the subscales were highly correlated ($r = .88$). However, it was necessary to combine three apparatus in order to adequately resolve the two factors and achieve this correlation. Second, trait arousability is theorized to be an individual difference rooted in physiological differences (i.e., in the brain and central nervous system). Thus, the argument is that while individuals' scores on the second subscale (orienting response) are unlikely to change, people can learn coping strategies to mitigate their tendency to experience negative emotions (i.e., the first subscale). Thus, the two subscale may be theoretically associated without yielding identical scores. Obviously, more evidence is needed to support (or refute) this hypothesis.

Nonetheless, this study (as well as Evans, Rothbart, and Smolewska et al.'s work) show that trait arousability is an established individual difference, even if researchers lack full agreement of its associated constructs and measures. Identifying trait arousability through self-report survey can be difficult; yet, by combining three measures of trait arousability, the two subscales associated with the phenomenon become more clear. Thus, with this new, more robust, composite scale the two factors are now better measured, and their underlying constructs appear correlated.

Summary and Response to Hypothesis 1

Hypothesis 1 stated that "*by factor analyzing existing measures of arousability a more reliable, more valid apparatus can be created. This apparatus will also help clarify the factor structure of arousability, which will make it more suitable for use in applied training systems*." This hypothesis was supported. A composite measure was successfully developed by comparing and combining existing apparatus. This new measure includes two unambiguous, theoretically-valid factors, and its reliability is outstanding ($\alpha = .91$).

CHAPTER SEVEN: AROUSABILITY TRAINING EXPERIMENT (STUDY 2)

The purpose of this study was to address Hypothesis 2, which suggested that individual differences in arousability correlate with trainees' depth of processing and consequently their success in training. In addition to addressing Hypothesis 2, this investigation also served as a validation of the apparatus that resulted from the first study.

Method

Forty-five participants (N = 45; male = 33; female = 12; ages = 18–57) completed this study. They were recruited from University of Central Florida graduate and undergraduate classes and by word-of-mouth outside of the university. Most of the graduate and undergraduate students received extra credit in Digital Media or Psychology classes for their participation; except for the extra credit no other incentives were offered to any participants.

Materials

The data-collection materials used in this study include the following: the informed consent document (Appendix B), a standard biographical survey (Appendix C), the arousability survey developed in Study 1, the State-Trait Anxiety Inventory for Adults (Spielberger, 1983), a verbatim knowledge pre-test/post-test questionnaire (Appendix D), a semantic knowledge pre-test/post-test questionnaire (Appendix E), the NASA-Task Load Index (NASA-TLX; Appendix G), and TPL-KATS Concept Map software (Hoeft et al., 2003). Most materials were presented in paper-and-pencil format; however, the semantic knowledge questionnaires, NASA-TLX, and concept maps were delivered via a computer.

The other apparatus used in this study was a five-minute multimedia (i.e., animated visual imagery and audio narration) computer-based presentation about US Marine Fire Support Teams (FiST), including one specific FiST task called a Call for Fire (CFF). Screen-captures of this presentation are available in Appendix H. The presentation was manipulated for the experimental conditions as follows.

In Condition 1 (the control condition) participants witnessed/heard the standard presentation. In Condition 2 (the slight-arousal condition) the standard presentation was coupled with a (redundant) textual representation of the narration, as well as a constant white noise. The audio narration ranged between 84.0–90.1 dB (relatively), and the volume of the white noise track was 84.5 dB (relatively). If participants adjusted the narration volume, the white noise volume changed correspondingly. Effectively, participants could clearly hear the narration, and yet the white noise was also clearly audible. Colloquially, it could be said that the narration sounded as if it has been recorded along with considerable static. Both the white noise and the redundant textual/audio narration have been shown to increase general arousal in previous investigations (e.g., white noise: Hockey (1986b); Brocke, Tasche & Beauducel (1997); Coren & Mah (1993); Davidson & Smith (1991); e.g., redundant text: Sweller (1999); Mayer (2002)).

A third condition was added after initial results indicated that Condition 2 was not sufficiently arousing. In Condition 3 (the moderate-arousal condition) the standard presentation was coupled with randomly-timed white-noise and visual-static bursts, which occurred at least once every 20 seconds. The redundant text narration was removed since it failed to significantly affect arousal. Again, the audio narration ranged between 84.0–90.1 dB (relatively). The white noise bursts were 100 dB (relatively) and lasted about half a second.

Procedure

This study required approximately 75 minutes to complete. When participants arrived, they were briefed on study requirements and then asked to review and sign the informed consent document (Appendix B). They then completed the following, in this order:

1. A standard biographical survey (Appendix C)
2. The arousability survey developed in Study 1
3. The State-Trait Anxiety Inventory for Adults (Spielberger, 1983)
4. A verbatim knowledge pre-test questionnaire (Appendix D)

Participants set their own pace for completing these initial surveys. Following their completion, the experimenter asked participants to move to a nearby laptop computer station. Using a standard word-processing program, participants responded to several essay questions:

5. Five semantic knowledge essay questions – pre-test (Appendix E)

Before beginning the essay questions, participants were informed that spelling and grammar would not be "graded" and also asked to report their confidence in the accuracy of each of their answers. They were given a maximum of 10 minutes to respond to the essay questions. Following this, participants were instructed to watch the five-minute multimedia presentation (see Appendix H for screen captures). The multimedia trainer was presented on the laptop and used QuietComfort noise-cancelling headphones to deliver the audio. Participants were able to adjust the master volume to suit their preference. Immediately after the multimedia presentation concluded the following questionnaires were administered, in this order:

6. The State-Trait Anxiety Inventory for Adults – form Y1 (state anxiety)
7. The NASA-TLX (Appendix G)
8. A verbatim knowledge post-test questionnaire (Appendix D)

9. Five semantic knowledge essay questions – post-test (Appendix E)

Finally, participants were asked to create concept maps depicting their mental models of the subject matter (i.e., USMC Fire Support Teams and their supporting units). TPL-KATS Concept Map software facilitated this step:

10. TPL-KATS Concept Map (Hoeft et al., 2003; Appendix F)

Before participants created their subject-matter concept maps, they were first given instructions on using the TPL-KATS system. Next, participants each created a basic, practice concept map about a typical classroom; at this point, they were able to ask the experimenter questions about the concept map process and/or the TPL-KATS software. Once participants completed the practice concept map, they were then instructed to complete the subject-matter concept map. The expert version of this map is shown in Appendix F. Participants were given an unlimited amount of time to complete their concept map, and when they concluded they were debriefed about the study (see the debriefing sheet in Appendix I).

Results

The *a priori* hypotheses developed for this study predicted complex interactions among several variables (i.e., the arousability factors, experimental condition, and several outcome measures). Moderated multiple regression (MMR) is the most appropriate analysis approach for this type of model. Unfortunately, several statistical biases are associated with MMR, including multicollinearity, low residual variance of the product term in the regression equation, residual variance heterogeneity, and multivariate normality (Kromrey & Foster-Johnson, 1998). To better control for these issues, data transformation procedures are typically applied before analysis begins.

Data Preprocessing

First, data were transformed using mean centering (also known as "mean deviation"). Mean centering is one of the most commonly employed data transformations, particularly in the social sciences. It is applied by subtracting the dataset's overall mean from each item within that set (for a more detailed discussion of this, see Kreft, Leeuw, & Aiken, 1994). Some statisticians suggest mean centering protects against multicollinearity (e.g., Aiken & West 1991; Jaccard et al. (1990); Cronbach, 1987) and improves the interpretability of data (e.g., Boysworth & Booksh, 2001; Finney et al, 1984). Other methodologists contend that mean centering offers no benefit over using raw scores (e.g., Echambadi & Hess, 2007; Kromrey & Foster-Johnson, 1998); for instance, Kromrey and Foster-Johnson claim that "the arguments about the benefits of centering are specious and serve only to distract researchers from the multitude of pertinent issues in the conduct of inquiry" (p. 44). Finally, other analysts take a middle ground, admitting that mean-centering may or may not be statistically meaningful, but that there are some cases where centering may at least facilitate interpretation. For instance, Kreft et al. (1994) conclude that "since scales in psychology are in the main arbitrary, rescaling predictors to approximately equal locations and variances prior to analysis is often both possible and desirable" (p. 12). Thus, taking these arguments into consideration, the arousability factors (discussed later in this chapter) were transformed using a traditional mean centering approach in order to aid interpretability and possibly (depending upon which argument is believed) help mitigate multicollinearity.

Next, dummy variables were used to represent the three experimental conditions. Dummy variables are useful for comparing the slopes associated with datasets from various groups (Aguinis, 2004). In this case, the control condition was given the dummy value of 0, the second and third conditions were each given dummy values of 1. Following this, each dummy variable was then multiplied against each arousability factor score (i.e., the mean-centered score) for each participant. This resulted in a new variable that simultaneously captured the condition and arousability scores. These scores were used later, in the regression analysis.

NASA TLX Scoring

The NASA TLX divides subjective workload into mental demand, physical demand, temporal demand, performance, effort, and frustration level. The NASA TLX also includes a weighting scheme, in order to account for individual differences regarding how different workload aspects are subjectively experienced. However, contemporary research suggests that weighted TLX scores provide no additional predictive power compared to non-weighted scores (Tsang & Wilson, 1997; Nygren, 1991; Christ et al., 1993; Hendy et al., 1993). Consequently, weighted scores were not used in this analysis; only raw scores were analyzed.

Normality of Data

The arousability data satisfy the assumptions of normality. The cells have equal *n*-sizes, demonstrate homogeneity of variance, and display normal distributions. For the orienting sensitivity arousability factor the skewness = 1.5 and the kurtosis = .98. For the negative emotionality arousability factor the skewness = .18 and the kurtosis = .01. These values verify that both factors are neither significantly skewed nor significantly kurtotic. Tables 7 and 8 contain more detailed information, and Figure 3 shows the distribution of the raw arousability factor scores.

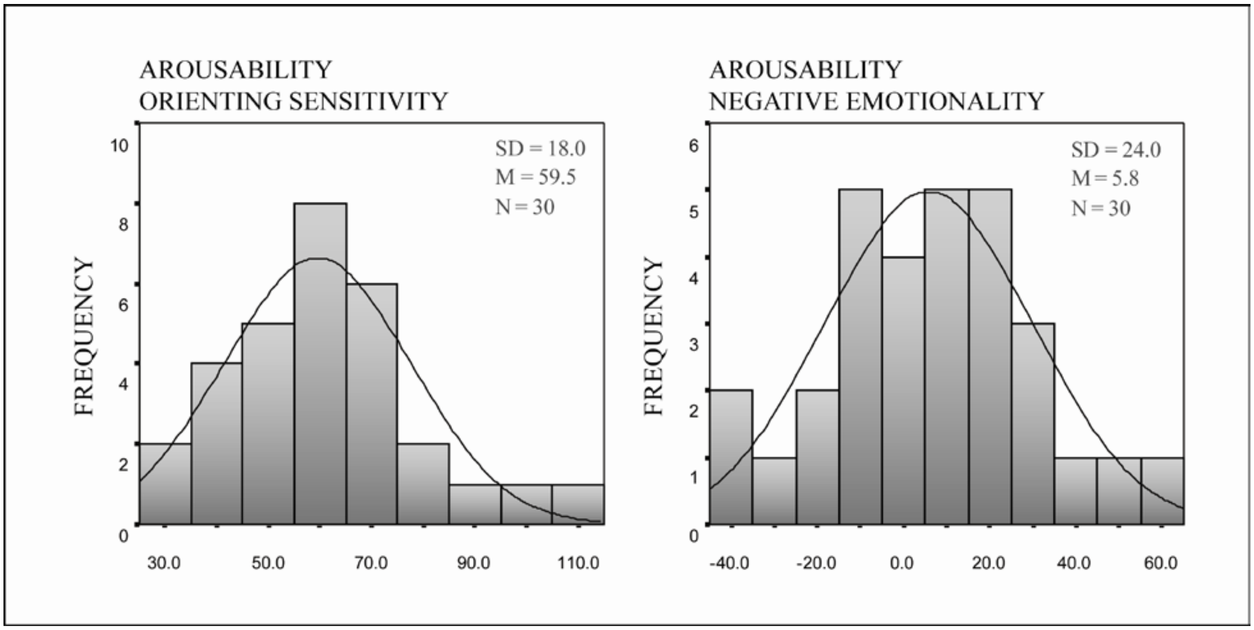


Figure 3. The distribution of participants' raw arousability scores, separated by factor. These distributions represent all participants in the control and most-stimulating conditions (i.e., Conditions 1 and 3).

Data Analyses

Once data were preprocessed, they were next analyzed. Since the initial experimental condition (Condition 2) failed to sufficiently affect individuals' general arousal, it is not included in the following analyses. Instead, the remainder of the discussion will focus on comparing the control (Condition 1) and more intense, second experimental (Condition 3) groups. Main effects for these two conditions (i.e., ignoring arousability scores) are shown in Table 7. As these data suggest no significant differences between the groups existed before the manipulation, but logical differences manifested after the manipulation. More specifically, individuals in the experimental condition reported slightly greater state anxiety and mental workload. These individuals also performed poorer on the more difficult section (i.e., part two) of the verbatim knowledge questionnaire and reported lower confidence in their essay question responses.

Next, the same descriptive statistics and mean comparisons were conducted based upon high- and low-arousability scores (i.e., ignoring condition). First, grand median values were calculated for both arousability factors (orienting sensitivity median = 58.5; negative emotionality median = 6.5). This approach ensured that each group contained an n = 15. Individuals with higher arousability were distributed evenly between conditions; for both factors 7 participants from the control condition were above the median. This grouping procedure was performed in order to gain additional statistical power.

The main effects for arousability (i.e., ignoring condition) are found in Table 8. As theory suggests, individuals scoring above the median value of arousability also reported significantly higher *trait* anxiety scores, although not significantly greater pre-training state anxiety scores. More sensitive individuals also reported greater state anxiety after the training—regardless of whether they experienced the control or experimental training—and they reported greater mental effort expenditure, again regardless of condition. Finally, the more arousable group also scored lower on the more challenging portion of the verbatim knowledge questionnaire (i.e., part two) but, unexpectedly, scored much *better* on the post-test semantic questions. These scores are shown in Table 8.

Table 7: Main Effects for Condition (Ignoring Arousability)

		Control (n = 15)	**Experimental (n = 15)**	***P***
Pre-tests	Sex	Males = 10	Males = 11	
	STAI – Trait Anxiety	Mean = 33.3; SD = 15.2	Mean = 38.8; SD = 8.5	n.s.
	STAI – State Anxiety	Mean = 44.3; SD = 13.0	Mean = 47.4; SD = 7.5	n.s.
	Arousability – orienting sensitivity	Mean = 62.2; SD = 23.1	Mean = 56.8; SD = 11.1	n.s.
	Arousability – negative emotionality	Mean = 1.67; SD = 19.6	Mean = 9.87; SD = 16.9	n.s.
	Verbatim knowledge (part 1)	Mean = 10.2; SD = 4.0	Mean = 10.8; SD = 2.8	n.s.
	Verbatim knowledge (part 2)	Mean = 8.0; SD = 2.4	Mean = 7.0; SD =2.6	n.s.
	Semantic knowledge	Mean = 1.47; SD = 1.1	Mean = 1.40; SD = 1.4	n.s.
	Semantic answer confidence	Mean = 2.7; SD = 8.8	Mean = 1.5; SD = 7.1	n.s.
Post-tests	STAI – State Anxiety (post-test)	Mean = 34.4; SD = 13.1	Mean = 42.4; SD = 9.0	**.031****
	TLX – Mental Workload	Mean = 62.0; SD = 21.9	Mean = 70.3; SD = 14.1	n.s.
	TLX – Physical Workload	Mean = 23.0; SD = 15.1	Mean = 25.3; SD = 15.8	n.s.
	TLX – Temporal Workload	Mean = 50.3; SD = 17.9	Mean = 54.3; SD = 19.5	n.s.
	TLX – Performance	Mean = 41.3; SD = 22.1	Mean = 54.3; SD = 19.5	**.044***
	TLX – Effort	Mean = 66.0; SD = 21.6	Mean = 69.0; SD = 15.6	n.s.
	TLX – Frustration	Mean = 40.3; SD = 25.0	Mean = 52.3; SD = 25.0	n.s.
	TLX – Total	Mean = 51.6; SD = 17.6	Mean = 62.3; SD = 11.7	**.031***
	Verbatim knowledge (part 1)	Mean = 18.0; SD = 3.0	Mean = 17.5; SD = 2.3	n.s.
	Verbatim knowledge (part 2)	Mean = 9.7; SD = 2.8	Mean = 8.0; SD =2.4	**.039***
	Semantic knowledge	Mean = 2.07; SD = 2.0	Mean = 1.87; SD = 1.8	n.s.
	Semantic answer confidence	Mean = 11.6; SD = 4.5	Mean = 6.7; SD = 6.2	**.013***
	Concept map scores	Mean = 13.0; SD = 4.5	Mean = 11.9; SD = 4.9	n.s.

* *p*-values are one-tailed with equal variances assumed

** *p*-values are one-tailed with equal variances *not* assumed

Table 8: Main Effects of "High" and "Low" Arousability Scores (Ignoring Condition)

		Below Median (*n* = 15) **"Low" Arousability**	**Above Median (*n* = 15)** **"High" Arousability**	***p***
Arousability – orienting sensitivity	Sex	Male = 11	Male = 10	
	STAI – State Anxiety (pre-test)	Mean = 32.3; SD = 9.8	Mean = 39.7; SD = 13.9	n.s.
	STAI – Trait Anxiety (pre-test)	Mean = 41.6; SD = 9.5	Mean = 50.2; SD = 10.0	**.011****
	STAI – State Anxiety (post-test)	Mean = 32.9; SD = 11.2	Mean = 44.0; SD = 9.8	**.004***
	TLX – Mental Workload	Mean = 65.3; SD = 19.9	Mean = 67; SD = 17.1	n.s.
	TLX – Physical Workload	Mean = 17.0; SD = 9.4	Mean = 31.3; SD = 16.7	**.003***
	TLX – Temporal Workload	Mean = 48.7; SD = 20.1	Mean = 56.0; SD = 15.8	n.s.
	TLX – Performance	Mean = 51.0; SD = 22.9	Mean = 45.0; SD = 20.1	n.s.
	TLX – Effort	Mean = 66.3; SD = 21.9	Mean = 74.7; SD = 11.3	**.018***
	TLX – Frustration	Mean = 39.7; SD = 27.5	Mean = 53.0; SD = 22.3	n.s.
	TLX – Total	Mean = 53.9; SD = 18.8	Mean = 60.0; SD = 11.7	n.s.
	Verbatim (part 1) pre/post test difference	Mean = 7.1; SD = 4.4	Mean = 7.4; SD = 2.7	n.s.
	Verbatim (part 2) pre/post test difference	Mean = 2.13; SD = 2.9	Mean = .53; SD = 3.2	n.s.
	Semantic pre/post test difference	Mean = -.27; SD = 1.5	Mean = 1.53; SD = 2.1	**.011*****
	Semantic confidence pre/post test difference	Mean = 6.6; SD = 8.0	Mean = 7.7; SD = 6.1	n.s.
	Concept map scores	Mean = 12.7; SD = 5.8	Mean = 12.2; SD = 3.5	n.s.
Arousability – negative emotionality	Sex	Male = 13	Male = 8	
	STAI – State Anxiety (pre-test)	Mean = 32.5; SD = 9.8	Mean = 39.5; SD = 14.1	n.s.
	STAI – Trait Anxiety (pre-test)	Mean = 41.6; SD = 9.6	Mean = 50.2; SD = 9.9	**.011****
	STAI – State Anxiety (post-test)	Mean = 34.2; SD = 11.2	Mean = 42.6; SD = 11.1	**.024***
	TLX – Mental Workload	Mean = 63.7; SD = 19.2	Mean = 68.7; SD = 17.5	n.s.
	TLX – Physical Workload	Mean = 21.0; SD = 12.6	Mean = 27.3; SD = 17.3	n.s.
	TLX – Temporal Workload	Mean = 48.3; SD = 21.3	Mean = 56.3; SD = 14.9	n.s.
	TLX – Performance	Mean = 51.0; SD = 24.2	Mean = 45.0; SD = 18.4	n.s.
	TLX – Effort	Mean = 61.3; SD = 21.3	Mean = 73.7; SD = 13.6	**.034***
	TLX – Frustration	Mean = 38.7; SD = 24.5	Mean = 54.0; SD = 24.9	**.05***
	TLX – Total	Mean = 52.4; SD = 18.1	Mean = 61.5; SD = 11.7	n.s.
	Verbatim (part 1) pre/post test difference	Mean = 7.3; SD = 4.0	Mean = 7.2; SD = 3.1	n.s.
	Verbatim (part 2) pre/post test difference	Mean = 2.3; SD = 3.1	Mean = .33; SD = 2.9	**.040***
	Semantic pre/post test difference	Mean = .07; SD = 1.8	Mean = 1.2; SD = 2.1	n.s.
	Semantic confidence pre/post test difference	Mean = 6.7; SD = 6.9	Mean = 7.5; SD = 7.3	n.s.
	Concept map scores	Mean = 12.7; SD = 6.0	Mean = 12.3; SD = 3.2	n.s.

* *p*-values are one-tailed with equal variances assumed

** *p*-values are one-tailed with equal variances *not* assumed

*** *p*-value is two-tailed with equal variances assumed

Finally, after taking these main effects into consideration, an MMR was performed using the condition (control or experimental) and the condition-by-arousability interaction scores. The condition-by-arousability scores were calculated by multiplying the dummy variable by each of the mean-centered arousability factor values (as was discussed above). This effectively made the control group interaction scores a statistical baseline. The results of the regression algorithms are shown in Tables 9–21.

STAI – State Anxiety (Post-test)

The results suggest that neither the overall model, nor the moderator variables, have significant predictive value. Specific results of this analysis are depicted in Tables 9a and 9b. However, for this dependent variable the R^2 value is meaningful; its importance is discussed in the Discussion section.

Table 9a: MMR Model, DV = STAI – State Anxiety (Post-test)

Regression Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**R^2 Adjusted**	***p***
1 Condition-only	480.0	1	480.0	3.8	.088	.061
2 Inclusion of interactions	966.8	3	322.3	2.8	.154	.063

Table 9b: MMR Model-2 Components, DV = STAI – State Anxiety (Post-test)

	B (Unstandardized Coefficient)	**Std. Error (Unstandardized Coefficient)**	***p***
(Constant)	34.4	2.8	.000
Condition	7.7	4.2	.078
Condition X Orienting Sensitivity	5.9	4.8	.227
Condition X Negative Emotionality	.23	.18	.198

TLX – Mental Workload

The results suggest that neither the overall model, nor the moderator variables, have significant predictive value. Specific results of this analysis are depicted in Tables 10a and 10b.

Table 10a: MMR Model, DV = TLX – Mental Workload

Regression Model	**Sum of Squares**	**df**	**Mean Square**	**F**	R^2 **Adjusted**	***p***
1 Condition-only	520.8	1	520.8	1.60	.20	.216
2 Inclusion of interactions	712.5	3	237.5	.692	-.033	.565

Table 10b: MMR Model-2 Components, DV = TLX – Mental Workload

	B (Unstandardized Coefficient)	**Std. Error (Unstandardized Coefficient)**	***p***
(Constant)	62.0	4.8	.000
Condition	7.2	.278	.178
Condition X Orienting Sensitivity	8.2	.141	.482
Condition X Negative Emotionality	.299	-.073	.716

TLX – Physical Workload

The results suggest that neither the overall model, nor the moderator variables, have significant predictive value. Specific results of this analysis are depicted in Tables 11a and 11b.

Table 11a: MMR Model, DV = TLX – Physical Workload

Regression Model	Sum of Squares	df	Mean Square	F	R^2 Adjusted	*p*
1 Condition-only	40.8	1	40.8	.172	-.029	.682
2 Inclusion of interactions	941.3	3	313.8	1.416	.041	.261

Table 11b: MMR Model-2 Components, DV = TLX – Physical Workload

	B (Unstandardized Coefficient)	Std. Error (Unstandardized Coefficient)	*p*
(Constant)	23.0	3.8	.000
Condition	4.2	5.7	.472
Condition X Orienting Sensitivity	12.7	6.6	.066
Condition X Negative Emotionality	.047	.24	.848

TLX – Temporal Workload

The results suggest that neither the overall model, nor the moderator variables, have significant predictive value. Specific results of this analysis are depicted in Tables 12a and 12b. Once again, the R^2 values suggest that additional information might be gleaned from this model; see the Discussion for greater detail.

Table 12a: MMR Model, DV = TLX – Temporal Workload

Regression Model	Sum of Squares	df	Mean Square	F	R^2 Adjusted	*p*
1 Condition-only	120.0	1	120.0	.342	-.023	.563
2 Inclusion of interactions	2068.9	3	689.6	2.28	.117	.103

Table 12b: MMR Model-2 Components, DV = TLX – Temporal Workload

	B (Unstandardized Coefficient)	Std. Error (Unstandardized Coefficient)	*p*
(Constant)	50.3	4.5	.000
Condition	8.0	6.7	.247
Condition X Orienting Sensitivity	19.6	7.7	.018
Condition X Negative Emotionality	-.12	.28	.672

TLX – Performance

The results suggest that neither the overall model, nor the moderator variables, have significant predictive value. Specific results of this analysis are depicted in Tables 13a and 13b.

Table 13a: MMR Model, DV = TLX – Performance

Regression Model	Sum of Squares	dF	Mean Square	F	R^2 Adjusted	*p*
1 Condition-only	1333.3	1	1333.3	3.1	.069	.087
2 Inclusion of interactions	1351.4	3	450.5	.99	-.001	.415

Table 13b: MMR Model-2 Components, DV = TLX – Performance

	B (Unstandardized Coefficient)	Std. Error (Unstandardized Coefficient)	*p*
(Constant)	41.3	5.5	.000
Condition	13.1	8.3	.125
Condition X Orienting Sensitivity	-1.7	9.5	.860
Condition X Negative Emotionality	-.02	.35	.961

TLX – Effort

The results suggest that neither the overall model, nor the moderator variables, have significant predictive value. Specific results of this analysis are depicted in Tables 14a and 14b. The R^2 values here are also somewhat higher than expected.

Table 14a: MMR Model, DV = TLX – Effort

Regression Model	Sum of Squares	dF	Mean Square	F	R^2 Adjusted	*p*
1 Condition-only	67.5	1	67.5	.190	-.029	.667
2 Inclusion of interactions	1805.7	3	601.9	1.9	.085	.154

Table 14b: MMR Model-2 Components, DV = TLX – Effort

	B (Unstandardized Coefficient)	Std. Error (Unstandardized Coefficient)	*p*
(Constant)	66.0	4.6	.000
Condition	3.5	6.9	.615
Condition X Orienting Sensitivity	13.9	7.9	.089
Condition X Negative Emotionality	.33	.29	.268

TLX – Frustration

The results suggest that neither the overall model, nor the moderator variables, have significant predictive value. Specific results of this analysis are depicted in Tables 15a and 15b. Again, note the high R^2 values, and the see the Discussion for more detail.

Table 15a: MMR Model, DV = TLX – Frustration

Regression Model	Sum of Squares	dF	Mean Square	F	R^2 Adjusted	*p*
1 Condition-only	1080.0	1	1080.0	1.7	.024	.203
2 Inclusion of interactions	4566.7	3	1522.2	2.8	.155	.062

Table 15b: MMR Model-2 Components, DV = TLX – Frustration

	B (Unstandardized Coefficient)	Std. Error (Unstandardized Coefficient)	*p*
(Constant)	40.3	6.1	.000
Condition	12.2	9.1	.192
Condition X Orienting Sensitivity	18.4	10.4	.088
Condition X Negative Emotionality	.52	.38	.181

TLX Total

The results suggest that neither the overall model, nor the moderator variables, have significant predictive value. Specific results of this analysis are depicted in Tables 16a and 16b.

Table 16a: MMR Model, DV = TLX Total

Regression Model	Sum of Squares	dF	Mean Square	F	R^2 Adjusted	*p*
1 Condition-only	853.3	1	853.3	3.8	.088	.061
2 Inclusion of interactions	1518.9	3	506.3	2.4	.123	.096

Table 16b: MMR Model-2 Components, DV = TLX Total

	B (Unstandardized Coefficient)	Std. Error (Unstandardized Coefficient)	*p*
(Constant)	51.6	3.8	.000
Condition	11.5	5.7	.054
Condition X Orienting Sensitivity	9.6	6.5	.152
Condition X Negative Emotionality	.147	.237	.540

Verbatim Knowledge (part 1) Post-Test

The results suggest that neither the overall model, nor the moderator variables, have significant predictive value. Specific results of this analysis are depicted in Tables 17a and 17b.

Table 17a: MMR Model, DV = Verbatim Knowledge (part 1) Post-Test

Regression Model	Sum of Squares	dF	Mean Square	F	R^2 Adjusted	*p*
1 Condition-only	2.1	1	2.1	.30	-.025	.589
2 Inclusion of interactions	8.9	3	3.0	.40	-.066	.756

Table 17b: MMR Model-2 Components, DV = Verbatim Knowledge (part 1) Post-Test

	B (Unstandardized Coefficient)	Std. Error (Unstandardized Coefficient)	*p*
(Constant)	18.0	.70	.000
Condition	-.22	1.1	.835
Condition X Orienting Sensitivity	1.1	1.2	.382
Condition X Negative Emotionality	-.02	.04	.609

Verbatim Knowledge (part 2) Post-Test

The results suggest that neither the overall model, nor the moderator variables, have significant predictive value. Specific results of this analysis are depicted in Tables 18a and 18b.

Table 18a: MMR Model, DV = Verbatim Knowledge (part 2) Post-Test

Regression Model	Sum of Squares	df	Mean Square	F	R^2 Adjusted	*p*
1 Condition-only	22.5	1	22.5	3.4	.075	.078
2 Inclusion of interactions	28.5	3	9.5	1.4	.035	.279

Table 18b: MMR Model-2 Components, Verbatim Knowledge (part 2) Post-Test

	B (Unstandardized Coefficient)	Std. Error (Unstandardized Coefficient)	*p*
(Constant)	9.7	.68	.000
Condition	-1.5	1.0	.167
Condition X Orienting Sensitivity	.31	1.2	.794
Condition X Negative Emotionality	-.04	.04	.367

Semantic Knowledge Post-Test

The results suggest that neither the overall model, nor the moderator variables, have significant predictive value. Specific results of this analysis are depicted in Tables 19a and 19b.

Table 19a: MMR Model, DV = Semantic Knowledge Post-Test

Regression Model	Sum of Squares	dF	Mean Square	F	R^2 Adjusted	*p*
1 Condition-only	.30	1	.30	.08	-.033	.779
2 Inclusion of interactions	6.9	3	2.3	.61	-.042	.614

Table 19b: MMR Model-2 Components, DV = Semantic Knowledge Post-Test

	B (Unstandardized Coefficient)	Std. Error (Unstandardized Coefficient)	*p*
(Constant)	2.1	.50	.000
Condition	-.12	.75	.870
Condition X Orienting Sensitivity	.95	.86	.279
Condition X Negative Emotionality	.02	.03	.637

Semantic Post-Test Answer Confidence

The results suggest that the model effectively predicted individuals' confidence in their semantic knowledge responses; however, the condition-by-arousability interaction did not significantly add predictive value beyond the condition component. Specific results of this analysis are depicted in Tables 20a and 20b.

Table 20a: MMR Model, DV = Semantic Post-Test Answer Confidence

Regression Model	Sum of Squares	dF	Mean Square	F	R^2 Adjusted	*p*
1 Condition-only	163.3	1	163.3	5.6	.136	.026
2 Inclusion of interactions	246.7	3	82.2	2.9	.164	.054

Table 20b: MMR Model-2 Components, DV = Semantic Post-Test Answer Confidence

	B (Unstandardized Coefficient)	Std. Error (Unstandardized Coefficient)	*p*
(Constant)	11.5	1.4	.000
Condition	-4.9	2.1	.025
Condition X Orienting Sensitivity	-3.3	2.4	.171
Condition X Negative Emotionality	-.06	.09	.517

Concept map scores

The results suggest that neither the overall model, nor the moderator variables, have significant predictive value. Specific results of this analysis are depicted in Tables 21a and 21b.

Table 21a: MMR Model, DV = TLX – Concept Maps

Regression Model	Sum of Squares	dF	Mean Square	F	R^2 Adjusted	*p*
1 Condition-only	8.5	1	8.5	.37	-.022	.546
2 Inclusion of interactions	91.4	3	30.5	1.4	.042	.258

Table 21b: MMR Model-2 Components, DV = TLX – Concept Maps

	B (Unstandardized Coefficient)	Std. Error (Unstandardized Coefficient)	*p*
(Constant)	13.0	1.2	.000
Condition	.00	1.8	.999
Condition X Orienting Sensitivity	3.8	2.1	.072
Condition X Negative Emotionality	-.07	.08	.331

Discussion

In this study, main effects for both condition and arousability were uncovered. Not surprisingly, participants in the arousing condition (i.e., those subjected to randomly timed white-noise and visual-static bursts) reportedly experienced higher state anxiety and mental workload during the training. They also performed somewhat poorer on the more difficult portion of the verbatim knowledge questionnaire (i.e., part 2) and reported less confidence in their essay question responses.

Arousability also influenced several main effects in theoretically-predictable ways. For this study, the arousability construct was broken into two factors: orienting sensitivity and negative emotionality. These factors were theoretically proposed by Evans, Rothbart, and Smolewska et al.'s work and were confirmed in Study 1. Orienting sensitivity refers to a person's nervous-system sensitivity to stimuli. Negative emotionality refers to individuals' cognitive/emotional responses to the processing of those stimuli (see Chapter 6 for additional detail). In this experiment, individuals with higher orienting sensitivity reported significantly greater trait anxiety and post-test state anxiety, as well as increased mental workload during the training. Quite surprisingly, individuals with higher orienting sensitivity performed much *better* on the semantic knowledge essay questions than did their less arousable counterparts (this unexpected finding is discussed in greater detail below). Individuals with greater negative emotionality also reported significantly higher mental workload during the training, and they performed poorer then their less-arousable peers on the more difficult portion of the verbatim knowledge questionnaire (i.e., part 2).

The hypothesized interaction effects for condition-by-arousability were not found. None of the regression models that used condition and arousability were significantly predictive. Thus, the results fail to support the hypothesis (originally presented in Chapter 5):

> *Hypothesis 2:* Highly-arousable individuals will demonstrate poorer semantic understanding of (highly-arousing) multimedia-based training, as compared to less-arousable individuals. However, all participants will likely show equal verbatim understanding of the training.

In fact from the overall analyses, it appears that participants' verbatim understanding was influenced by main effects but not by the interaction of condition-by-arousability. Further, it appears that all hypersensitives performed better than their hyposensitive counterparts—

regardless of condition—on the semantic knowledge questionnaires. These results are explored and hypotheses for their causes are given below.

Statistical Bias and Error

Clearly, the influence of arousability was not sufficiently robust, relative to error, in this study. However, what remains unclear is whether the nonsignificant results definitively support the Null Hypothesis or whether they are better attributed to other issues. Certainly, both low statistical power and sampling bias (discussed below) affected the results. The statistical complication created by having only 15 participants per group is obvious: Low statistical power increases the likelihood of making a Type II error (that is, of making a false negative).

The second statistical complication is initially less obvious, and its true impact can only be surmised. When the study was originally conceived, the arousing manipulation in the experimental condition was very mild. This manipulation proved ineffective at producing general arousal; therefore, an additional condition was added. This third condition was added at the end of the study, and consequently, all participants in that condition were run consecutively. This created an unexpected sampling bias: Low-arousability individuals in the second experimental condition were significantly more anxious *before the experiment began* compared to the low-arousability participants in the control condition. Since the STAI was used to determine individuals' states, these data can be interpreted to mean that the lower-arousability participants in the experimental condition were already experiencing high arousal *states* before the experiment even began. See Table 22 for specific details on this data and Figure 4 for a more interpretable graph of these data.

Table 22: Pre-test STAI – State Anxiety Scores, Separated by Condition and Arousability

			STAI – *State* Anxiety (pre-test)			**STAI – *Trait* Anxiety (pre-test)**		
			Mean	**Median**	***SD***	**Mean**	**Median**	***SD***
Control	Orienting Sensitivity	Lower (below median)	**23.3**	26.0	4.7	38.9	38.5	8.9
		Higher (above median)	41.3	30.0	19.3	50.6	50.0	14.7
	Negative Emotionality	Lower (below median)	**28.1**	38.5	9.4	26.0	**36.0**	9.2
		Higher (above median)	39.1	30.0	19.0	51.0	48.0	14.0
Experimental	Orienting Sensitivity	Lower (below median)	**39.3**	42.0	9.7	44.6	46.0	9.8
		Higher (above median)	38.4	37.0	7.9	49.9	50.0	3.8
	Negative Emotionality	Lower (below median)	**37.6**	42.0	8.0	45.1	**49.0**	9.4
		Higher (above median)	39.9	37.0	9.3	49.5	48.5	5.0

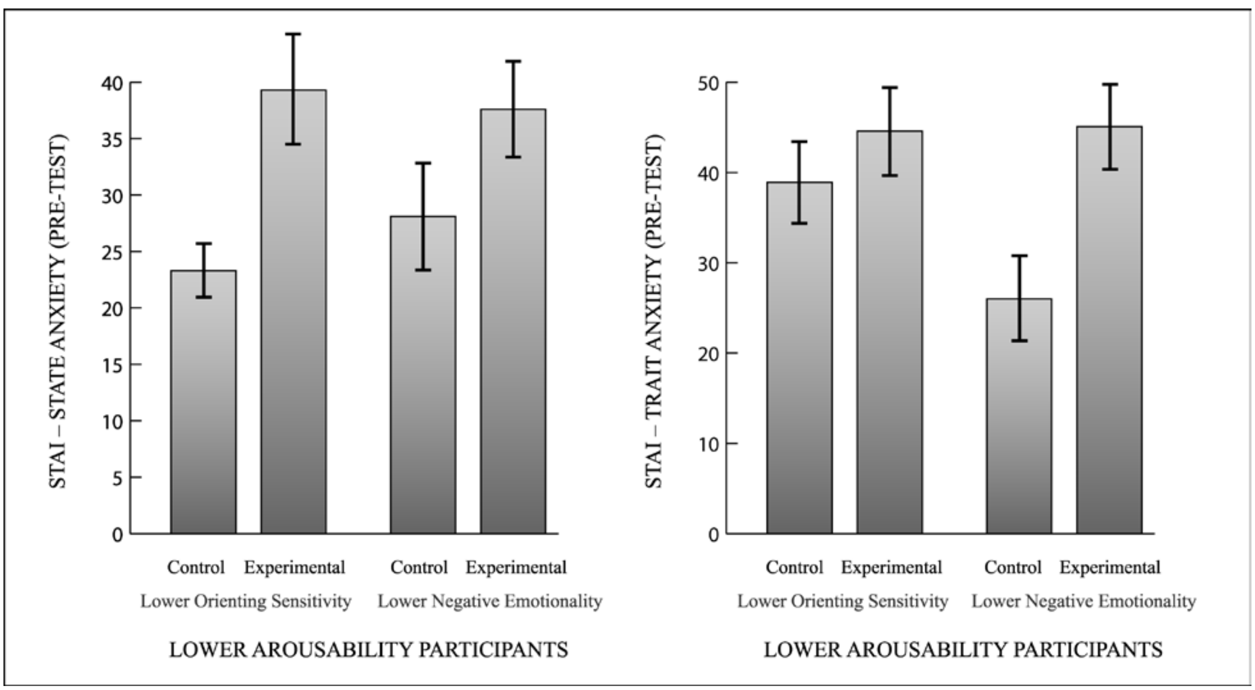


Figure 4. Mean STAI (pre-test) scores of lower-arousability participants, separated by the control and experimental conditions.

Although it is unclear why this sampling bias exists, it is logical to believe that the bias impacted the results found in the regression analyses. A pair-wise comparison between pre- and post-test STAI state anxiety scores demonstrates the impact of the sampling bias very clearly (see Figure 5). In the control condition, high-arousability individuals showed greater state anxiety than low-arousability participants (as expected), and all participants' STAI state anxiety scores following the (control) training were approximately equivalent to their initial STAI scores. This shows that neither group found the training to be particularly arousing (as expected). In the experimental condition, high-arousability individuals did not show meaningfully greater initial state anxiety as compared with low-arousability participants, and in fact, all participants in the experimental condition reported initial (pre-test) state anxiety equivalent to the high-arousability participants in the control condition (this is the sampling bias). Despite this bias, the high-arousability participants did react more negatively to the experimental (i.e., arousing) training than did the low-arousability participants (see Figure 5). This post-test difference in reaction is expected, based upon theory; however, the odd pre-test state and trait anxiety results are not readily explainable.

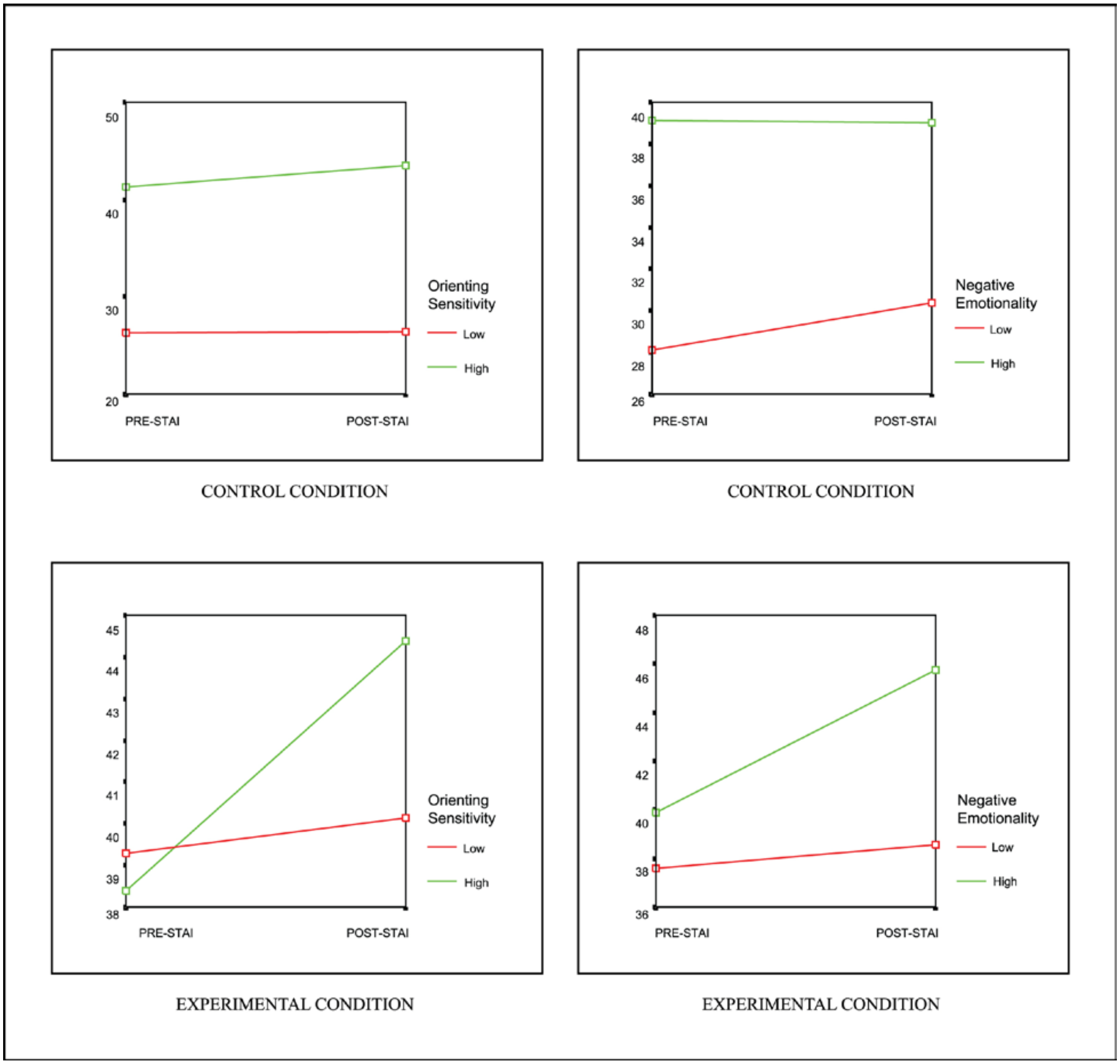


Figure 5. Pre- and post-test STAI state anxiety scores, separated by condition and arousability.

Essay Question Results

For this study, the *a priori* hypothesis suggested that highly-arousable individuals would perform more poorly on semantic questions following the arousing training. In fact, significant results support the opposite. That is, hypersensitives in the experimental condition actually performed *better* on the essay questions than did their hyposensitive counterparts. Figure 6 demonstrates this phenomenon.

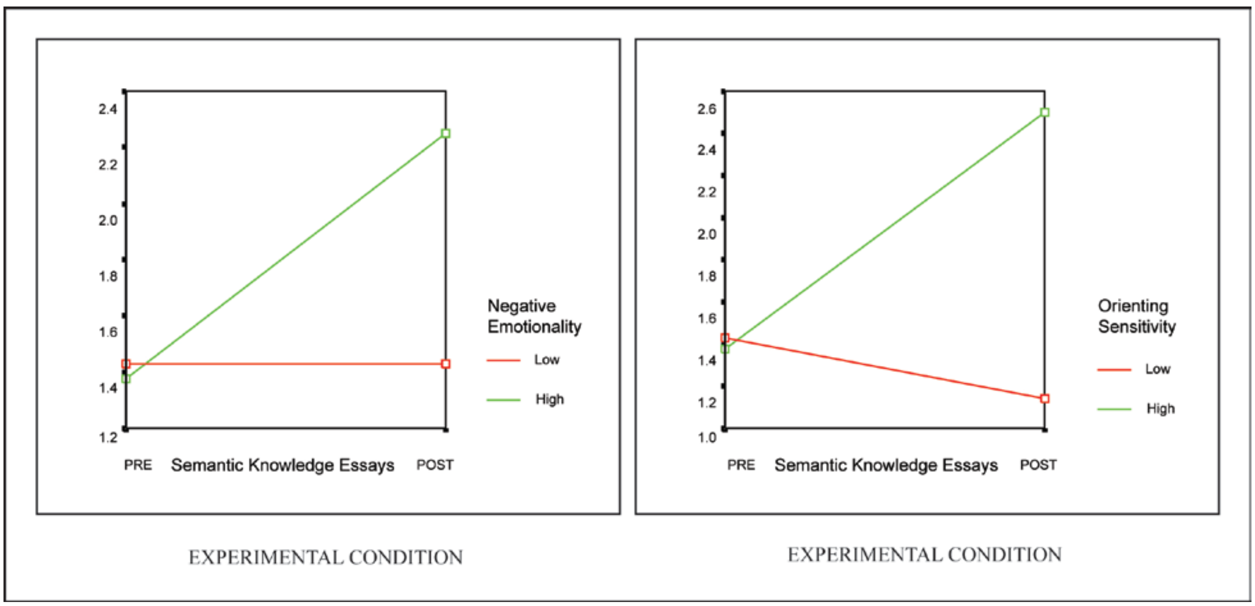


Figure 6. Mean pre- and post-test semantic knowledge essay question scores separated by and arousability for participants in the experimental condition only.

Similar results were uncovered in the control condition (see Figure 7). Together, these finding demonstrate that arousable individuals performed better on this study's essay questions, regardless of whether the participants were exposed to white noise bursts during training or not. These results were not predicted. They might be explained by reexamining some of the known correlations with hypersensitivity; that is, highly-arousable individuals are known to demonstrate greater imaginative ability (see Chapter 3 for more detail). Perhaps the essay questions tapped into participants' creativity more so (or instead of) their deeper processing abilities. More investigation into this may be warranted.

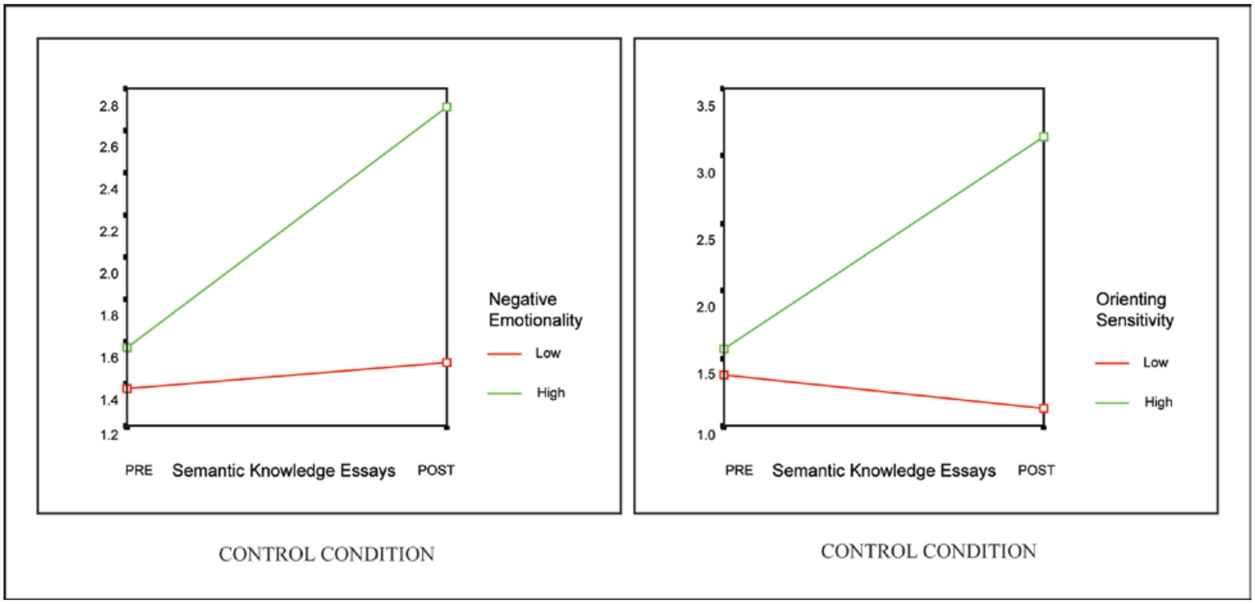


Figure 7. Mean pre- and post-test semantic knowledge essay question scores separated by and arousability for participants in the control condition only.

R^2 Values

The amount of variance accounted for by a regression model is captured in the R^2 statistic. *Adjusted* R^2 is a more conservative R^2 estimate. It adjusts the R^2 value to give a more realistic measure when the model includes multiple factors. In the above regression analyses, high *Adjusted* R^2 values were associated with several models, including temporal workload, effortful workload, and frustration. In each of these cases, the interaction of arousability-by-condition contributed meaningful variance to the regression algorithm, beyond the variance captured by including the only condition factor.

For temporal workload, the interactions of arousability-by-condition accounted for about 9.4% of the variance beyond the predictive power of using condition alone; in this case, the relevant interaction was orienting sensitivity-by-condition. For effortful workload, the interaction accounted for about 5.6% of the variance beyond condition alone, and again orienting sensitivity-by-condition represented the most meaningful interaction. For frustration, the orienting sensitivity-by-condition interaction accounted for 13.1% of the variance beyond using condition alone.

In each of these cases, the regression models failed to achieve $p = .05$ statistical significance; however, the results approach significance. That, combined with these meaningful *Adjusted* R^2 values suggest that further investigation may be justified. More specifically, additional research may uncover meaningful interaction effects between over-stimulation and high orienting sensitivity that affects individuals' mental workload. Since mental workload capacity plays an integral role in training, these potential interaction effects may be relevant to future training systems.

Implications for Arousability and Training

Does Arousability Meaningfully Affect Training?

This study, and the overall paper, are ultimately concerned with improving adaptive training by using data beyond traditional performance measures to inform systems. Specifically, these data include information about trainees' individual differences. Trait arousability was theorized to be a relevant and potentially useful variable to consider. The results from this study fail to support that hypothesis. However, some conclusions can be drawn, and speculations can be made about the meaning of the results.

First, arousability does not appear to meaningfully moderate learning performance, at least if the arousal inherent to the training is moderate (like in this study). One hypothesis is that hypersensitive individuals are able to cope with moderate over-stimulation during training. Assuming this is the case, it still remains unclear whether hypersensitives would be equally able to cope with greater amounts of arousal during training.

A second hypothesis is that the arousal created by the experimental condition was merely enough to narrow participants' attentional focus. Considerable research has already demonstrated that too much arousal leads to narrowing of focus and reduction in individuals' attentional capacities. Typically, limited attention is considered detrimental to learning; however, if attention is limited so that only the training material is focused upon, then additional arousal may actually facilitate dominant information recall. (This was reviewed in Chapter 3.) This study attempted to account for this phenomenon by including measures of both verbatim information and deeper "semantic" surveys; however, using concurrent measures of attentional resources (such as a dual-task paradigm) may have better addressed this issue.

Third, it is possible that the curvilinear (i.e., inverted–U) nature of the arousal–performance relationship obscured meaningful differences in this study. If, for example, hyposensitive participants were slightly *below* their optimum arousal states while hypersensitive participants were slightly *above* their optimum states of arousal, then the two groups' performance would still be equivalent—even though they both experienced nonoptimal states for different reasons. While it is statistically unlikely for this to occur, the data from the current study cannot refute the possibility. This speculation harkens back to Muse, Harris, & Field's (2003) complaint about inverted–U opponents (see Chapter 3). Specifically, they argue that linear comparisons cannot disprove curvilinear models. Thus additional empirical study, preferably using multiple levels of stimulation to facilitate a curvilinear regression analysis, are required to address this issue.

Finally, even though arousability failed to meaningfully affect training outcomes directly (e.g., performance), trends in the results suggest that arousability may significantly affect moderators of training outcomes, specifically mental workload. The moderately-sized *Adjusted* R^2 values and significant main effect results seem to support this notion. Certainly, additional, research directed at the workload–arousability relationship would be required to objectively support this theory.

In summary, whether this study's nonsignificant results were caused by statistical "noise" in the experimental design, by hypersensitives' ability to cope with moderate stress during training, by hypersensitives accessing additional attentional resources, or because of the curvilinear nature of arousal and performance, one thing is clear: Real-world training situations are more uncertain than any experimental setting. If arousability is to be seriously considered as a meaningful variable for adaptive training systems, then the above issues must be completely addressed and the specific effects of arousability on training outcomes (or their moderators) must be better articulated.

What Do These Results Mean for the Two-Factor Scale?

One purpose of this investigation was to validate the conglomerate, two-factor arousability scale developed in Study 1. Again, the nonsignificant results found in the above analyses neither clearly support nor clearly reject the viability of the scale. By considering the significant main effects and near-significant trends in the regression algorithms, it seems probable that the scale's two factors do measure related, but not identical, constructs (as was hypothesized). Of the two factors, orienting sensitivity influenced more dependent variables in this study, which seems appropriate considering the nature of the arousing stimuli used (i.e., sensory stimuli with no inherent emotional valence).

Overall, this study failed to validate—or invalidate—the two-factor scale. Additional research should be aimed at determining which dependent variables are most influenced by each factor, and the profiles of individuals who score highly on one factor, on the other factor, and on both. Finally, further validation testing is required before the conglomerate two-factor scale becomes an appropriate research tool.

Implications for Arousability and Training: Conclusion

In general, the nonsignificant interaction effects of this experiment lead to more questions than answers. The theory and complementary research conducted on arousability suggest that it impacts training, and interaction effects between stimulation level and arousability should be theoretically expected. However, these results suggest that researchers should be a little less optimistic about the direct impact and effect size of the arousability-by-stimulation interaction effect on training outcomes. Future studies should instead explore the interaction's influence on moderators, such as mental workload, and more clearly determine how the components of arousability individually, and collectively, influence dependent variables.

APPENDIX A: IRB APPROVAL LETTERS

Study 1

University of Central Florida

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Notice of Expedited Initial Review and Approval

From : **UCF Institutional Review Board**
FWA00000351, Exp. 5/07/10, IRB00001138

To : **Denise M. Nicholson**

Date : **December 13, 2007**

IRB Number: **SBE-07-05309**

Study Title: **Screening Ability: A Factor Analysis**

Dear Researcher:

Your research protocol noted above was approved by **expedited** review by the UCF IRB Chair on 12/12/2007. **The expiration date is 12/11/2008.** Your study was determined to be minimal risk for human subjects and expeditable per federal regulations, 45 CFR 46.110. The category for which this study qualifies as expeditable research is as follows:

7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The IRB has approved a **consent procedure which requires participants to sign consent forms.** Use of the approved, stamped consent document(s) is required. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Subjects or their representatives must receive a copy of the consent form(s).

All data, which may include signed consent form documents, must be retained in a locked file cabinet for a minimum of three years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained on a password-protected computer if electronic information is used. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

To continue this research beyond the expiration date, a Continuing Review Form must be submitted 2 – 4 weeks prior to the expiration date. Advise the IRB if you receive a subpoena for the release of this information, or if a breach of confidentiality occurs. Also report any unanticipated problems or serious adverse events (within 5 working days). Do not make changes to the protocol methodology or consent form before obtaining IRB approval. Changes can be submitted for IRB review using the Addendum/Modification Request Form. An Addendum/Modification Request Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at http://iris.research.ucf.edu .

Failure to provide a continuing review report could lead to study suspension, a loss of funding and/or publication possibilities, or reporting of noncompliance to sponsors or funding agencies. The IRB maintains the authority under 45 CFR 46.110(e) to observe or have a third party observe the consent process and the research.

On behalf of Tracy Dietz, Ph.D., UCF IRB Chair, this letter is signed by:

Signature applied by Janice Turchin on 12/13/2007 09:12:37 AM EST

Janice M. Turchin

IRB Coordinator

Study 2

University of Central Florida

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Notice of Expedited Initial Review and Approval

From : **UCF Institutional Review Board**
FWA00000351, Exp. 5/07/10, IRB00001138

To : **Jennifer Vogel**

Date : **October 17, 2007**

IRB Number: **SBE-07-05194**

Study Title: **A Replication of Berka et. al.'s (2004) Real-Time Analysis of EEG Indexes of Alertness, Cognition, and Memory Study**

Dear Researcher:

Your research protocol noted above was approved by **expedited** review by the UCF IRB Chair on 10/17/2007. **The expiration date is 10/16/2008.** Your study was determined to be minimal risk for human subjects and expeditable per federal regulations, 45 CFR 46.110. The categories for which this study qualifies as expeditable research are as follows:

4. Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed they must be cleared/approved for marketing.

7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The IRB has approved a **consent procedure which requires participants to sign consent forms.** Use of the approved, stamped consent document(s) is required. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Subjects or their representatives must receive a copy of the consent form(s).

All data, which may include signed consent form documents, must be retained in a locked file cabinet for a minimum of three years past the completion of this research. Any links to the identification of participants should be maintained on a password-protected computer if electronic information is used. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

To continue this research beyond the expiration date, a Continuing Review Form must be submitted 2 – 4 weeks prior to the expiration date. Advise the IRB if you receive a subpoena for the release of this information, or if a breach of confidentiality occurs. Also report any unanticipated problems or serious adverse events (within 5 working days). Do not make changes to the protocol methodology or consent form before obtaining IRB approval. Changes can be submitted for IRB review using the Addendum/Modification Request Form. An Addendum/Modification Request Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at http://iris.research.ucf.edu .

Failure to provide a continuing review report could lead to study suspension, a loss of funding and/or publication possibilities, or reporting of noncompliance to sponsors or funding agencies. The IRB maintains the authority under 45 CFR 46.110(e) to observe or have a third party observe the consent process and the research.

On behalf of Tracy Dietz, Ph.D., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 10/17/2007 03:31:32 PM EDT

Joanne Muratori

IRB Coordinator

APPENDIX B: INFORMED CONSENT FORMS

Study 1

Dear Participant:

We are conducting a research study to learn about how different people react to stress and distractions. You will be asked to complete three (3) questionnaires about stress and distractions. The questionnaires will take about one hour to complete.

You may choose if you would like to be in the study and you may stop at any time without penalty. Information obtained during the course of the study will remain confidential, to the extent allowed by law. The results of the research study may be published, but your name will not be used. The only persons with access to the data are the researchers.

This study may help provide more information about how some people deal with stress and respond to distractions. No compensation will be provided for participation in this project. However, the decision to give extra credit may be made by individual instructors. If you have any questions, please call me.

All data will be analyzed without direct reference to the name or identity of the individual. Data files for each participant will be coded so that the identity of participants will be protected. All data will be secured in a computer database accessible only by password in the office of the researcher. Any hard copies of data will be kept in a locked file cabinet in the researcher's office. Further, any information published in journal articles or presented at conferences will not reveal any participant names.

Please call me at (407) 719-2234 or e-mail: jjvogelwalcutt@yahoo.com. You may also reach Dr. Denise Nicholson at (407) 882-1444 or email: dnichols@ist.ucf.edu.

If you have questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Institutional Review Board, University of Central Florida, Office of Research and Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL, 32826-3246 or by telephone at (407) 823-2901.

Sincerely,
Jennifer J. Vogel-Walcutt, Ph.D.
Research Assistant

I will participate in the above study.

Participant's Name:____

Participant's Signature _________________________________ (Date) ________________

Study 2

Dear Participant:

We are conducting a research study to learn how different people react to stress and distractions during training. You will be asked to complete a series of two (3) questionnaires about stress and distractions, two (2) questionnaires about training, and one concept mapping exercise. Overall, the experiment will take about one-and-a-half hours to complete.

You may choose if you would like to be in the study, and you may stop at any time without penalty. Information obtained during the course of the study will remain confidential, to the extent allowed by law. The results of the research study may be published, but your name will not be used. The only persons with access to the data are the researchers.

This study may help provide more information about how some people deal with stress and respond to distractions. No compensation will be provided for participation in this project. However, the decision to give extra credit may be made by individual instructors. If you have any questions, please call me.

All data will be analyzed without direct reference to the name or identity of the individual. Data files for each participant will be coded so that the identity of participants will be protected. All data will be secured in a computer database accessible only by password in the office of the researcher. Any hard copies of data will be kept in a locked file cabinet in the researcher's office. Further, any information published in journal articles or presented at conferences will not reveal any participant names.

Please call me at (407) 719-2234 or e-mail: jjvogelwalcutt@yahoo.com. You may also reach Dr. Denise Nicholson at (407) 882-1444 or email: dnichols@ist.ucf.edu.

If you have questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Institutional Review Board, University of Central Florida, Office of Research and Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL, 32826-3246 or by telephone at (407) 823-2901.

Sincerely,
Jennifer J. Vogel-Walcutt, Ph.D.
Research Assistant

I will participate in the above study.

Participant's Name:____

Participant's Signature ____________________________ (Date) _______________

APPENDIX C: STUDY 2 BIOGRAPHIC INFORMATION FORM

1. **Age** _______

2. **Gender** (please circle) a. Female b. Male

3. **Race/Ethnicity** (please circle one only):
a. Caucasian b. Africa-American c. Asian-American d. Hispanic e. Other: ________________

4. **SES/combined income of house hold** (if known, please circle one only):
a. $0-29,999 b. $30,000-59,999 c. $60,000-89,999 d. $90,000 +

5. **Marital status** (please circle one only):
a. Single b. Married c. Divorced d. Widowed e. Living with partner

6. **What is your current working status?** (You may circle more than one.)
a. Staying at home b. Work full-time c. Work part-time d. Student e. Retired

7. **What is the highest degree that you have obtained?** (Please circle one only.)
a. Some High School b. High School Diploma c. Some College

d. Bachelor's Degree e. Some Graduate Experience f. Completed Graduate Degree

8. **What is your primary language?** (Please circle one only.)
a. English b. Spanish c. Other: __________________

9. **What is your hand preference?** (Please circle one only.)
a. Right-Handed b. Left-Handed c. No Preference

10. **Do you require corrected vision?** (Please circle one only.) Yes No
If so, do you wear glasses or contacts? (Please circle one only.) Yes No
And if so, are you wearing them now? (Please circle one only.) Yes No

11. **Have you ever served in the military or ROTC?** (Please circle one only.) Yes No
If so, with whom and when? ____

12. **How often do you play video games** (computer or console)? _____ hours/week

13. **How often are you on the computer**? _____ hours/week

14. **How would you describe your degree-of-comfort with computers?** (Please circle one only.)
a. Poor b. Fair c. Average d. Above Average e. Proficient

APPENDIX D: STUDY 2 VERBATIM KNOWLEDGE QUESTIONNAIRE

Developed by Gebrim, Vogel-Walcutt, & Schatz (2007)

1. **In this simulation, what does FIST stand for?** (Please circle one only.)
a. Fire Support Team b. Fleet Imagery Support Terminal c. Fleet Initial Strike Team

2. **Which one of the following items would a FIST have at their disposal?** (Please circle one only.)
a. Anti-Aircraft b. Infantry c. Long-range cannons d. Tanks

3. **Which of the FIST members is responsible for each of the following activities/duties?**

1) Assigns each target to someone on the team. (Please circle one only.)
a. FIST leader b. Forward air controller c. Forward observer artillery d. Forward observer mortars

2) Communicates with supporting units that are very accurate, but limited by fuel capacity, ammunition capacity and weather conditions. (Please circle one only.)
a. FIST leader b. Forward air controller c. Forward observer artillery d. Forward observer mortars

3) Communicates with supporting units that can shoot up to 30km. (Please circle one only.)
a. FIST leader b. Forward air controller c. Forward observer artillery d. Forward observer mortars

4) Communicates with supporting units that can shoot up to 5.5km. (Please circle one only.)
a. FIST leader b. Forward air controller c. Forward observer artillery d. Forward observer mortars

5) Coordinates the battle plan. (Please circle one only.)
a. FIST leader b. Forward air controller c. Forward observer artillery d. Forward observer mortars

6) Determines the order in which targets will be destroyed. (Please circle one only.)
a. FIST leader b. Forward air controller c. Forward observer artillery d. Forward observer mortars

7) Determines which ammunitions to use. (Please circle one only.)
a. FIST leader b. Forward air controller c. Forward observer artillery d. Forward observer mortars

8) Determines which targets to attack. (Please circle one only.)
a. FIST leader b. Forward air controller c. Forward observer artillery d. Forward observer mortars

9) Makes sure that none of our units are hit by friendly fire. (Please circle one only.)
a. FIST leader b. Forward air controller c. Forward observer artillery d. Forward observer mortars

4. **In this simulation, what role will you be playing?** (Please circle one only.)
a. FIST leader b. Forward air controller c. Forward observer artillery d. Forward observer mortars

5. **In this simulation, what will your main task be?** (Please circle one only.)
_____ a. Alert forces in the air and on land to begin combat.
_____ b. Request air support to destroy enemy forces.
_____ c. Request cannon fire to disable the enemy forces.
_____ d. Request tank support to slow down enemy forces.

6. **In this simulation, which three (3) of the following will you have to do in order to accomplish your main task?** (Please circle three.)

_____ a. Communicate the positions and types of enemy units.
_____ b. Follow enemy units.
_____ c. Identify enemy units.
_____ d. Locate enemy units.

_____ e. Shoot at enemy units.
_____ f. Surround enemy units.

7. **In this simulation, what is the communication process called?** (Please circle one only.)
a. Aim for Fire (AFF) b. Call for Fire (CFF) c. Fire at Target (FAT) d. Fire at Will (FAW)

8. **In this simulation, which piece of equipment would you use to do each of the following tasks?**

1) Figure out the coordinates of your location. (Please circle one only.)
a. Binoculars b. Clipboard c. Compass d. GPS e. Map f. Radio g. Rangefinder

2) Figure out a target's distance from you. (Please circle one only.)
a. Binoculars b. Clipboard c. Compass d. GPS e. Map f. Radio g. Rangefinder

3) Figure out in which direction a target is located. (Please circle one only.)
a. Binoculars b. Clipboard c. Compass d. GPS e. Map f. Radio g. Rangefinder

4) Inform your location to your support team. (Please circle one only.)
a. Binoculars b. Clipboard c. Compass d. GPS e. Map f. Radio g. Rangefinder

5) Inform a target's location to your support team. (Please circle one only.)
a. Binoculars b. Clipboard c. Compass d. GPS e. Map f. Radio g. Rangefinder

6) Inform your support team on how to attack an enemy unit. (Please circle one only.)
a. Binoculars b. Clipboard c. Compass d. GPS e. Map f. Radio g. Rangefinder

9. **In this simulation, which three (3) pieces of equipment will you need to use?** (Please circle three.)
a. Binoculars b. Clipboard c. Compass d. GPS e. Map f. Radio g. Rangefinder

PROCEDURAL KNOWLEDGE

1. **What is the order of events that a FIST member must follow to successfully perform his task?** (Please enumerate from 1 to 4.)
_____ a. Confirm the plan with his support team by having them repeat it back.
_____ b. Determine the target's exact location.
_____ c. Tell his support team about the FIST leader's timeline.
_____ d. Tell his support team the exact location of the target.

2. **In this simulation, what order of events do you have to follow?** (Please enumerate from 1 to 8.)
_____ a. Call your support team.
_____ b. Figure out a target's coordinates.
_____ c. Figure out your coordinates.
_____ d. Transmit a target's coordinates to your support team.
_____ e. Transmit *Danger Close*, *Trajectory* and *Splash* information to your support team.
_____ f. Transmit *Target Description*, *Method of Engagement* and *Method of Control* to your support team.
_____ g. Transmit *Warning Order* and *Location Method* to your support team.
_____ h. Transmit your coordinates to your support team.

3. **In this simulation, which is the first piece of equipment you have to use?** (Please circle one only.)
a. Binoculars b. Clipboard c. Compass d. GPS e. Map f. Radio g. Rangefinder

4. **In this simulation, which is the second piece of equipment you have to use?** (Please circle one only.)

a. Binoculars   b. Clipboard   c. Compass   d. GPS   e. Map   f. Radio   g. Rangefinder

5. **In this simulation, which is the third piece of equipment you have to use?** (Please circle one only.)

a. Binoculars   b. Clipboard   c. Compass   d. GPS   e. Map   f. Radio   g. Rangefinder

6. **In this simulation, what is the earliest time when you can declare *End of Mission*?**

a. It's the first thing that should be done.
b. Right after transmitting a target's coordinates.
c. Right after transmitting *Danger Close*, *Trajectory*, and *Splash*.
d. Right after transmitting the *Location Method* ('Polar').
e. Right after transmitting the *Method of Control* ('When Ready').
f. Right after transmitting your position.
g. Right after your support team fires.

7. **In this simulation, when will your support team fire?**

a. It's the first thing that should happen.
b. Right after declaring the *End of Mission*.
c. Right after transmitting a target's coordinates.
d. Right after transmitting *Danger Close*, *Trajectory*, and *Splash*.
e. Right after transmitting the *Location Method* ('Polar').
f. Right after transmitting the *Method of Control* ('When Ready').
g. Right after transmitting your position.

8. **In this simulation, how will you transmit your position to your support team?**

a. Click on the Binoculars, left click to figure out the direction, right click to figure out the distance, click on the radio, select the agency you'd like to talk to, enter the digits from the Binoculars, and click on 'k'.
b. Click on the Compass, right click to figure out the direction, click on the radio, select the agency you'd like to talk to, enter the digits from the Compass, and click on 'k'.
c. Click on the GPS, click on the radio, select the agency you'd like to talk to, enter the red digits from the GPS, and click on 'k'.
d. Click on the Map, right click to figure out the direction, left click to figure out the distance, click on the radio, select the agency you'd like to talk to, enter the digits from the Map, and click on 'k'.
e. Click on the Rangefinder, left click to figure out the direction, right click to figure out the distance, click on the radio, select the agency you'd like to talk to, enter the digits from the Rangefinder, and click on 'k'.

9. **In this simulation, what is the right time to transmit your position to your support team?**

a. It's the first thing that should be done.
b. Right after declaring the *End of Mission*.
c. Right after transmitting a target's coordinates.
d. Right after transmitting *Danger Close*, *Trajectory*, and *Splash*.
e. Right after transmitting the *Location Method* ('Polar').
f. Right after transmitting the *Method of Control* ('When Ready').
g. Right after your support team fires.

10. **In this simulation, how will you transmit a target's coordinates to your support team?**

a. Using the Binoculars, left click to figure out the direction, right click to figure out the distance, click on the radio, select the agency you'd like to talk to, enter the digits from the Binoculars, and click on 'k'.
b. Using the Compass, right click to figure out the direction, click on the radio, select the agency you'd like to talk to, enter the digits from the Compass, and click on 'k'.
c. Using the GPS, click on the radio, select the agency you'd like to talk to, enter the red digits from the GPS, and

click on ‘k’.

d. Using the Map, right click to figure out the direction, left click to figure out the distance, click on the radio, select the agency you’d like to talk to, enter the digits from the Map, and click on ‘k’.
e. Using the Rangefinder, left click to figure out the direction, right click to figure out the distance, click on the radio, select the agency you’d like to talk to, enter the digits from the Rangefinder, and click on ‘k’.

11. **In this simulation, what is the right time to transmit a target’s coordinates to your support team?**

a. It’s the first thing that should be done.
b. Right after declaring the *End of Mission*.
c. Right after transmitting *Danger Close*, *Trajectory*, and *Splash*.
d. Right after transmitting the *Location Method* (‘Polar’).
e. Right after transmitting the *Method of Control* (‘When Ready’).
f. Right after transmitting your position.
g. Right after your support team fires.

APPENDIX E: STUDY 2 SEMANTIC KNOWLEDGE QUESTIONNAIRE

How confident do you feel in this answer:								
-4	-3	-2	-1	0	+1	+2	+3	+4
very strongly unconfident	strongly unconfident	moderately unconfident	slightly unconfident	neither confident nor unconfident	slightly confident	moderately confident	strongly confident	very strongly confident

1. Why do you think it is important for the Forward Observer Artillery to know what the Close Air Support unit is doing?

On a scale of -4 (very strongly unconfident) to +4 (very strongly confident) how confident are you in the accuracy of your answer?

2. Mortar teams are more exposed, use smaller-caliber munitions, and do less damage than Artillery teams. But Mortar teams serve an important purpose, what do you think that is?

On a scale of -4 (very strongly unconfident) to +4 (very strongly confident) how confident are you in the accuracy of your answer?

3. Why do think its important for the Forward Observer Artillery to tell his supporting unit whether to use a high or low arching trajectory?

On a scale of -4 (very strongly unconfident) to +4 (very strongly confident) how confident are you in the accuracy of your answer?

4. If an enemy tank is rapidly approaching the FiST team, which type of munitions would be best to use against it? Why?

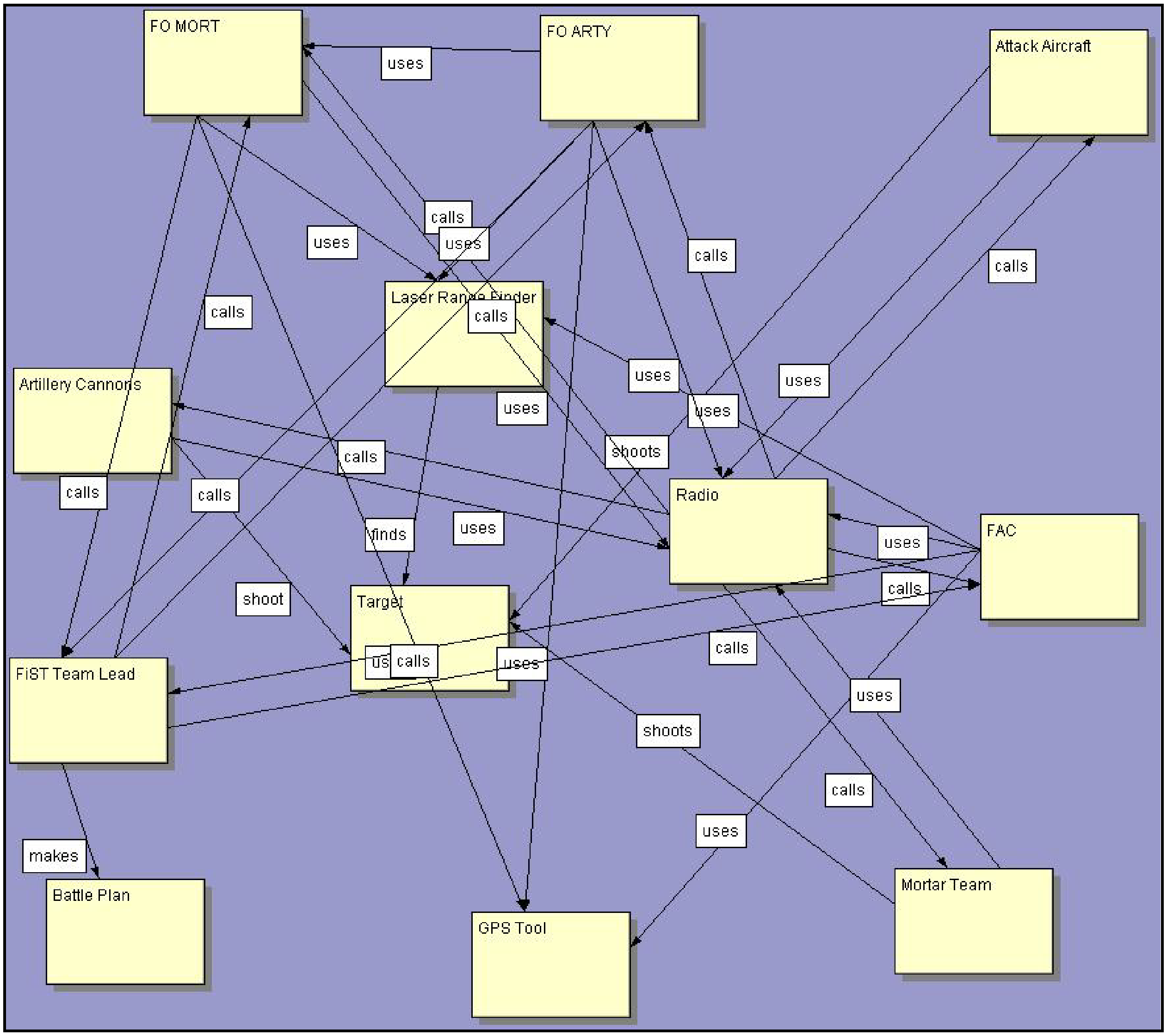
On a scale of -4 (very strongly unconfident) to +4 (very strongly confident) how confident are you in the accuracy of your answer?

5. Why is a FiST team necessary? Why don’t the supporting units simply fire in the direction of the enemy?

On a scale of -4 (very strongly unconfident) to +4 (very strongly confident) how confident are you in the accuracy of your answer?

APPENDIX F: STUDY 2 EXPERT CONCEPT MAP

Developed by Sciarini, Schatz, & Vogel-Walcutt (2008)



APPENDIX G: NASA-TLX

Figure 8.6

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

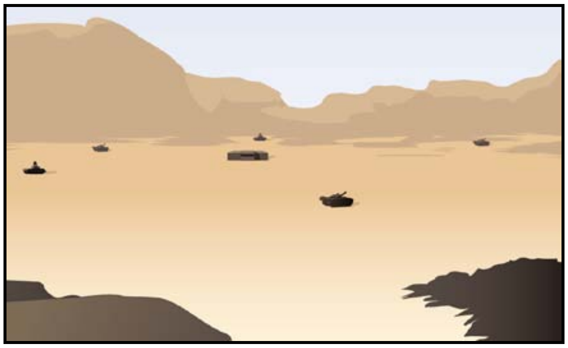
Effort — How hard did you have to work to accomplish your level of performance?

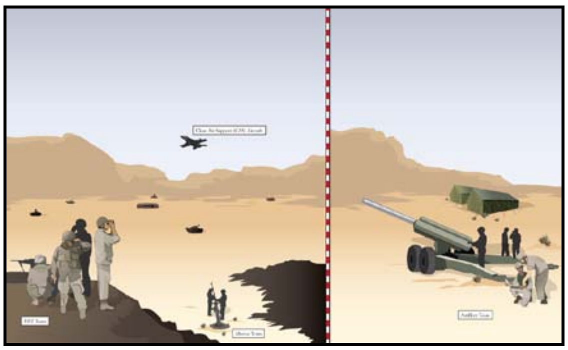
Very Low — Very High

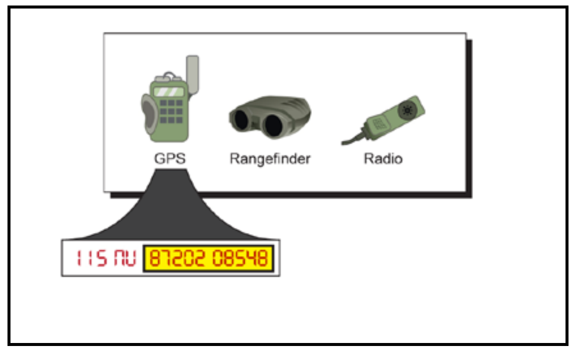
Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

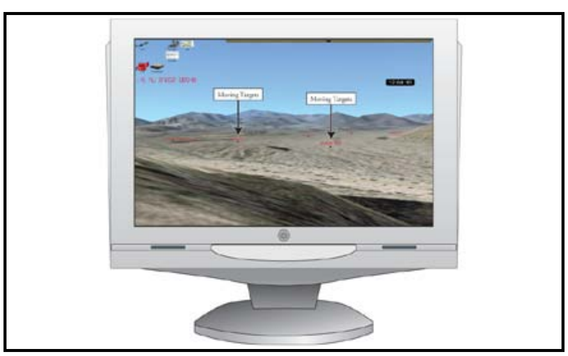
APPENDIX H: SCREEN CAPTURES OF THE TRAINER (STUDY 2)

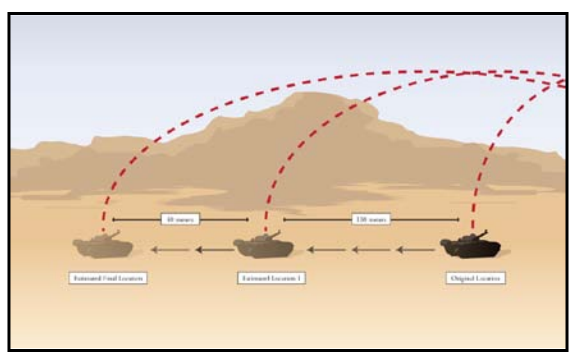





GPS
Rangefinder
Radio
115 NU 87202 08548


TARGET# 1





APPENDIX I: DEBRIEF FORMS

Study 1

Debrief

Screening Ability: A Meta-Analysis

Thank you for participating in this research study. This study was conducted so that we may combine the current questionnaires used to study screening ability into one improved and shortened version. In the future, we hope to use this scale with military recruits to determine if different educational strategies would be beneficial for those with low versus high screening abilities. If you would like more information about this study or questionnaire, please feel free to contact us at any time:

Clint Bowers, Ph.D., phone 407-823-1733, or bowers@mail.ucf.edu

Jennifer Vogel-Walcutt, phone 407-882-1366, or jvogel@mail.ucf.edu

Study 2

Debrief

Trait Arousability and Training Performance

Thank you for participating in this research study. This study was conducted so that we may examine the ways different people react to over-stimulating (or "distracting") training situations. In the future, we hope use the results from this study to help train military recruits more effectively and efficiently. If you would like more information about this study or questionnaire, please feel free to contact us at any time:

Clint Bowers, Ph.D., phone 407-823-1733, or bowers@mail.ucf.edu

Jennifer Vogel-Walcutt, phone 407-882-1366, or jvogel@mail.ucf.edu

APPENDIX J: COPYRIGHT PERMISSION

For Hardy & Parfitt's Catastrophe Model

Subject: FW: Permission to use figure (for dissertation)
Date: Wed, 14 May 2008 10:15:13 +0100
From: "Jasmin Sore" <Jasmin.Sore@bps.org.uk>
To: <sae@cs.ucf.edu>

Dear Sae

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