Moving Vigilance Out of the Laboratory: Dynamic Scenarios for UAS Operator Vigilance Training

Tarah Daly[1(✉)], Jennifer Murphy[1], Katlin Anglin[1], James Szalma[2], Max Acree[3], Carla Landsberg[4], and Laticia Bowens[4]

[1] Quantum Improvements Consulting, Orlando, FL, USA
{tdaly, jmurphy, kanglin}@quantumimprovements.net
[2] University of Central Florida, Orlando, FL, USA
james.szalma@ucf.edu
[3] GameSim, Orlando, FL, USA
max.acree@gamesim.com
[4] Naval Air Warfare Center Training Systems Division, Orlando, USA
{carla.landsberg, laticia.bowens}@navy.mil

Abstract. Our technology laden world continues to push the limits of human cognitive performance. Human performers are increasingly expected to assume roles of passive monitors rather than active engagers of technology systems [1]. Active and physical tasks have shifted to more sedentary tasks requiring significant cognitive workload at a rapid pace. Consequently, researchers and academics alike struggle to find a balance between effective user interface, usability, and ergonomic designs that will allow the performer to successfully complete their tasks while sustaining attention in these complex environments. It is no surprise that human error is at the root of tragic mishaps relating to vigilance across a wide range of applications and operational environments [2–4].

Researching vigilance is not new [5–7]. In fact, vigilance has been studied in laboratory settings for nearly seventy years across many conditions and tasks [8]. Traditional laboratory tasks involve static displays with simple image targets presented to individuals over prolonged periods of time. Participants are required to detect rare and temporally spaced targets among abundant "noise" images while sustaining their attention. The results using these vigilance tasks have found evidence of vigilance decrements, increased stress [7], and high cognitive demand [9]. The issue of training the skill to sustain attention has also been addressed [10, 11]. Findings from traditional research show that the most effective way of improving vigilance performance is through providing feedback in the form of knowledge of results [12].

Although the contrived, laboratory-based vigilance tasks can produce and mitigate the vigilance decrement, tasks that directly relate to complex operational environments are severely underrepresented in research. There have only been few researchers that utilize dynamic environments in vigilance research. For example, Szalma et al. [13] developed a video game-based training platform with the goal to extend the traditional vigilance training paradigm to complex, dynamic, and virtual environments that are more representative of visual detection tasks in the real world. Our current research is focused on extending

© Springer International Publishing AG 2017
D.D. Schmorrow and C.M. Fidopiastis (Eds.): AC 2017, Part II, LNAI 10285, pp. 20–35, 2017.
DOI: 10.1007/978-3-319-58625-0_2

the vigilance training paradigm to operationally relevant areas with the development of a game-based system for training operator attention within unmanned aerial systems (UAS).

UAS are an integral part of mission operations within many branches of our military. New developments and improved technology allow extended mission operations of UAS up to, and exceeding 12 h. However, many UAS mishaps are the result of mechanical failures, and an alarming rate – 60.2% – of mishaps have been attributed to operator error [2]. This finding is not surprising, as UAS operations are highly cognitively demanding. Prolonged shiftwork and surveillance missions require sustained attention toward tracking or identifying rare targets, often in visually degraded conditions. This paper discusses current efforts to take the vigilance training paradigm out of the laboratory setting and into operational environments, including our current work in creating game-based training of vigilance for UAS operators. We describe the challenges associated with defining and standardizing targets, developing scenarios, and assessing performance.

Keywords: Vigilance · Game-based training · Sustaining attention · Vigilance decrement · Operational environment · UAS training · Game attributes

1 Introduction

Technological innovations, those which purport to improve human performance, allow operators to extend work hours significantly, and keep operators safe in hostile or extreme environments are increasingly pushing humans to assume roles of passive monitors within technology systems [1]. This shift, while certainly allowing the extension of human capabilities in some regards, has left the operator in a state of required sustained attention, under alerted conditions, to perform vigilance tasks. Vigilance refers to the ability to sustain attention for rare, temporally spaced signals among noise over prolonged periods of time. As time on task progresses, performance tends to decline as difficult task requirements decrease engagement and increase distress [7]. It is no surprise that human error is at the root of tragic mishaps relating to vigilance across a wide range of applications and operational environments [2–4].

Many occupational and operational settings require operators to perform vigilance tasks. Air traffic controllers, Transportation Security Administration (TSA) agents, and nuclear power plant controllers are more obvious occupations requiring continuous monitoring of information. However, other operational environments require extreme vigilance including unmanned aerial systems operations. Improved technology allows extended mission operations of UAS up to, and exceeding, 12 h. While many UAS mishaps are the result of mechanical failures, an alarming rate – 60.2% – of mishaps have been attributed to operator error [2]. Real-world data suggest that the vigilance paradigm observed in the laboratory is a phenomenon occurring in operational settings as well, and poses a significant threat to the safety and wellbeing of individuals in the real-world.

1.1 Training for Vigilance

Vigilance has been studied in laboratory settings for nearly seventy years [8] across many conditions and tasks. A consistent finding in this research is the *vigilance decrement,* in which performance on tasks that require vigilance declines over time. Traditionally, laboratory vigilance tasks involve a response to a relatively rare target over a lengthy period of time. The vigilance decrement usually occurs within the first 15 min of task performance, however, if the task is sufficiently cognitively demanding, it can take as little as five minutes for performance to decline [9]. While this effect has been historically interpreted as a decline in arousal, research investigating perceived workload and task induced stress show that vigilance tasks are in fact very stressful to the participant [7]. Thus, the vigilance decrement can be attributed to the high cognitive demands of the task. Under an Army effort investigating vigilance in route clearance missions, it was found that Warfighters are aware of these strains and attempt to mitigate them with energy drinks, cigarette smoking, and other stimulants [14].

Research shows that vigilance depends upon a combination of participant characteristics, environmental conditions, and task characteristics and performance varies widely from person to person [15]. In a previous Army Research Institute (ARI) study, performance on a vigilance task predicted peer ratings of Soldiers' intelligence, decision-making ability, attentiveness, and resilience [16]. Vigilance also depends upon the physiological state of the participant; arousal may be influenced by stimulant use, fatigue, time of day, and numerous other factors. Importantly, the extent to which a participant exhibits relatively high levels of vigilance has been found to predict performance in game platform-based training for Warfighter tasks [16]. Environmental conditions could include stimulant usage, sleep, or time of day which have been shown to affect vigilance performance [17, 18]. Additionally, task characteristics refer to vigilance task parameters and these range from static, laboratory-based tasks, dynamic stimuli within videogame-based environments, or even feedback presented to the trainee during or after a vigil.

There have been substantial research efforts to identify effective training methods for vigilance. Research indicates that the most effective way of improving sustained attention is through performance feedback in the form of knowledge of results (KR) (for early reviews see [12, 19]). KR has been shown to improve operators' perceptual sensitivity (the ability to discriminate signal from nonsignal; [20]). Early research demonstrated that providing feedback regarding performance outcomes (i.e., detections, false alarms, missed targets, or response time) improved performance during both a training session where feedback on these outcomes is provided as well as in a test or transfer session in which the feedback is withdrawn. The transfer of training to a test vigil is commonly used to establish that skill retention (i.e., learning) is a result of training intervention (in this case, feedback in the form of KR) rather than due to the immediate performance support afforded by the intervention itself during the training session [21].

Several studies have shown that KR training can improve vigilance, but there has been some debate regarding whether KR effectiveness is due primarily to operator motivation or to learning mechanisms. There is evidence to support both perspectives. Mackworth [22] demonstrated that performance improvement can be achieved using false feedback, i.e., feedback provided on a random schedule that provides no accurate information regarding performance, pointing to KR's motivational influences (see [23, 24]). Later studies established that performance can be improved by the use of partial KR schedules (KR only provided some of the time), goal setting interventions, or providing monetary awards in addition to KR [25–29]. These findings support a motivational explanation.

There is also evidence to support a non-motivational role for KR. Much of this evidence derives from evaluation of the transfer of training from one task to another. The nature of the vigilance task itself has been found to moderate differences in performance. Vigilance tasks may be categorized into those requiring successive discriminations and those requiring simultaneous discrimination. In successive discrimination tasks the observer must compare a stimulus event against a standard in memory (absolute judgment), and in simultaneous discrimination tasks the observer must compare a stimulus element to another element present in the display (comparative judgment). If KR effectiveness were due only to increasing motivation, then task type should not affect transfer. However, research has shown that training on a task requiring simultaneous or a successive discrimination transfers to a criterion task within the same task type but not across types [10, 11]. These findings suggest a strong learning component to vigilance training using this paradigm. The task specificity of vigilance training has important implications for training the vigilance component of any task. To maximize the effectiveness of SkySpotter, it is important to replicate the sorts of tasks end users will be performing in the operational setting.

1.2 Vigilance Training in Simulated Environments

The research summarized above describes training for vigilance as it has been traditionally examined in a laboratory setting. In these experiments, participants view static displays that feature simple targets in order to maximize experimental control. While these paradigms have been effective in inducing a vigilance decrement, they do not capture the complexity of the operational environment. As sustaining attention becomes more difficult as cognitive demands increase, a true understanding of how vigilance works in the real world is required. Further, because previous research shows successful training transfer depends upon the extent to which a training task mirrors the transfer task, it is imperative to accurately represent operator tasks.

Under an ARI funded effort, Szalma and colleagues [13] developed vigilance training in a videogame-based platform. The goal of this research was to extend the traditional vigilance paradigm to a dynamic, complex virtual environment that more accurately represents the visual detection tasks required of route clearance personnel engaged in improvised explosive device (IED) detection. The primary challenge the team faced was developing scenarios that were sufficiently boring and monotonous to induce a vigilance decrement despite the engaging and motivating aspects characteristic of game-based training platforms. An additional challenge was to design scenarios in such a way to define consistent, equivalent "trials," which is required in order to examine the degradation of performance over time. To accomplish this goal, scenarios were designed in which participants engaged in a virtual dismounted route clearance mission. Movement was limited to guided navigation at a steady pace, effectively putting the participant "on rails." The participant's goal was to identify suspicious targets known to be indicators of IEDs (e.g. fuel cans, command wire, pressure plates) that appeared sporadically throughout the scenario. The participant received KR feedback about the accuracy of their response: "Correct" for a correct detection, "Miss" for a missed target, and "False Alarm" for a response when no target was present. Figure 1 depicts screenshots of a correct identification and sample feedback.

Fig. 1. Screenshots from Vigilance Training Module in VBS2 [13]

After participants completed the training phase in which feedback was presented, transfer was assessed by completing a similar scenario with no feedback. Interestingly, these participants did not exhibit a vigilance decrement, either during training or transfer. However, scores on measures of perceived workload and stress indicated task engagement declined over the course of the training, while distress and avoidant coping increased, a finding consistent with previous vigilance research [8]. Importantly, participants who received feedback in terms of KR outperformed those who did not, identifying more targets and responding more quickly. These findings hold promise for the development of videogame-based training for UAS operators.

1.3 Videogame-Based Training

The use of videogame-based simulation by the military has steadily increased as these technologies have improved in popularity, fidelity, and accessibility. Videogame-based platforms are typically used for training purposes within a military context and provide an inexpensive, flexible means of introducing Soldiers to a variety of domains. The effectiveness of videogame-based platforms for training has been demonstrated for a variety of cognitive skills and abilities [30]. Skills acquired have been shown to transfer to external tasks, particularly if the skills and abilities required to succeed in the game and the transfer task are consistent [31].

There is an important distinction between training using a videogame-based platform and training using "serious games." Typical military applications of game-based training platforms, such as VBS2 and *America's Army*, provide a moderate level of fidelity in a low-cost desktop simulation. These applications are not truly "games" as they lack many of the attributes of games that provide an engaging, motivating experience. In his review of game-based training, Hays [32] defines a game as "an artificially constructed, competitive activity with a specific goal, a set of rules, and constraints that is located in a specific context." Wilson et al. [33] provide an extensive review of these game attributes, and consider the most important to be fantasy, representation, sensory stimuli, challenge, mystery, assessment, and control. These attributes determine the extent to which a game is, among other things, fun.

Our goal with SkySpotter is to develop a true game. A hallmark of vigilance tasks is the extent to which they induce stress, high cognitive workload, and decreased motivation. Consequently, these tend to be tasks that individuals avoid. For vigilance training to be maximally effective, trainees must continue to practice in order to maintain their skill level. Our aim is to develop a program that is challenging enough to be effective but also engaging enough that trainees will continue to put effort into developing their vigilance skills despite the stress or other negative emotions they may feel.

1.4 Adaptive Training Technology

Adaptive training has been defined as the personalization of training content during the course of instruction to the individual student, based on an assessment of that student's knowledge, abilities, experiences, and/or skills [34]. The Navy, as well as the other services, is increasingly interested in implementing adaptive training technologies as a means of providing effective learning experiences while reducing costs. To date, most adaptive training interventions have focused on improving the learner's understanding of a particular knowledge domain, such as math (e.g., [35]), conceptual science (e.g., [36]), or vocabulary (e.g., [37]). Adaptive training tends to be more effective for well-defined domains in which there is a "right" answer to a problem. In these cases, adaptive techniques tend to involve manipulating the challenge or complexity of information based on a real-time assessment of student understanding. Such techniques include scaffolding [38, 39], fading of worked examples [40–42], and comprehension gauging [39, 43–45], among others.

Unlike knowledge-based domains, sustained attention is a cognitive skill. Adaptive algorithms have been successfully used in training programs for cognitive and perceptual skills. In these paradigms, the difficulty of a discrimination or similar task is manipulated based on an ongoing assessment of the trainee's performance. While these programs have shown improvement in trainee performance, the extent to which the adaptation itself provides a benefit is unclear [46–48]. This is likely because the costs associated with developing adaptive and non-adaptive versions of the same training simply for research purposes are prohibitive [49]. Further, there is little opportunity to evaluate long-term benefits of these programs and generalize the empirical evidence of adaptive training to complex environments [50].

In addition to real-time adaptations, macro-level adaptive strategies can be employed in order to determine placement within a training program, adjust content format, or appropriate level of control. These adaptations are often based on learner characteristics related to performance, such as aptitude, personality, and learning style. Because individual differences are suggested to influence the effectiveness of training instruction, content, feedback, and difficulty, these variables may be critical in determining how and when to adapt training [50]. In the context of vigilance, age, physiological state (e.g. fatigue and stress), learning difficulties (e.g. ADHD), and other characteristics influence an individual's ability to sustain attention.

Elements of adaptive training will be applied to SkySpotter to support individualized approaches to ongoing assessment of performance with the use of the system. Macro-level adaptions will be leveraged to place trainees, pre-task, based on predictor variables such as participant characteristics (individual differences) and environmental factors. Adaptive placement will provide opportunities for trainees to experience task challenges and appropriate levels of effort and stress while not feeling overwhelmed and disengaged. The goal is to achieve maximal motivation so trainees feel compelled to return to training for challenges, personal achievement, and improved performance.

2 Current Research

Presently, work is being conducted for the design and development of a videogame-based adaptive attentional training platform for UAS operators under an effort supported by the Naval Air Warfare Center Training Systems Division (NAWCTSD). SkySpotter is the current effort researching the effectiveness of vigilance training within a videogame-based platform. While previous research has leveraged dismounted, ground-based environments [13] this domain is novel. However, the innate characteristics of vigilance tasks remain consistent within this instantiation of dynamic, operationally relevant work.

UAS long-duration mission operations are the primary point of concern, given the expanded capabilities of more technologically sound unmanned aircraft. Current and new UAS will allow for prolonged mission duration up to, and even exceeding, 12 h. This extended operational environment causes UAS operators to work in extreme, alerted conditions, while expected to perform at optimal levels. To maintain training gains, it is imperative that trainees maintain continued practiced and while improvements in vigilance can be found after just one session, sustained attention is a perishable skill. Therefore, it is imperative that a sound, scientifically-based, effective training system be available to UAS operators at all times, to improve their ability to sustain attention.

SkySpotter is a web-based training program composed of four core functionalities: a pre-training assessment, vigilance training scenarios, a test scenario, and a profile. The pre-training assessment is designed to capture state, trait, and demographic characteristics, predictor variables that could have an effect on vigilance performance. The vigilance training scenario and test scenarios simulate a UAS performing a sweep of an area, a geo-typical middle eastern terrain. The scenarios follow a very precise prescription for target and environmental elements so that vigilance performance may be evaluated with the same laboratory scrutiny. Finally, a user profile tracks performance progression through training. Not only will data be collated here to provide trainees feedback and after action review (AAR), data will drive adaptive training elements as well.

2.1 Predictor Variables

Vigilance depends upon a combination of participant characteristics, environmental conditions, and task characteristics. Vigilance also depends upon the physiological state of the participant; arousal may be influenced by stimulant use, fatigue, time of day, and numerous other factors. Importantly, the extent to which a participant exhibits relatively high levels of vigilance has been found to predict performance in game platform-based training for Warfighter tasks [16]. As such, research suggests that it is possible to predict vigilance (e.g., [36, 51–54].

Traits, characteristic behaviors and attitudes that are long-term and consistent, that predict vigilance include personality (extroversion, conscientiousness, and neuroticism/trait anxiety; [51]), cognitive skills (working memory and spatial ability; [51, 52]), and fatigue proneness (propensity for sleepiness and boredom; [54]).

States, temporary behaviors or attitudes that depend on a person's situation at a specific time, have also been identified to predict vigilance. State variables of interest include stress/coping and sleepiness (different from fatigue proneness). Subjective state and coping dimension questionnaires are typically used to identify elements that reduce task engagement, leading to vigilance decrements. Sleepiness has been found to impair vigilance. Usually occurring during night shifts, sleepiness is more prevalent at the end of the night [55], as there are significant correlations between errors and subjective sleepiness [18]. Sleep restriction may also contribute to sleepiness and vigilance decrements, greatly impacting response time and alertness.

Environmental influences are variables such as stimulant consumption, time of day, and sleep the previous night. To maintain vigilance, stimulants are often used to enhance performance and attention. A 32-mg dose of caffeine, which is equivalent to the amount of caffeine in a typical cola drink and less than that of a cup of coffee, improved auditory vigilance hit rates and visual reaction time [17]. Caffeine given in the early morning also improved overall vigilance performance during late morning [56].

Additional items for consideration include demographics information such as age, academic achievement, videogame experience, etc. While age is found to influence vigilance, performance was more variable among older adults as stimulus degradation increased and the vigil progressed [57]. Furthermore, vigilance is associated with video game experience. Research has found that videogame players (VGPs) outperform non-video game players (NVGPs) in attention and visual search that are most commonly used during vigilance tasks [58–60].

2.2 Scenario Elements (Training and Test Vigils)

Researching vigilance in a dynamic, videogame-based environment is relatively novel. Only a few have performed this work in the past [13, 16]. In order to scientifically evaluate vigilance performance within a novel platform, one must validate that the vigilance paradigm is being replicated in that environment. Distinct paradigm parameters include rare and temporally spaced targets separated by "noise" or distractor elements (context and environment specific), sufficient task length (vigilance decrements have been seen in a little as five minutes [9]), and the phenomenon known as the vigilance decrement, when performance declines as time on task or task difficulty increases [61].

A review of literature and publicly available doctrine and handbooks was conducted as well as interviews with a subject matter expert. This requirement collection procedure informed content and environment creation for the vigils (both training and test scenarios). Most notably, SME input informed targets of interest to include that would be both operationally relevant and effective for vigilance training within the UAS context. In addition to targets, environmental conditions (e.g., smoke, fog, rain), distractors (e.g., civilians), and other contextually relevant information were included in scenario development. The scene in which trainees will view content consists of a bird's eye view through a clear scope (natural eye view) whereby the rural geo-typical middle eastern terrain will pass by. Buildings, vehicles, people, animals, foliage, and terrain features will also be included.

Following laboratory based vigilance tasks, training scenarios typically employ KR while test vigils remove this feedback to gauge transfer of training [19]. Following this approach, training scenarios within SkySpotter display KR, real-time feedback of trainee performance, while the test vigils do not provide KR. Scenario length must be sufficiently long enough to capture performance decrements while also providing time to collect performance data across time on task. Additionally, target appearance should be relatively random throughout the scenarios and follow parameters previously set by Szalma and colleagues [13]. The duration of the scenario should consist of distinct epochs of time in which targets are randomly selected to appear within the scene. Speed through the scene should accommodate target appearance interval time to allow the target to remain onscreen from moment of visibility (through line of sight) for a short variable duration. Only one target will be presented on screen at a time, such that as soon as the current target flows off screen, the next target shall appear in the allotted epoch of time. Targets should be a mixture of all variable types (those selected for inclusion in the scenario). These parameters cause trainees to remain alerted to scenario elements while looking for targets on screen (there are no repeated elements and trainees cannot anticipate what will come on screen).

Game elements are an additional feature included in the scenarios that are not typical to laboratory-based vigilance tasks. For this effort, game features were an important part in developing a true vigilance training game. Since vigilance tasks tend to induce stress, high cognitive workload, and decreased motivation, trainees are likely to abandon or avoid the training system. However, with the inclusion of game elements, the goal was to develop a program that is challenging enough to be effective but also engaging enough that trainees will continue to use the system in order to develop their vigilance skills despite stress they may feel. Gameplay aspects including a storyline and mission, leveling, engaging characters, performance goals, mystery, and consistent style will be utilized to maximize immersion and presence.

2.3 Performance Tracking

In order to instantiate adaptive training within SkySpotter, the system will collect various demographic and performance metrics across training sessions to utilize in providing a tailored training experience. First time users will be presented with an introduction and tutorial to system functionality and game play. However, subsequent game play will be based on quick state assessments captured at the beginning of a training session. The predictor variables collected will inform the system of which training level a trainee will encounter. Levels vary in difficulty (e.g., target type, target rate, signal-to-noise ratio, speed of presentation, etc.). The system will recommend a level to trainees based on current state and past performance (percent correct, positive predictive power, etc.). Once in a level, real-time feedback will be presented across training vigils (i.e., hits, misses, and false alarms) and users will be shown a summary screen of their performance at the end of a completed session (e.g., KR, percent correct score, and feedback). Various performance metrics across time can be accessed through the user profile at any time (e.g., last session, last session score, current level, current score, improvement over time, etc.).

2.4 Research Questions

There are challenges associated with providing a novel platform to train vigilance tasks. For one, the dynamic environment must be created to afford the replication of the vigilance performance decrement and other salient vigilance paradigm parameters. Additionally, unique challenges also occur with performance metrics themselves. How would one evaluate a simultaneous false alarm and miss? Static vigilance tasks would not allow this type of behavior to occur. Not only do our research questions focus on the design and validation of a videogame-based adaptive training platform for vigilance, we also consider the effectiveness of the training delivery system once developed. There are five major steps for experimentation in support of the development of SkySpotter. Following a prescription of experimental scenario development, we can hope to address some of the more unique challenges associated with the use of dynamic environments.

2.4.1 Identify a Target Set

First, we must identify a set of potential targets. Although the final number of targets for inclusion in the scenario may between 5–7, more should be identified in this step in case some selected targets do not have the desired psychophysical properties (too small and can't be seen, too salient and always seen, etc.). Work toward this step has already been accomplished. Based on SME interviews we have identified a list of several targets that can also be modified for additional permutations of the base target.

Identification of non-target objects with features that are similar to those of targets must be performed. Non-target objects can potentially be used as "distractors" and will provide greater flexibility in manipulating task difficulty (civilians, animals, buildings, miscellaneous everyday objects, etc.). Distractor objects will be used to fill the environment within the scenario with sufficient "noise". Additionally, distractor objects will give the scenario a more realistic and operationally relevant context.

Environmental features must also be identified for scenario development, specifically target placement within the scenario. Targets that come on screen should not just appear. They should slowly come into view as they would in a real-world context.

Large objects or structures that can occlude targets and non-targets will be placed strategically so that target/non-target objects may emerge from behind them.

2.4.2 Create Testing Clips

Parameters surrounding the game environment, specifically for UAS operations include altitude and speed. A selection of 3–5 levels of altitude should be considered as well as 3–5 levels of speed. Testing can be accomplished with the creation of brief clips of movement through the environment. The set of clips should represent the range of environments under consideration for use in the scenarios. A sufficiently large set of clips would allow a selection of a random sample to control for environmental variations. This step would also strengthen any inferences we make regarding the psychophysical characteristics of the target and non-target stimuli.

An equal number of clips should be created for each combination of altitude and speed and each should contain sufficient clutter to prevent easy target identification. Impoverished environments would make it difficult to control task difficulty. Target placement would need to remain identical throughout each clip. When feasible, a third version of each clip can be created in which a non-target is placed at the same location. This step allows researchers to evaluate target control specifications. After a set of targets has been identified, a set of locations throughout the scenario (with occlusion and non-target influences to keep in mind) should then be selected. These locations, however, should be held constant across varying altitudes and speed clips. The number of target placement locations should be sufficiently large so that a randomly sampled selection can be treated as a random effects variable. In past instantiations of videogame-based vigilance tasks, computer software selected targets (from a pool of available targets) at a given location across an epoch of time. It is likely that will be executed here as well.

2.4.3 Establish Psychophysical Parameters of the Task

It is necessary to establish the psychophysical parameters of the task to avoid either floor or ceiling effects during the target detection task. To do so, a two-alternative forced choice (2AFC) procedure will be conducted to establish how variations in target type, presence of distractors, altitude, and speed of movement affect detectability of targets under alerted conditions. In this procedure, a trial consists of two versions of stimuli that are presented sequentially. On each trial, one stimulus always includes a target to be detected and the other stimulus is the identical environment but without the target present. The observer's task is to decide whether the target was presented first or second. The 2AFC procedure permits evaluation of the discriminability under alerted conditions because the participant knows that a target is presented on each trial and decides when in the sequence that target was presented. The iterative approach to stimulus development provides stronger empirical evidence for the validity of the stimulus parameters used in developing the vigilance task.

2.4.4 Develop and Validate the Vigilance Task

Once psychophysical parameters have been established, task and stimuli identified should be adopted to create a full vigilance task of 15–30 min. A sufficient duration will induce monotony. The changing environment should not appear novel. Without the monotony element, it may be difficult to establish this as a vigilance task.

To validate the vigilance task, an evaluation on performance decrements and trainee stress and workload need to be conducted. If the performance decrement was induced and trainee stress and workload are high, this provides a strong argument that the task is a vigilance task as it contains paradigm features seen in laboratory vigilance tasks and research. If indicators emerge that indicate performance is not declining as time on task increases there are several ways to manipulate the task. These manipulations include altering and editing stimuli and target/non-target parameters to better accommodate the performance decrement.

Lastly, gamification needs to the tested for motivational effects. Game elements can be tested by adding them in systematically or simultaneously and evaluating performance, workload, and stress associated with the task. Developing game elements will need to consider the vigilance requirement that always needs to remain present (i.e., continuous demand to monitor the environment for targets over prolonged watch periods). Other items for consideration include manipulating motivational variables to determine their effects on the outcome measures. This includes instructional manipulations and game rules and structure that facilitate autonomous motivation and an experience of competence in game-play, as well as instructions and a game environment that convey the importance of the task. If a person has a good rationale for why a task is important they tend to experience stronger autonomous motivation for it even if the task is boring. KR effects should also be tested. This could be done in tandem with gamification, or as a separate step prior to gamification. The latter approach would determine whether the vigilance task we develop shows typical training effects when using KR. The latter approach would test the effects of KR in the context of the gamified version. Testing KR effects would involve manipulating the provision of feedback during a training phase, and then testing all participants in a transfer phase consisting of the same task without feedback.

3 Closing Remarks

Vigilance is both a laboratory phenomenon and a serious real-world issue. After approaching vigilance questions in the laboratory for over 60 years, the meticulously contrived static tasks became irrelevant in today’s fast paced, technologically advanced environment. The vigilance paradigm needed an upgrade to accommodate the study and evaluation of its effects within contextually relevant settings. Operators do not perform their tasks in isolation. They are, more often, typically observing incredible amounts of data within highly complex systems, a task that humans are not particularly good at doing. This necessitates an equally effective adaptive training solution to prepare operators for the task, provide opportunities for remediation of skill degradation, and encourage optimal performance through maintained gains.

Leveraging state-of-science contributions in the novel exploration of vigilance using videogame-based platforms, SkySpotter aims to provide engaging and effective adaptive vigilance training to UAS operators. Following a careful prescription of target element and scenario parameters, SkySpotter can be used to perform effectiveness evaluations on the vigilance paradigm itself (performance decrements, stress, and workload), gamification, and vigilance gains with use of the system compared to those who are not receiving adaptive vigilance training. This gamified vigilance platform provides a way to answer many research questions regarding vigilance in the real-world while offering solutions to current and emerging critical issues in the operational landscape today.

References

1. Hancock, P.A.: Mind, Machine, and Morality: Toward a Philosophy of Human-Technology Symbiosis. Ashgate Publishing, Burlington (2009)
2. Tvaryanas, A.P., Thompson, B.T., Constable, S.H.: U.S. military unmanned aerial vehicle mishaps: assessment of the role of human factors using HFACS. Technical report, Brooks City-Base, TX, USAF Human Performance Directorate (2005)
3. Reinach, S., Gertler, J.: An examination of railroad yard worker safety. Technical report. U.S. Department of Transportation (2001). https://www.fra.dot.gov/Elib/Document/2938
4. Reinerman-Jones, L., Matthews, G., Mercado, J.E.: Detection tasks in nuclear power plant operation: vigilance decrement and physiological workload monitoring. Saf. Sci. **88**, 97–107 (2016)
5. Parasuraman, R., Davies, D.R.: A taxonomic analysis of vigilance performance. In: Mackie, R.R. (ed.) Vigilance: Theory, Operational Performance, and Physiological Correlates. Plenum Press, New York (1977)
6. See, J.E., Howe, S.R., Warm, J.S., Dember, W.N.: Meta-analysis of the sensitivity decrement in vigilance. Psychol. Bull. **117**(2), 230–249 (1995)
7. Warm, J.S., Parasuraman, R., Matthews, G.: Vigilance requires hard mental work and is stressful. Hum. Factors **50**(3), 433–441 (2008)
8. Mackworth, N.H.: The breakdown of vigilance during prolonged visual search. Q. J. Exp. Psychol. **1**, 6–21 (1948)
9. Helton, W.S., Dember, W.N., Wann, J.S., Matthews, G.: Optimism, pessimism, and false failure feedback: Effects on vigilance performance. Curr. Psychol. **18**, 311–325 (2000)
10. Becker, A.B., Warm, J.S., Dember, W.N.: Specific and nonspecific transfer effects in training for vigilance. In: Mouloua, M., Parasuraman, R. (eds.) Human Performance in Automated Systems: Current Trends, pp. 294–299. Erlbaum, Hillsdale (1994)
11. Szalma, J.L., Miller, L.C., Hitchcock, E.M., Warm, J.S., Dember, W.N.: Intraclass and interclass transfer of training for vigilance. In: Scerbo, M.W., Mouloua, M. (eds.) Automation Technology and Human Performance, pp. 183–187. Erlbaum, Mahwah (1999)
12. Mackworth, J.F.: Vigilance and Attention: A Signal Detection Approach. Penguin, Middlesex (1970)
13. Szalma, J.L., Schmidt, T.N., Teo, G.W., Hancock, P.A.: Vigilance on the move: video game-based measurement of sustained attention. Ergonomics **57**(9), 1315–1336 (2014)
14. Schweitzer, K.M., CuQlock-Knopp, V.G., Klinger, D.K., Martinsen, G.L., Rodgers, R.S., Murphy, J.S., Stanard, T.W., Warren, R.: Preliminary research to develop methodologies for identifying experts in the detection of Improvised Explosive Devices (IEDs): Phase I. Technical report, Aberdeen Proving Ground, MD. Accession number: ADB337683 (2008)
15. Ballard, J.C.: Computerized assessment of sustained attention: a review of factors affecting vigilance performance. J. Clin. Exp. Neuropsychol. **18**, 843–863 (1996)

16. Murphy, J.S.: Identifying experts in the detection of improvised explosive devices: IED2 Technical report, TR 1269, Arlington, VA (2010)
17. Lierberman, H.R., Wurtman, R.J., Emde, G.G., Roberts, C., Coviella, I.L.: The effects of low doses of caffeine on human performance and mood. Psychopharmacology **92**(3), 308–312 (1987)
18. Manly, T., Huetink, J., Evans, K., Woldt, K., Robertson, I.: Rehabilitation of executive function: facilitation of effective goal management on complex tasks using periodic auditory alerts. Neuropsychologica **40**, 271–281 (2002)
19. Davies, D.R., Tune, G.S.: Human Vigilance Performance. American Elsevier, Oxford (1969)
20. Szalma, J.L., Hancock, P.A., Warm, J.S., Dember, W.N., Parsons, K.S.: Training for vigilance: using predictive power to evaluate feedback effectiveness. Hum. Factors **48**(4), 682–692 (2006)
21. Salmoni, A.W., Schmidt, R.A., Walter, C.B.: Knowledge of results and motor learning: a review and critical reappraisal. Psychol. Bull. **95**, 355–386 (1984)
22. Mackworth, J.F.: The effect of true and false knowledge of results on the detectability of signals in a vigilance task. Can. J. Psychol. **18**, 106–117 (1964)
23. Antonelli, D.C., Karas, G.G.: Performance on a vigilance task under conditions of true and false knowledge of results. Percept. Mot. Skills **25**(1), 129–138 (1967)
24. Weidenfeller, E.W., Baker, R.A., Ware, J.R.: Effects of knowledge of results (true and false) on vigilance performance. Percept. Mot. Skills **14**, 211–215 (1962)
25. Montague, W.E., Webber, C.E.: Effects of knowledge of results and differential monetary reward on six uninterrupted hours of monitoring. Hum. Factors **7**(2), 173–180 (1965)
26. Sipowicz, R.R., Ware, J.R., Baker, R.A.: The effects of reward and knowledge of results on the performance of a simple vigilance task. J. Exp. Psychol. **64**(1), 58–61 (1962)
27. Warm, J.S., Hagner, G.L., Meyer, D.: The partial reinforcement effect in a vigilance task. Percept. Mot. Skills **23**(3), 987–993 (1971)
28. Warm, J.S., Kanfer, F.H., Kuwada, S., Clark, J.L.: Motivation in vigilance: effects of self-evaluation and experimenter-controlled feedback. J. Exp. Psychol. **92**(1), 123–127 (1972)
29. Warm, J.S., Riechmann, S.W., Grasha, A.F., Seibel, B.: Motivation in vigilance: a test of the goal-setting hypothesis of the effectiveness of knowledge of results. Bull. Psychon. Soc. **1** (5–A), 291–292 (1973)
30. Wong, J., Nguyen, A., Ogren, L.: Serious game and virtual world training: instrumentation and assessment. Naval Undersea Warfare Center Division, Newport, RI. Accession number: ADA582003 (2012)
31. Tobias, S., Fletcher, J.D., Dai, D.Y., Wind, A.P.: Review of research on computer games. In: Tobias, S., Fletcher, J.D. (eds.) Computer Games and Instruction, pp. 127–222. Information Age, Charlotte (2011)
32. Hays, R.T.: The effectiveness of instructional games: a literature review and discussion Technical report. 2005–004. Naval Air Warfare Center, Orlando, FL (2005)
33. Wilson, K., Bedwell, W., Lazzara, E., Salas, E., Burke, C., Estock, J., Orvas, K., Conkey, C.: Relationships between game attributes and learning outcomes. Simul. Gaming **40**(2), 217–266 (2009)
34. Spain, R.D., Priest, H.A., Murphy, J.S.: Current trends in adaptive training with military applications: an introduction. Mil. Psychol. **24**(2), 87–95 (2012)
35. Chien, T.C., Yunus, A.S., Ali, W.C.W., Bakar, R.: The effect of an intelligent tutoring system (ITS) on student achievement in algebraic expression. Int. J. Instr. **1**, 25–38 (2008)
36. Rosé, C.P., Jordan, P.W., Ringenberg, M., Siler, S., VanLehn, K., Weinstein, A.: Interactive conceptual tutoring in Atlas-Andes. In: Moore, J.D., Redfield, C., Johnson, W.L. (eds.) Artificial Intelligence in Education: Ai-ED in the Wired and Wireless Future, pp. 256–266. IOS, Washington, DC (2001)

37. Metzler-Baddeley, C., Baddeley, R.J.: Does adaptive training work? Appl. Cogn. Psychol. **23**, 254–266 (2009)
38. VanLehn, K.: The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. Educ. Psychol. **46**(4), 197–221 (2011)
39. Chi, M.T.H., Siler, S., Jeong, H., Yamauchi, T., Hausmann, R.G.: Learning from human tutoring. Cogn. Sci. **25**, 471–533 (2001)
40. Renkl, A., Atkinson, R.K., Maier, U.H., Staley, R.: From example study to problem solving: Smooth transitions help learning. J. Exp. Educ. **70**(4), 293–315 (2002)
41. Salden, R., Aleven, V., Schwonke, R., Renkl, A.: The expertise reversal effect and worked examples in tutored problem solving. Instr. Sci. **38**, 289–307 (2010)
42. Salden, R.J.C.M., Aleven, V.A., Renkl, A., Schwonke, R.: Worked examples and tutored problem solving: redundant or synergistic forms of support? Top. Cogn. Sci. **1**(1), 203–213 (2009)
43. Chi, M.T.H.: Active-Constructive-Interactive: a conceptual framework for differentiating learning activities. Top. Cogn. Sci. **1**, 73–105 (2009)
44. Graesser, A.C., Person, N., Magliano, J.: Collaborative dialog patterns in naturalistic one-on-one tutoring. Appl. Cogn. Psychol. **9**, 359–387 (1995)
45. Graesser, A.C., Person, N.K.: Question asking during tutoring. Am. Educ. Res. J. **31**(1), 104–137 (1994)
46. Montani, V., De Filippo De Grazia, M., Zorzi, M.: A new adaptive videogame for training attention and executive functions: design principles and initial validation. Frontiers in Psychology **13**(5), 409 (2014). doi:10.3389/fpsyg.2014.00409
47. Lintern, G., Gopher, D.: Adaptive training of perceptual-motor skills; issues, results, and future directions. Int. J. Man Mach. Stud. **10**, 521–551 (1978)
48. Peng, P., Miller, A.C.: Does attention training work? A selective meta-analysis to explore the effects of attention training and moderators. Learn. Individ. Differ. **45**, 77–87 (2016)
49. Durlach, P.J., Ray, J.M.: Designing adaptive instructional environments: insights form empirical evidence. Technical report no. 1297. U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA (2011)
50. Landsberg, C.R., Astwood Jr., R.S., Van Buskirk, W.L., Townsend, L.N., Steinhauser, N.B.: Review of adaptive training system techniques. Mil. Psychol. **24**, 96–113 (2012)
51. Finomore, V., Matthews, G., Shaw, T., Warm, J.: Predicting vigilance: a fresh look at an old problem. Ergonomics **52**, 791–808 (2009). doi:10.1080/00140130802641627
52. Matthews, G., Warm, J., Shaw, T., Finomore, V.: Predicting battlefield vigilance: a multivariate approach to assessment of attentional resources. Ergonomics **57**(6), 1–19 (2014)
53. Shaw, T., Matthews, G., Warm, J., Finomore, V., Silverman, L., Costa Jr., P.: Individual differences in vigilance: personality ability and states of stress. J. Res. Pers. **44**, 297–308 (2010)
54. Teo, G.W.L., Szalma, J.L., Schmidt, T.N., Hancock, G.M., Hancock, P.A.: Evaluating vigilance in a dynamic environment: methodological issues and proposals. Poster presented at the 56th Annual Meeting of the Human Factors and Ergonomics Society, Boston, MA, October 2012
55. Boivin, D.B., Boudreau, P.: Impacts of shift work on sleep and circadian rhythms. Pathol. Biol. (Paris) **62**(5), 292–301 (2014)
56. Smith, A.P., Kendrick, A.M., Maben, A.L.: Effects of breakfast and caffeine on performance and mood in the late morning and after lunch. Neuropsychobiology **26**(4), 198–204 (1992)
57. Bunce, D.: Age differences in vigilance as a function of health-related physical fitness and task demands. Neuropsychologia **39**(8), 787–797 (2001)
58. Green, C.S., Bavelier, D.: Action video game modifies visual selective attention. Nature **423**, 534–537 (2003)

59. Pavlas, D., Rosen, M.A., Fiore, S.M., Salas, E.: Using visual attention video games and traditional interventions to improve baggage screening. In: Proceedings of the Human Factors and Ergonomics Society, vol. 52 (2008)
60. Schmidt, TN., Teo, G.W.L., Szalma, J.L., Hancock, G.M., Hancock, P.A.: The effect of video game play on performance in a vigilance task. Poster presented at the 56th Annual Meeting of the Human Factors and Ergonomics Society, Boston, MA, October 2012
61. Tiwari, T., Singh, A.L., Singh, I.L.: Task demand and workload: Effects on vigilance performance and stress. J. Indian Acad. Appl. Psychol. **35**(2), 265–275 (2009)

http://www.springer.com/978-3-319-58624-3

Augmented Cognition. Enhancing Cognition and
Behavior in Complex Human Environments
11th International Conference, AC 2017, Held as Part of
HCI International 2017, Vancouver, BC, Canada, July
9-14, 2017, Proceedings, Part II
Schmorrow, D.D.; Fidopiastis, C.M. (Eds.)
2017, XXIII, 540 p. 185 illus., Softcover
ISBN: 978-3-319-58624-3