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# Motor skill under pressure: games, stress and automaticity

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## Abstract

Choking under pressure is described by distraction and explicit monitoring theories (DeCaro, Thomas, Albert, & Beilock, 2011). Distraction theories propose that distraction disrupts tasks that rely on working memory, while explicit monitoring disrupts automatic processes such as proceduralized motor skills. Furthermore, the attentional control theory (ACT) incorporates emotion in the form of anxiety to predict detrimental effects on performance efficiency, but not effectiveness (Eysenck, Derakshan, Santos, & Calvo, 2007). The present study examined the use of a video game task intended to manipulate performance pressure and anxiety and investigated the resulting effects on a motor skill task. The discrete sequence production (DSP) task was proceduralized by practice and used as the motor skill task in a task switching design with the pressure manipulating game task. Evidence was found for both explicit monitoring, affecting the proceduralized DSP task, and distraction theories, affecting switching between the game task and the DSP task. Effects of anxiety were also found, but no main affects that were predicted by ACT, indicating the need for further research on this matter. In conclusion, it appears that video games are indeed suitable to manipulate pressure situations on motor skills.

## Motor skill under pressure: games, stress and automaticity

Folk psychology states that pressure and anxiety should have an adverse effect on performance. An interesting question could be, for instance, how well does a police officer perform at aiming his weapon and firing when he or she is under direct threat? The task of firing a weapon has been learned beforehand, so there is no novelty in performing the action itself. More generalized, motor skill is involved in this action, and therefore the question can be generalized to how motor skill is affected by high pressure situations, and how this can be investigated with an experiment. However, first we will take a look at the relevant literature.

Pressure, or more specifically performance pressure can be described as an anxious desire to perform as well as possible in a situation that is important to the person experiencing it. Usually, people perform worse under this kind of pressure. That is, they perform worse in a situation where the importance of a good performance is high (Baumeister, 1984). So, although the motivation to perform better is higher, they actually perform worse. This paradoxical performance effect has been described as *choking under pressure* (DeCaro, Thomas, Albert, & Beilock, 2011). To be more specific: choking does not only imply that people perform worse, they perform worse than could be expected from their skill level, in situations where the pressure to perform well is maximal.

Multiple theories exist on choking under pressure. Firstly, we will look at two groups of theories concerning negative skill performance and pressure. The first group deals with negative performance due too much attention paid to the execution of a skill, and the latter with too little. These are the *explicit monitoring theories* and the *distraction theories*, relatively. These two groups of theories deal with two extremes of pressure, but nonetheless will appear to be two sides of the same coin. Secondly, we will discuss another, separate theory dealing with performance under pressure that also takes emotion into consideration: the *attentional control theory*, or ACT.

Explicit monitoring theories propose that in high pressure situations, self-awareness of a person for the need for a good performance is increased. This leads to a heightened focus on the execution of a skill with the intent to ensure a better performance. It is believed that such a heightened focus on the step-by-step process of execution disrupts proceduralized processes in both learning and execution. Proceduralized processes can be performed while not requiring constant step-by-step attentional control. For example, complex sensorimotor skill tasks, such as golf putting, can be proceduralized with practice. When a skill becomes proceduralized through learning, they can also become susceptible to explicit monitoring (Beilock & Carr, 2001; Langer & Imber, 1979).

A different approach are distraction theories, which suggest that poorer performance is caused by the inability or a delay in switching attention away from distracting task-irrelevant thoughts, such as worries about surrounding events, towards the task at hand (Wine, 1971; Beilock & Carr, 2001). A competition for attention emerges between the task to be performed on the one hand and worries over consequences on the other. Attention is an important component of working memory, which deals with task-relevant short-term memories and inhibits irrelevant information. Distraction of attention is associated with working memory problems, as irrelevant tasks take up the limited attentional resources of the working memory. As a consequence, tasks that are negatively influenced by attentional distractions are memory-demanding tasks such as maths, reasoning and rule-governed category learning (Gimmig, Huguet, Caverni, & Cury, 2006).

Attempting to combine both groups of theories, DeCaro et al. (2011) propose that aspects of the pressure situation can lead to either distraction and/or explicit monitoring, and that these situations disrupt skills that rely (mostly) on working memory and/or attentional control in different ways. They investigated this with two experiments, which will be discussed next. The first experiment employs a primary/secondary task setup, in the second experiment the pressure conditions during a task were changed.

In their first experiment, DeCaro et al. (2011) tested how categorization tasks are differently affected by distraction and explicit monitoring secondary tasks. They used both a rule-based and an information-integration categorization task, with either a distracting secondary task or an explicit monitoring secondary task. The rule-based categorization task consisted of dividing symbols into categories depending on rules, such as color or shape. The prediction was that if the rule-based categorization learning task relied on attention and working memory, it would be disrupted by distraction secondary task, but unaffected by explicit monitoring secondary task. In the information-integration categorization task, the participant had to divide groups of 3 symbols into two categories, depending on the sum of the three symbols. For example, take green = +1 and red = -1, then if the sum of the three symbols $> 0$, classify as category A, otherwise as category B. For information-integration category learning task, the opposite effects should occur compared to the rule-based categorization task, as good performance on information-integration tasks have small attention and working memory requirements and should only be impaired by an explicit monitoring secondary task. This task required the integration of multiple dimensional values at a pre-decisional stage, presumably unconsciously, and is thought to be similar to proceduralized complex sensorimotor skills, such as golf putting. As distracting secondary task, a go/no-go task was used in which the participants had to react to a certain letter and press the space bar when this letter was displayed. The importance of the task was emphasized by displaying feedback on the performance. The secondary explicit monitoring task was a confidence judgment task, which attempted to get the participant to explicitly monitor the steps of the categorization process. This was done by asking the participants to think about how they were going to categorize the next task and then making them give a confidence rating beforehand. After that, they performed the categorization task as usual. Results confirmed the predictions, as rule based category learning was only disrupted by the distracting secondary task, and information-integration category learning was only disrupted by the explicit monitoring secondary task.

In the second experiment, DeCaro et al. (2011) investigated high-pressure conditions to test if the effects for different conditions were analogous to the effects of the secondary tasks of the first experiment. The setup for the second experiment was the same as the first, but instead of secondary tasks, the conditions were changed to either outcome-pressure or monitoring pressure conditions. In the outcome-pressure condition, the participants were promised a monetary reward for a good performance. The participants were told that they were working together with a partner, who would also benefit from a good performance. This partner was in fact fictional and used to further increase outcome-pressure. In the monitoring pressure condition, the participants were informed that they were going to be video-taped for students and professors so that others could watch how the skill was performed, and that the film might be used to study category learning by researchers and psychology classes. During the task, the camera was placed 1 m away from the participant, and the experimenter remained standing behind the camera during the task. The results were analogous to the secondary task setup: the rule-based categorization task suffered from the outcome-pressure condition, and the information-integration categorization task suffered from the monitoring pressure condition.

DeCaro et al. (2011) conclude that both theories of choking appear correct and that skill performance under pressure not only depends on the task (attentional demanding or procedural), but also on the type of pressure itself (distraction or explicit monitoring).

DeCaro et al. (2011) (purposely) do not address the factor of emotion, which often plays a role in for instance the example of a shooting police man mentioned in the introduction. A pressure theory that does incorporate emotion, in the form of anxiety, is the attentional control theory (ACT), proposed by Eysenck, Derakshan, Santos, and

Calvo (2007).

In the context of ACT, anxiety can be described as an emotional and motivational state during a threatening situations. The level of anxiety of a person at a certain moment, the *state anxiety*, is determined by the anxiety dimension of the personality of the person, *trait anxiety*, and the *pressure situation* at that moment. Trait anxiety is a stable characteristic in the personality of a person. It determines how that person reacts to stimuli and environment and whether that person perceives these as threatening. People with high trait anxiety will more likely show higher state anxiety in normal situations, and show heightened levels of state anxiety in anxiety-inducing situations in comparison to people with lower trait anxiety. State anxiety can be described as a state of tension interrupting the normal emotional state of a person, and can manifest itself with physiological reactions, such as increased sweating and heart rate. The person will experience worry or restlessness, and may react strongly to external stimuli. High levels of state anxiety are especially unpleasant. In the field of psychology, anxiety is associated with adverse effects on cognitive tasks. These effects are what ACT attempts to explain. ACT itself is based on the processing efficiency theory (PET) by Eysenck and Calvo (1992), which attempted to map these effects of anxiety. PET discriminates between performance effectiveness (response accuracy) and performance efficiency (how the effectiveness of a task compares to the effort invested to perform that task). PET rests on two major assumptions.

Firstly, it assumes that worry is the component of state anxiety that has an effect on accuracy and efficiency. Worry is activated in high pressure situations and is more likely in individuals with high trait anxiety. Furthermore, worry has two effects. The first effect is that worry takes up attentional resources of the working memory so that less capacity is left for other tasks. This can be compared to task-irrelevant information taking up resources from the working memory in distraction theories. The second effect is the motivation to avoid or reduce the effects of the anxiety by using compensatory strategies. Compensatory strategies, such as enhanced effort and supplementary processing, cause the effectiveness to remain at the same level at the cost of efficiency, but only when enough resources are available. Subsequently, when these resources are not available, effectiveness suffers as well.

Secondly, PET assumes that anxiety affects the working memory. According to the working memory model used by PET, the limited-capacity working memory consists of three components: 1) a **central executive** involved in the processing of information and equipped with self-regulatory functions such as performance monitoring, planning and strategy selection; 2) a **phonological loop** to process verbal information; 3) a **visiospatial sketchpad** for processing visual and spatial information. ACT assumes that worry, and more generally anxiety, mainly affects the central executive component of working memory. Therefore, worry interferes the most with tasks that require the processing and storage capacity of the working memory. Anxiety makes demands on the self-regulatory mechanism that has to inhibit worrisome thoughts and at the same time must also support supplementary processes.

However, PET does not specify which function of the central executive is adversely affected by anxiety. ACT does, as it uses a refined function set for the central executive: 1) **Inhibition**: using attentional control to inhibit disrupting task-irrelevant stimuli and responses; 2) **Shifting**: shifting between multiple tasks, operations or mental sets and and using attentional control at the demand of the tasks at hand; 3) **Updating**: updating and supervising working memory.

The relation between inhibition and attentional control is that the inhibition function uses attentional control to refrain from using resources for task-irrelevant stimuli. The shifting function uses attentional control to shift attention to task-relevant stimuli. As updating is not directly involved with attentional control, the effect of anxiety on this function should be weak. It is suggested that all three functions rely on the same resources of the central executive, and that demands on one function reduces the resources left for the other functions. To explain the detrimental effects of anxiety on attention, ACT uses the view that there are two attentional systems. Firstly, there is the goal-directed attentional system which is influenced by expectation, knowledge and goals, visualizable as a top-down control of attention. Secondly, there is a stimulus driven attentional system influenced by salient stimuli, which can be seen as a bottom-up control of attention. According to ACT, anxiety distorts the balance between these two systems, resulting in an increased influence of the stimulus-driven attentional system and a decrease in influence of the goal-direct attentional system. It is also implied that both systems influence each other. This results in a reduction of the attentional control and a subsequent disturbance of the inhibition and shifting functions, as these rely on the top-down goal-directed attentional system. These disturbances finally lead to a poorer performance.

### *Motor skills and pressure*

The motor skill tasks that have been used in pressure experiments differ from golf putting (Masters, 1992; Beilock & Carr, 2001; Mullen & Hardy, 2000) to table tennis and (Williams, Vickers, & Rodrigues, 2002)and basketball (Wang, Marchant, Morris, & Gibbs, 2004).

Masters (1992) studied explicit and implicit skill acquisition of golf putting and testing under stress conditions, what can now be interpreted as a study of explicit monitoring effects. Implicit training happened without the knowledge of rules, while explicit training was done with knowledge of rules. They used a combination of self-evaluation and monetary rewards to induce stress, and found that performance was less effected in people with less explicit knowledge, showing support for explicit monitoring theories.

The sensorimotor task of golf putting was also used to investigate effects of stress by Mullen and Hardy (2000) under stressful conditions with either implicit or explicit skill learning in an effort to find evidence for PET. Their goal was also to investigate if explicit skill learning was detrimental in comparison to implicit skill learning. Explicit learning condition had the participants recite task-relevant instructions to themselves to guide performance, intended to incite self-monitoring. The implicit learning condition had the participants were asked to recite task-irrelevant information in the form of random letters. The low pressure situation was neutral, while the high pressure situation gave direct feedback on their performance in comparison with other participants, being judged by golf professionals, together with the outlook of a monetary reward. Although they find some support for explicit monitoring in the task-relevant reciting condition, their results overall were reported as inconclusive.

Once more, golf putting as used by Beilock and Carr (2001) to look at explicit monitoring effects. First, they investigated generic knowledge and episodic memories of putting in golfers, and found out that these memories were generally poor, which they interpreted as evidence of that the golf putting skill is procedural. They then propose that such a proceduralization of putting makes it that skill susceptible to explicit monitoring. In their next experiments, they investigated the effects of training conditions to reduce choking both putting and an arithmetic skill, by using self-consciousness training (inducing explicit monitoring by audience observation) and dual-task (inducing distraction by irrelevant information). They found that choking happened in putting but not in arithmetic skill. Furthermore, they found that dual-task training did not change choking in golf putting, but that self-consciousness training eliminated it. They conclude that their findings support explicit monitoring and that attention to proceduralized skills has a detrimental effect on performance.

Williams et al. (2002) investigated PET with a table tennis task with either high or low working memory demands to test the assumption that high anxious persons use increased effort keep their performance effective at the cost of performance efficiency. However, when a too heavy demand is made on working memory, anxiety should lead to poorer efficiency and effectiveness. They used the accuracy in hitting concentric circle targets in a certain sequence as a measure of performance effectiveness, while reaction time, mental effort, visual search data and arm kinematics were used as a measure of efficiency. They found that anxiety had a detrimental effect on effectiveness in both high and low working memory tasks, and found further evidence for decreased performance efficiency in increased reaction time and mental effort. Also, high working memory demands showed more pronounced decrements in efficiency than in low working memory demands, showing support for PET.

Wang et al. (2004) used a basketball skill to investigate the effects of dispositional self-consciousness and trait anxiety on choking. The participants did 20 free throws in high and low pressure conditions. Shooting basketballs was shown to be a successful way to induce choking in experiments. This task was described as a mixture between gross motor skill (knee, shoulder and elbow extension) and fine motor skill (wrist and finger turning and rotation), the latter requiring detailed attention. The Wang et al. (2004) experiment manipulated pressure by having an audience witness the shooting. People with high self-consciousness and high trait anxiety performed worse when the audience was present, showing evidence for what can be seen as explicit monitoring effects. A link to this group of theories is not made in their experiment, however.

Now that we have discussed the theories and have seen different motor skills under experimental investigation, we must choose a suitable motor skill and pressure manipulation.

### *Manipulating pressure*

Inducing pressure for an experiment has been done in many different ways. As we have seen, a participant can be given arbitrary times or goals to finish a task, have an audience observe his or her performance, be given feedback about performance etc. (DeCaro et al., 2011). Each of these pressure manipulations have been shown to have different effects, depending whether they distract or induce explicit monitoring, or induce anxiety. We will attempt to use a different, new method to manipulate pressure, namely a video game. The choice for this method will be explained now.

The goal of many video games is to recreate real life, or at least realistic situations. The possibilities in current gaming technology are no longer limited to abstract tasks, but make it an ideal tool to create realistic, immersive, complex and even emotional situations. A great advantage of games is the amount of control that can be administered over the situation, while at the same time being a cheap alternative to for instance hiring actors or arranging a set for an experiment. Investigating the possibilities of using game technology for creating elaborate pressure situations is intriguing and new. Another advantage is the attractiveness of games, which makes experiments more enjoyable for the participants. For our experiment, a game could therefore be quite suitable to create high and low pressure and anxiety inducing situations. Now that we have our pressure manipulation, we will decide on a motor skill task for our experiment.

In the example of the police officer, fine motor skill is involved in aiming the weapon and pulling the trigger at the right moment. This task has been learned beforehand, so there are no novelty effects on performance. For the motor skill task to be usable in an experiment, it too must be learned beforehand. ACT suggests reaction time as an indication of performance efficiency, while proportion correct entered keys is suitable to indicate performance effectiveness (Eysenck et al., 2007). As such, the reaction time and the amount of errors made must be recorded to investigate the performance efficiency and the performance effectiveness, relatively, to interpret the results with ATC and the other two groups of pressure theories. Finally, it must be possible to somehow integrate the motor skill task into the game. The discrete sequence production (DSP) task used by De Kleine and Verwey (2009) is an appropriate candidate for this job, as it can fulfill all these requirements. The DSP task requires motor skill in the form of sequences that must be entered by hand. The DSP task can be learned until it is proceduralized, that is, through learning the DSP will go from an attentional phase, where step-by-step attention is needed, to an automatic phase in which the DSP can be performed without the need of attention. This is comparable to, for instance, the execution of a tennis smash that at first requires attention in the practice phase, but after practice appears to be performed automatically. The length of the sequences (7 characters) that are used, leads to a segmentation of the sequence into smaller independent segments, which are believed to represent motor chunks. Motor chunks are grouped responses retrieved from memory, which are demonstrated by a short delay between the chunks in which the next chunk is retrieved from memory. De Kleine and Verwey (2009) found evidence of chunking at element 5 of the sequences. A possible side-investigation would be to explore the effects of pressure on chunking. Both pressure manipulation and motor skill task have been selected. We now need a way to let these elements interact.

To recreate the dynamic situations of real life, a task switching design is both suitable and practical. Task switching could be compared to the situation in which a police officer must react all of a sudden during different pressure conditions, and draw his or her weapon and fire. Task switching also reduces confounding of the skill performance in the tasks, that would happen with a dual task design, especially when using a game with unpredictable events. With task switching, performance of in-game tasks should not interfere with the performance of the DSP task.

The purpose of the present study was firstly to investigate the usability of a video game to induce performance pressure, and possibly anxiety. Furthermore, we attempt to determine any effects that pressure may have on motor skill in a situation comparable to the shooting police man. To be more specific, we looked for evidence of explicit monitoring and attentional theories, but also for evidence for ACT, by investigating the predictive value of trait anxiety on performance and effectiveness. The current experiment will therefore measure the reaction time (RT) and proportion correct entered keys (PC) with a task switching design consisting of a motor skill *DSP task* and a pressure manipulating *Game task*.

## Experiment

First, the participant must practice entering the DSP sequences in order for the motor skill to become proceduralized so that it can be used in the experiment. This will be accomplished by practice sessions in a neutral environment, separately from the game. The sequence is first practiced step by step, called the *Normal DSP task*. Then, the task is changed to resemble the situation in the game by removing the step-by-step hints and forcing the participant to enter the sequence from memory. A time penalty system is also installed. These sequences are called the *Blind DSP task*. After the practice sessions, the participants are prepared for the *In-game DSP task*, the DSP task that is used as the switching task.

The pressure manipulating game task is a 3D puzzle game, called *Amnesia: The Dark Descent* (Grip, Nilsson, & Hedberg, 2010) in which the participant will experience moments of high and low threat pressure, or anxiety. Amnesia is a 3D survival horror adventure game created by Frictional Games. The player takes on the role of an unarmed man exploring a dark and foreboding castle in the early 19th century, while avoiding monsters and other obstructions and solving puzzles. Critical reception of the game was generally high.[1] The game is comparable to 3D shooters as it operates from a first-person perspective and navigates parts of a castle using mouse and keyboard. A major difference is that the player has no ability to use a weapon or even fight back, the only thing he or she can do is to hide or to run. This is one the hallmark traits of the game. The game is described as especially immersive and frightening, which makes it a good candidate to recreate high pressure and anxiety situations. Another advantage is that Amnesia is not a 3D shooter but a 3D puzzle game, and therefore will not require the skill and precision associated with shooter games. This will mostly diminish any skill advantages that seasoned gamers among the participants may have.

During the playing of the game, the Game task, the participant will be confronted with a direct threat in the form of a monster that is able to roam about freely, called *Monster*. The task of the participant is then to save himself or herself from this threat by moving away or by hiding, or otherwise the participant is 'killed' and the game has to be started over again.

When the Game task is switched to the DSP task, the DSP task is presented and the participant loses control of keyboard and mouse of the Game task to the DSP task. This means that the events in the Game task will continue and remain visible and audible during the performance of the DSP task. After completing the DSP task, control is restored back to the Game task. However, when the DSP fails, a time penalty is given before control is restored. This penalty, together with the presence of Monster, will motivate the participant to act fast. The presence of Monster is the high pressure situation, its absence is the low pressure situation.

As the game allows the participant to roam freely and events can occur randomly, situations cannot be reproduced precisely. This limits this experiment to within-subject measurements. As a valid study into the effects of trait anxiety requires large numbers of participants instead of the 15 used in this experiment, this investigation is limited to an exploratory study.

A possible source of confounding is movement of the player at the moment of switching from the Game task to the DSP task. This can mean that the player was pressing a button to control the game, which might confound with pressing the buttons for the DSP task, possibly influencing the response time for the first key of the DSP sequence. Therefore, we must register whether the player was moving at the moment of switching and investigate any possible confounding effects statistically.

Another possible source of confounding is motivation. When Monster is present, the participant are particularly motivated to finish the DSP task quickly, to get back to controlling the game, and accurately to avoid the time penalty. When the effects of the hight pressure situation are purely motivational, the speed and accuracy should increase in these situations. Another result could be a speed/accuracy trade-off, where high speed is traded in for lower accuracy or the other way around, depending on which of the two factors the participant concentrates on.

According to the distraction theories, the presence of Monster will cause worry and take up attentional resources. Task switching, which requires working memory, should therefore be negatively affected, which would result in higher RT and lower PC at the first key of the sequence.

If Monster also causes explicit monitoring, the DSP task will suffer as it is proceduralized, but not the task switching.

With regard to ACT, switching between tasks is known to make demands on working-memory, as it relies on the shifting function. If the Game task is successful in creating anxiety, shifting would be less efficient in high trait anxiety people, resulting in longer switching delays to the DSP task (higher RT for key 1). Furthermore, inhibition would also suffer, and worry about Monster will take up resources as task-irrelevant information that will also have a detrimental effect on efficiency. However, effectiveness (PC) should not necessarily be affected as much, unless the anxiety effects puts to great demands on working memory so much that compensatory strategies are ineffective. If these demands are too high, effectiveness will suffer too.

### *Method*

*Participants.* The group of participants consisted out of 15 Dutch and German persons, 11 male and 4 female, ranging between the ages of 19 and 30 (M = 24.4, SD = 3.8). Part of the group were psychology students from the University of Twente who received course credits for participating, the remaining participants were students from other fields and ex-students and received no compensation. All of the participants had received or were in the process of at least a first-year university level education. All subjects reported to have previous experience with playing 3D games. The experiment was approved by the University of Twente's ethical board.

*Apparatus.* Hardware requirements for this experiment were 2 personal computers, the DSP task PC and the Game task PC, both running Windows XP (with Service Pack 3 installed). The DSP Task PC was able to run E-Prime 2.0, used to execute the DSP task program. The Game task PC was a multimedia PC capable of running Amnesia, with a high-end dedicated graphics card and surround audio ability. A software controlled KVM (Keyboard, Video, Mouse) switch connected the two PCs with one keyboard and one mouse. The KVM switch allowed the participant to use the same keyboard and mouse for controlling either of the two PCs by switching control from one PC to the other and back. In the experiment, control switched from the Game task PC to the DSP task PC to allow the subject to complete the DSP task, after which control was switched back to the Game task again.

A specially adapted keyboard was used for the DSP task. The keys of the numpad below the keys '4', '5', '6' and '+', which were mapped to the DSP experimental program in E-Prime, were removed to allow for better access. The keys were blackened so the markings could not be used by the subjects.

Special software was written in Java, called *PrimSomJ*, to communicate between the E-Prime PC and the Amnesia PC. The jobs of PrimSomJ were to facilitate the switch between the game task and the DSP task with the KVM, to allow communication between the Amnesia PC and the E-Prime PC and to log events.

For the practice sessions, the Normal DSP task used an existing E-Prime program written for a DSP task experiment (De Kleine & Verwey, 2009) that was adapted. For ease of use, we only used 2 different sequences instead of the 4 that were used by De Kleine and Verwey (2009). The Blind DSP task program was a further adaptation the Normal DSP task program. The way the task was displayed and the handling of user input error was altered for the experiment. Lastly, the In-game DSP task used the same program as the Blind DSP task, but with added functionality for communication with PrimSomJ.

The software of Amnesia lent itself to be modified only up to a certain level, as it was not open source. The Amnesia software was used to induce the moment of the switch, which was transmitted via PrimSomJ to the PC running E-Prime. Game levels that had been selected for the experiment were modified to send a message when a level was completed, instructing the subject to contact the experiment supervisor.

Events during the game were logged via the built-in logger of Amnesia. The software of Amnesia was modified to log certain events such as the usage of a lantern or the opening of a door in-game. The presence Monster was also logged. Time codes were written in milliseconds. PrimSomJ read the Amnesia log file and merged the DSP task events and reports it received from E-Prime. The log file was written as plain text. The E-Prime PC wrote the data from the DSP task into a separate E-Prime data file, which could later be linked to the Amnesia log using the timestamps and the numbering of the DSP tasks. Besides textual logging, video and audio was recorded during gameplay using video capture software.

*The DSP task.* Each of the 2 sequences consisted of a combination of 7 keystrokes of 4 different keys positioned next to each other horizontally. Sequence A was '5+6+564', sequence B was '+545+46'.

Normal DSP task:

At the start of the task, the letter representing the sequence was presented to the participant and remained on screen until the sequence was completed. The background of the letter was color-coded and was consistent for sequence A (cyan) and B (magenta) respectively. The position of four squares on the screen corresponded with the lay-out of the keys. For each item in the sequence, the correct key received a coloring. The participant then had to press the corresponding key, followed by the next until the sequence was completed or an error was made. If the wrong key was pressed, the participant saw a screen with an error message, and the same key was presented once more, giving the participant the opportunity to try again. After all 7 characters had been entered correctly, there was a short pause until the next sequence.

Blind DSP task:

The blind DSP task started in the same fashion as the Normal DSP task, showing the sequence letter and color, and the four squares with the first key of the sequence colored. This display did not change during the task, forcing the participant to enter the sequence from memory. Furthermore, instead of allowing the participant to correct him- or herself when an error was made, the task would end and the screen would show a red square with a countdown of 3 penalty seconds. After these penalty seconds were completed, the participant was allowed to carry on with the next sequence again. The same penalty system would be applied during the game.

In-game DSP Task:

The DSP In-game task was the same as the Blind DSP task, the only difference being that the indicator of the to-be-executed sequence (the letter of the sequence and the first stimuli) was presented in the lower right corner of the game as an overlay rather than full-screen (see figure 1). The presenting of the DSP task was accompanied by a 200 Hz warning tone. If the task was completed successfully, the presentation of the task disappeared immediately. If the task was unsuccessful, a count-down of 3 penalty seconds on a red background was shown in the lower right corner, just as with the Blind DSP task.

FrameTime: 17.9ms FPS: 55.9

Complete the sequence to regain control!

*Figure 1.* Screenshot of the game with the overlay for sequence A (Blind)

### Task session setup

For the practice sessions, both Normal and Blind versions of the DSP task were arranged in 80 sequences per session (40 repetitions of each sequence A or B in a random order). Halfway through each session was a break of 20 seconds to rest. Feedback of the performance, the mean RT for sequence and the number of errors, was presented to the participant during this break and also the end of the session. For the In-game task, no statistics were presented to the participant.

*Game task.* The main goal of the game is to reach a certain character somewhere in the castle. This goal is divided into several levels with sub-goals, such as breaking through a certain lock or activating an elevator to gain access to another part of the castle. While navigating through the castle, the player can manipulate objects in the game by picking them up, rotating them and dropping them. Special game items can be picked up and stored into an inventory, after which the player can combine them or use them on the environment to complete puzzles.

Early on in the game (in practice level 0), the player obtained an oil lamp that can be used to illuminate the world. The supply of lamp oil is limited, and finding new sources of lamp oil is one of the game elements throughout the levels. In level 1, the game changes as the player is confronted with a threat of Monster for the first time. When the monster sees the player, it will move towards the player and attempt to kill the player. The monster can be described as a nightmarish, mutilated humanoid being, by which it should be suitable to generate anxiety. The player can escape by running away and hiding until the monster loses interest and leaves.

In the case that the participants managed to finish level 1, they were instructed to inform the experiment supervisor after which they could continue with level 2 in the same fashion as they did with level 1. Level 2 could not be finished before the end of the experiment.

*Procedure.* The experiment consisted of four hours in total, spread over two consecutive days with two hours per day.

Day 1:

At the start of the experiment, the participants were informed of their rights and that it was allowed for them to stop participating at all times. Then, they were asked to fill in the Revised NEO Personality Inventory (NEO-PI-R) personality test (Hoekstra, Ormel, & Fruyt, 2003) to obtain their trait anxiety score, which took 30 to 40 minutes to complete. The written NEO-IP-R consists of 240 questions to measure the Five Factor Model: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to Experience. Each Factor itself is divided into six facets. A facet of Neuroticism is Trait Anxiety, which we sought to measure.

Next, the participants were asked to take a seat in a cubicle for the practice the DSP task. They were seated in front of a PC running E-Prime with the experiment program. First, the participants were instructed about the DSP task in that it consisted of two unchanging 7-item sequences consisting of 4 different keys and that they were to remember the sequences. They then were told to follow the instructions on screen and to react to the DSP task as accurately and fast as possible using the special keyboard and headphones for audio feedback.

The first day consisted of 4 Normal sessions (1-4), followed by 1 Blind session (5), followed by 4 Normal sessions (5-9) and finalizing with 1 Blind (10) and 1 Normal session (11), resulting in a ooooXooooXo setup of 11 sessions total (o = Normal, X = Blind). After each session, the next session was manually started by the experimenter, again giving the test persons time to rest. Each session took around 7 minutes to complete and the 11 sessions filled up the remainder of the two hours. During the sessions, RT for each of the 7 keystrokes was recorded, as was the PC.

Day 2

The second day started with another recap Normal session (12), followed by a Blind session (13), which on average took a total of 15 minutes. Again, RT and PC were recorded.

The participants were seated in front of the Game task PC for the first session with the game after which the room lights were dimmed for optimal game experience. They were instructed to try and finish the introduction level (level 0) with the instructions that the game would be interrupted for the In-game DSP task. This happened at random intervals between 20 and 40 seconds.

Either after finishing level 0 of the game or after 30 minutes of playtime, the experiment supervisor started up level 1 of the game. This time, again the participants were urged to finish the level, but they also received instructions that there would be a monster present and that the only thing they could to to save themselves was to run and hide. They were also made aware of their limited supply of lamp oil. The remainder of the two hours (ca. 60 minutes) was then spent playing the game.

RT and PC per DSP key was recorded, as well as statistics from the game telling when Monster was active. Video of the gameplay was also recorded with a timestamp for annotation and reference.

E-Merge was used to merge the data from the Normal and Blind practice sessions 1-13. The data from the In-game DSP tasks was also merged in the same manner.

The game log files were processed with a text editor using macros. The video of the gameplay and the associated processed log files were then imported in the multimedia annotator software ELAN 4.1.1 (Psycholinguistics, 2011; Sloetjes & Wittenburg, 2008) to create an annotated video file. Further processing was done do align the log file and video properly. The annotated video was then used to annotate the DSP task moments according to Movement (moving or not moving at the moment of DSP task display), for later investigation of possible confounding.

Statistical analysis software SPSS (version 16.0) was used to analyze the results statistically.

## *Results*

*Data inspection.* When inspecting the data for the practice DSPs, RT for one participant was considered as outlier and discarded. The overall mean was 318.5 ms (SD 105.0 ms) over all participants and the outlier participant had a mean of 652.6 ms, a difference of more than 3 standard deviations.

*NEO-PI-R.* Trait Anxiety recorded from the written NEO-PI-R test was on average 23.9, SD = 5.8, [15,36].

*Practice phase: RT.* Figure 2 shows the mean RT per session. Sessions 1-4, 6-9, 11 and 12 are Normal DSP tasks, while sessions 5, 10 and 13 are Blind DSP tasks. Note that sessions 12 and 13 are performed on day 2. The figure shows an overall decrease as the DSP task is learned, and also indicates higher RTs for the Blind sessions, which will both be investigate shortly.

Figure 3 shows the means of RT for the 7 keys for the Normal (left) and Blind sessions (right). The figure also shows the typical shape of RT over Key which was also found by De Kleine and Verwey (2009), together with an overall RT decrease over sessions. We will investigate this also.

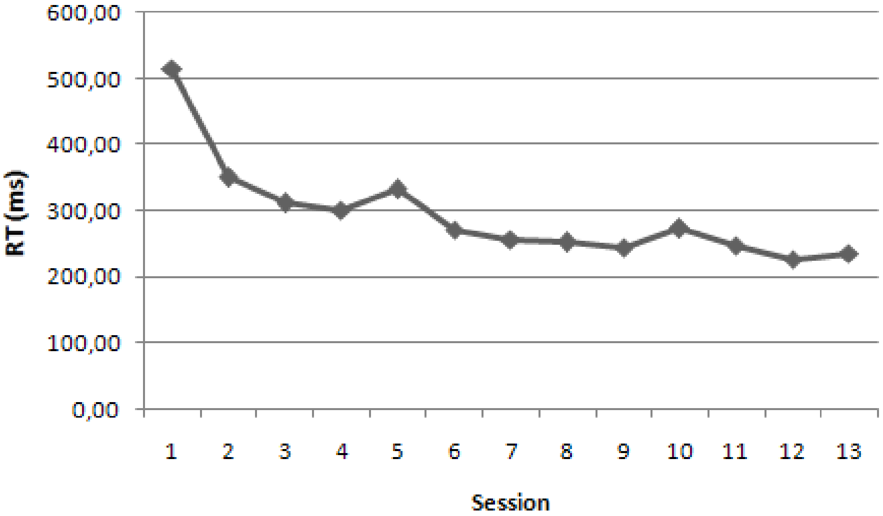

*Figure 2.* Mean RT for session 1-13.

To inspect the learning process in the Normal sessions, a repeated measures

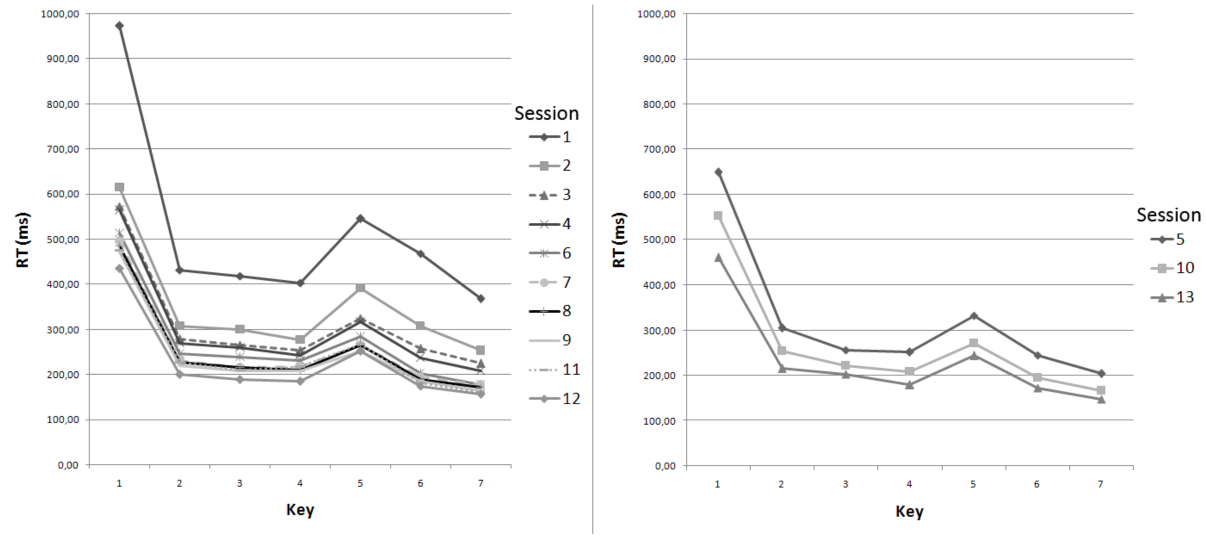

*Figure 3.* Mean RT for key 1-7 for Normal sessions (left) and Blind sessions (right).

ANOVA was performed for the RT with Keys (7; Key 1-7) and (Normal) Session (10 levels) as within-subject variables (see figure 3). The main effect of Session was highly significant: $F(9{,}117)=30.3$, $p<0.01$, the main effect of Keys was also highly significant: $F(6{,}78)=76.0$, $p<0.01$. There was a nearly significant interaction effect of Session x Keys: $F(54{,}72)=3.8$, $p=0.056$. These results show a significant difference between RT for the keys, a change in relative RT for keys over the sessions and a significant improvement of performance over the sessions, especially for keys 2-7 (see also figure 3). Further inspection of RT shows significant differences between key 1 and 2, $t(13)=8.2$, $p<0.01$, key 4 and 5, $t(13)=-5.6$, $p<0.01$, 5 and 6, $t(13)=7.0$, $p<0.01$, and 6 and 7, $t(13)=4.7$, $p<0.01$. The significant difference between keys 4 and 5 and 5 and 6 are evidence of chunking that was also found by De Kleine and Verwey (2009) at key 5.

Another repeated measures ANOVA was performed for the RT with Keys (7; Key 1-7) and Blind session (3 levels) as within-subject variables. This test also showed highly significant main effects for Session, $F(2{,}12)=48.6$, $p<0.001$, and Keys, $F(6{,}8)=78.1$,

$p<0.01$, as well as a significant effect for the interaction effect of Session x Keys: $F(12,2)=6.1$, $p<0.005$. The Blind sessions also show significant improvement in performance.

A third repeated measures ANOVA was performed to investigate the learning effect further by comparing Blind sessions with their preceding Normal session: sessions 4 and 5, sessions 9 and 10 and sessions 12 and 13 (see again figure 3). The ANOVA for Keys (7; Key 1-7), type of session, either Blind or Normal, (Type, 2 levels) and Session (3 levels) showed significant main effects for Keys, $F(6,78)=94.5$, $p<0.01$, Type $F(1,13)=12.5$, $p<0.01$ and Session $F(2,26)=70.1$, $p<0.01$, implying significant differences between sessions, keys and Normal or Blind. Significant interaction effects were also found for Type x Session, $F(2,26)=5.3$, $p<0.05$, Type x Keys, $F(6,78)=4.3$, $p<0.05$ and Session x Keys, $F(12,156)=4.3$, $p<0.05$. These results suggest that the Blind sessions are performed significantly poorer than the Normal sessions, but that they improve over the sessions in parallel with the Normal sessions, and become more alike. Further inspection with paired t-tests showed significant differences (decrease) between Blind and preceding Normal sessions. For sessions 4 and 5, $t(13)=2.6$, $p<0.05$ and sessions 9 and 10, $t(13)=4.8$, $p<0.01$, but no longer when comparing sessions 12 and 13 ($p=0.21$). This indicates that after session 12, the Blind sessions no longer significantly improves in our setup.

Finally, a significant difference in mean RT was found between sessions 11 and 12, $t(13)=4.5$, $p<0.01$, showing evidence that the motor skill had improved overnight (see figure 2). This increase of motor skill during sleep can be explained by ”offline” processing of memories during consolidation (Robertson, 2009). However, exhaustion or a reduced motivation of the participant with the end of the experiment in sight might also explain the higher RT for session 11 in comparison to session 12.

*Practice phase: PC.* No significant effects were found for PC for session 1-13.

To inspect possible improvement in the Blind sessions, a repeated measures ANOVA was performed for the PC with Keys (7; Key 1-7) and Blind Session (3 levels) as within-subject variables. Only a significant main effect was found for Key: $F(6,78)=11.2$, $p<0.01$, which shows that PCs did not change significantly over the 3 sessions, and indicates that the sequence itself was already learned before session 5. This was confirmed when PC showed no significant difference between sessions 4 and 5, 9 and 10, and 12 and 13 ($p>0.39$).

*Game Task Performance.* We inspected the annotated logs of the Game task to determine whether the task was performed as intended. This was done by looking at how the arbitrary goals in the game were accomplished and by looking at how many times participants were killed in-game and especially during the execution of the DSP task for possible confounding.

For example, all participants were able to finish the practice level 0, were able to open doors etc. and all participants found a certain in-game goal item (a note) in level 1 which was situated far from the starting point, indicating that the Game task was indeed performed adequately. Furthermore, 57% of the participants reached level 2 of the game. Visual inspection of the recorded video material of each participant again confirmed that all participants were enganged in performing the Game task, and that, for instance, no-one refused to move about for long periods of time.

The participants died times on average 3.6 times during the 60 minute Game task (level 1 and 2). 0.5% of the DSP tasks had a participant dying during excecution of the DSP task. It is therefore unlikely that dying during the execution of the DSP task had a significant confounding effect on performance.

*Test phase: RT*. A repeated measures ANOVA was performed for the RT with Keys (7; Key 1-7) and Monster (2 levels) as within-subject variables. The main effect of Keys was highly significant: $F(6{,}78)=292.5$, $p<0.01$, the main effect of Monster was not ($p=0.28$). There was a significant interaction effect of Monster x Keys: $F(6{,}78)=4.0$, $p<0.05$ (see figure 4).

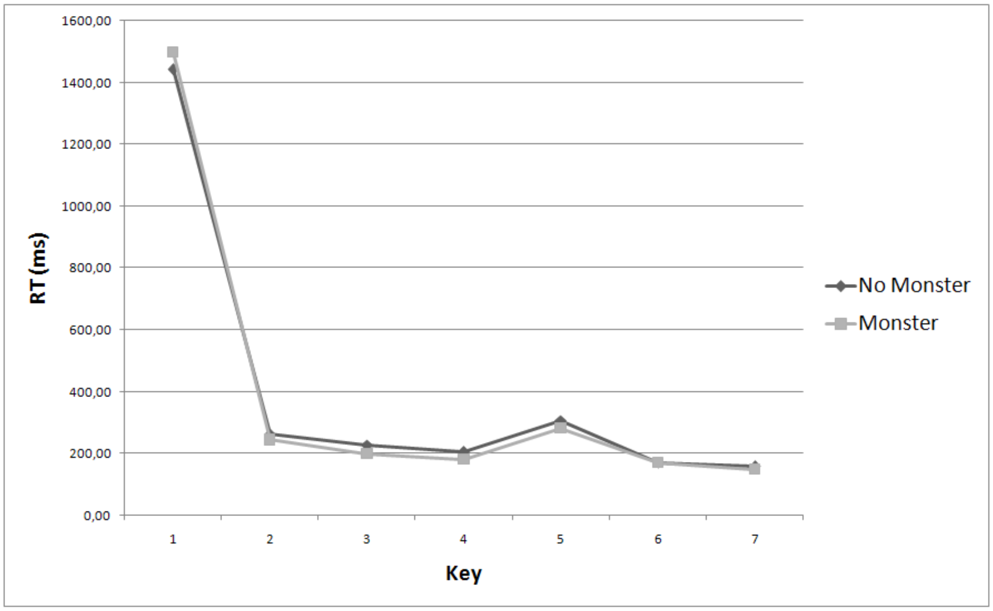

*Figure 4*. Mean RT for key 1 to key 7 for no Monster present and Monster present.

Figure 4 shows RT for each key for Monster. When investigating the mean RTs, Key 1 showed a significant positive difference in RT, $t(13)=2.3$, $p<0.05$ for Monster, while the other keys showed no significant difference ($ps>0.38$).

To investigate the same effects for keys 2 to 7 (as only the difference of key 1 for Monster was significant), another repeated measures ANOVA was performed for only those keys. The main effect of Keys was significant: $F(5{,}65)=13.4$, $p<0.01$. There was no significant interaction effect of Monster x Keys ($p=0.65$). The main effect of Monster was also not significant (p=0.44).

*Test phase: PC.* A repeated measures ANOVA was performed for the PC with Keys (7; Key 1-7) and Monster (2 levels). The main effect of Monster ($F(1{,}13)=4.8$, $p<0.05$) and Keys ($F(6{,}78)=4.0$, $p<0{,}05$) was significant, showing significant poorer performance with Monster present. The effect of Monster x Keys was nearing significance ($p=0{,}08$), which called for further investigation.

A significant difference were found in PC for Monster for key 3 $t(13)=2.5$, $p<0.05$, with a near significant difference in key 4 $t(13)=2.1$, $p=0.059$. This is important, as it shows that the effect was not caused by key 1.

Further investigation was done with an ANOVA for Keys 2-7 (6; Key 2-7). This showed again a significant main effect for Monster, $F(1{,}13)=5.2$, $p<0{,}05$, and Keys,$F(5{,}65)=3.9$, $p<0{,}05$. Again, there was no significant interaction effect of Monster x Keys ($p=0.15$).

*Movement effects.* To investigate possible confounding of movement (Movement) at the moment of switching from the Game task to the DSP task, Movement was used as an extra variable in combination with Monster and Keys, the effects were investigated on RT and PC. No significant effects were found, showing no evidence of confounding.

*Trait Anxiety effects.* Using Trait Anxiety measured with the NEO-P-IR personality test, the possible effects of this variable were investigated. A repeated measures ANOVA for both RT as PC was performed with Keys (7; Key 1-7) and Monster (2 levels) as within-subject variables and Trait Anxiety as covariate.

Trait Anxiety RT:

The main effect of Keys was significant, $F(6{,}72)=7.8$, $p<0.01$, and the interaction effect of Keys x Trait Anxiety was nearing significance: $F(6{,}71)=3.4$, $p=0.068$ and required further investigation (see figure 5). For clarity, the participants were divided over a Low Trait Anxiety and High Trait Anxiety group, each consisting of 7 participants. No further interaction effect of Trait Anxiety was found (*ps*>0.31).

The same ANOVA was repeated, but now for Keys (6; Key 2-7) and Monster (2 levels). Again, there was a main effects of Keys, $F(6,72)=4.8$, $p<0.01$. However, the main effect of Monster, $F(1,12)=8.5$, $p<0.015$, and the interaction effect of Keys x Trait Anxiety were also significant, $F(5,59)=2.9$, $p<0.02$. This shows that Monster has an effect on overall RT and that High and Low Trait Anxiety showed differences in RT for Keys. There was also a significant effect of Monster x Trait Anxiety, $F(1,11)=7.6$, $p<0.02$ (see image 6). This indicates that people with High or Low Trait Anxiety react differently on Monster. Furthermore, the interaction effect of Monster x Keys neared significance: $F(5,59)=2.9$, $p=0.06$.

Pairwise comparison showed no significant differences in RT (*ps*>0.09) between Keys for the High and Low Trait Anxiety groups. Furthermore, there we no significant differences between mean RT for Monster and High and Low Trait Anxiety groups (*ps*>0.55).

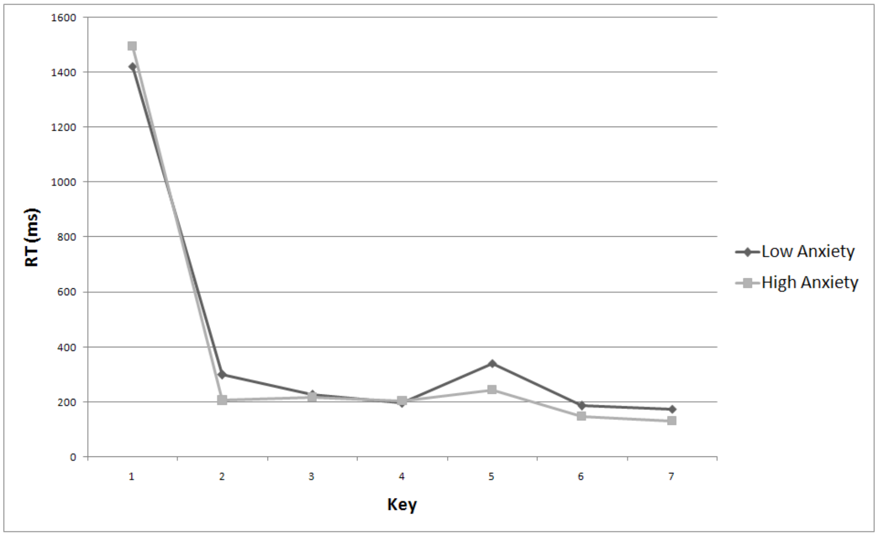

*Figure 5.* RT for key 1 to key 7 for Low and High Trait Anxiety groups.

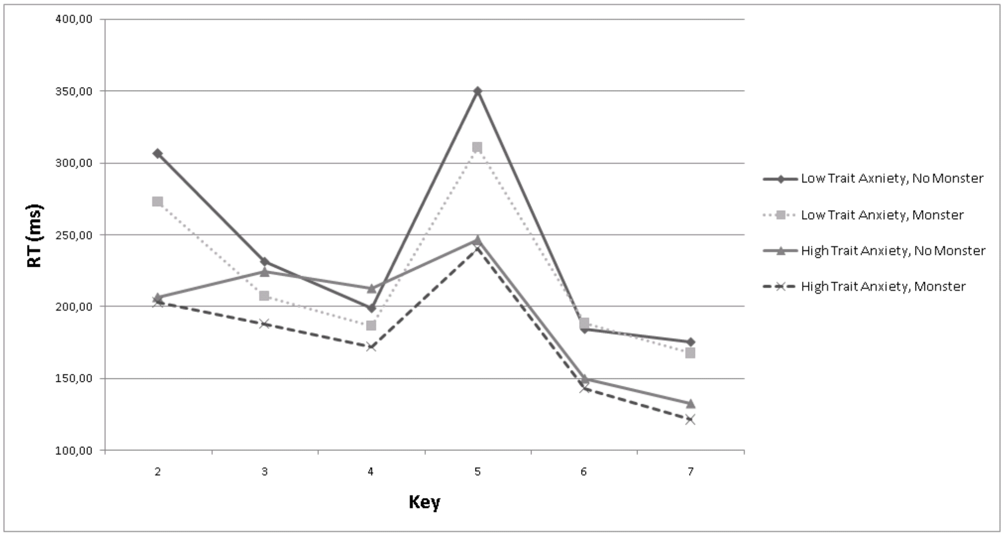

*Figure 6.* RT for key 1 to key 7 for Trait Anxiety and Monster

Trait Anxiety PC:

The main effect of Monster neared significance with $F(1{,}13){=}4.4$, $p{=}0.065$, indicating more errors for Monster. The main effect of Keys showed significance with $F(6{,}72){=}3.0$, $p{<}0.05$. The interaction effect of Monster x Keys was significant: $F(6{,}72){=}3.6$, $p{<}0{,}01$. The interaction effect of Monster x Keys x Trait Anxiety was highly significant: $F(6{,}71){=}4.4$, $p{<}0{,}01$ (see figure 7).

The interaction effect between Monster x Keys x Trait Anxiety required further investigation (see figure 7). When comparing the difference between Monster not present and Monster present in High and Low Trait Anxiety groups, a significant negative difference was found for key 3 in the Low Trait Anxiety group, $t(13){=}2.5$, $p{<}0{,}05$, for Monster present, and a significant positive difference for key 5 in the High Trait Anxiety group, $t(13){=}2.5$, $p{<}0{,}05$ for Monster present. So, Low Trait Anxiety persons made significantly more errors at key 3 when Monster was present, while High Trait Anxiety persons made significantly less errors at key 5 when Monster was present. How this can be

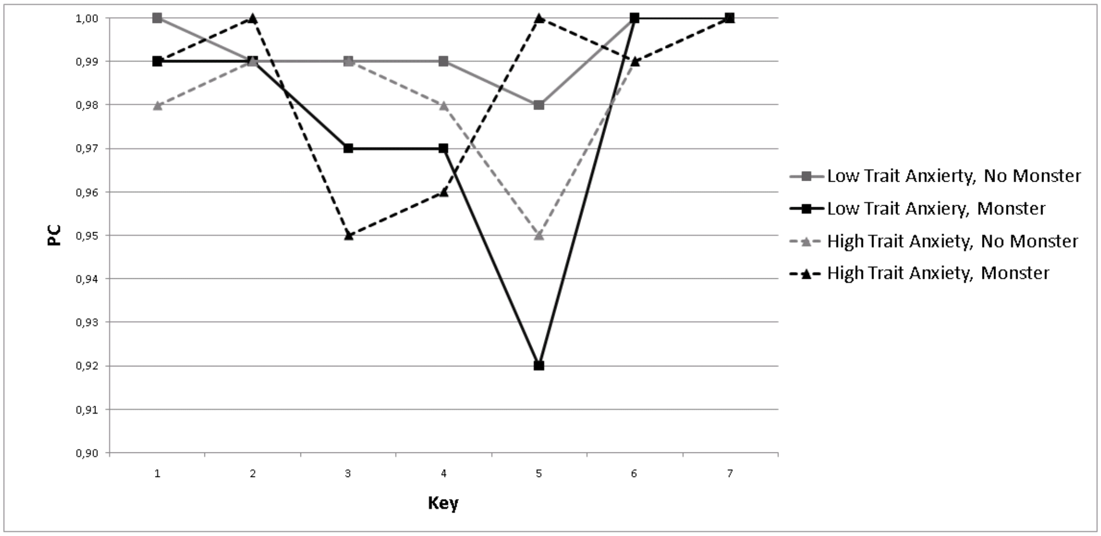

*Figure 7.* PC for key 1 to key 7 for Trait Anxiety and Monster.

interpreted, remains to be seen.

## Discussion

We measured the performance in speed and accuracy of 15 participants on a proceduralized motor task in a switching task setup with a high and low pressure generating game task. We now attempt to explain our findings by using the choking theory groups, distraction and explicit monitoring, and ACT.

In the practice phase, the participants learned the DSP task. Reaction times for keys 1-7 show the same typical pattern as the experiments of De Kleine and Verwey (2009) did. As with their experiment, the same significant increase in reaction time at key 5 is an indicating of chunking. On the second day, the Blind DSP task performance no longer differed significantly from the Normal DSP task performance, indicating that the Blind task was well enough learned to be used as the motor skill switching task in out experiment.

When looking at the results for the test-phase, the presence of the monster had a significant negative effect on the reaction time for the initiation time of the DSP task, that is Key 1. There were no significant differences for the presence of the monster for the remaining keys. Furthermore, the presence of the monster had a significant main effect on the amount of errors for all the keys.

By looking at these results, one can discard the possible confounding effect of motivation on performance. If the presence of the monster would only lead to higher motivation of the participant to perform well, either reaction time or the amount of errors should have improved, which is not the case. Also, there is no speed/accuracy trade-off, as both reaction time and amount of errors became actually worse when the monster was present.

Some significant effects of trait anxiety on reaction time were found, however these could not be retraced to a high and low trait anxiety groups. Even so, a significant interaction effect on the amount of errors between the presence of monster, the keys and trait anxiety was found. High trait anxiety groups performed significantly better for key 5 when Monster was present, while low trait anxiety group performed significantly worse for key 3 when Monster was present. These effects cannot be explained, however.

Movement at the moment the DSP task was offered did not make a difference in either reaction time or amount of errors for the presence of the monster, so there was no evidence found that pressing a key or moving was confounding with reaction times or errors made the presence of the monster.

Judging by the results of the number of errors made during the DSP task, evidence for explicit monitoring theories were found as these predict a detrimental effect on proceduralized skills. Reaction time, however, was only different for key 1, right after the moment of switching between tasks.

As predicted, the increased delay in switching between tasks when the monster was present shows evidence for the effect of distraction theories, as switching between tasks requires working memory. When the monster is present, the participants worries increase as survival is an important factor of the game task which is threatened by the monster. These worries pose demands on working memory and attention, and distracts him or her from shifting attention to and starting the DSP task.

When using ACT, our predictions were that the worry that we attempted to create by the presence of the monster should adversely affect performance efficiency, but not effectiveness. However, efficiency is only affected for key 1, not for the remaining keys. This can be explained by the shifting function of the central executive which was effected by reduced attentional control caused by increased attention for task-irrelevant threatening stimuli. Effectiveness suffered in the high-anxiety situation (more errors when monster was present), which was not directly predicted by ACT. A cause could be that attentional resources were so occupied that supplementary processing could no longer help, resulting in a drop of effectiveness. There were some unexplainable, but significant effects of trait anxiety on our results. For instance, some significant differences were found between high and low trait anxiety groups in the number of errors made for keys 3 and 5. It is possible that high and low anxiety group show differences in the way motor chunks are performed during pressure. However, no main differences were found that were predicted by ACT, such as worse overall performance for the high trait anxiety group. Derakshan, Smyth, and Eysenck (2009) point out another possibility in the form of a hypothesized fourth function of the central executive: dual-task coordination. This not yet investigated function could possibly play a role in our experiment. Then, according to ACT, if this function would require attentional control, it would suffer from anxiety. However limited, the apparent effects of anxiety generated by the game deserve to be looked into more closely, and with a larger group of participants.

We attempted to generate anxiety by using a video game. An issue with this experiment is, however, that we could not currently confirm the actual presence of state anxiety by measuring psychophysiological response in the participants. This could be done by measuring data such as skin conductivity, heartbeat or EEG that are normally associated with high state anxiety conditions. For example, Liu, Agrawal, Sarkar, and Chen (2009) used heartbeat, temperature, electromyography (electrical activity produced by skeletal muscles) and skin conductivity to determine state anxiety.

Another limitation was that the game that was used was not open source, thus limiting the kind of data that could be recorded, such as the relative position of the monster and participant in the game, the distance between the monster and the participant, the current buttons being pressed and mouse movement and other variables that might give further insight in the results and possible confounding effects.

Besides measuring state anxiety, future work could add a control situation, in which a threat is also present but not in a salient, anxiety inciting form such as was the case of the horrific monster in the game that we used. This set-up could further strengthen the evidence that anxiety indeed was generated by the monster, and not merely performance pressure.

Coming back to our police officer form the introduction, our results would indicate that he or she would react slower with shooting in the face of threat, and also less accurate, which could lead to problematic performance. In conclusion, we showed evidence that a video game is able to successfully create high and low pressure situations, and that evidence was indeed found for the effects of explicit monitoring and attentional theories. Some evidence was found that anxiety was also generated, although further work must be done to really confirm effects of ACT and thus anxiety in our design.

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## Author Note

Special thanks goes out to my parents and family for making this possible and to the participants who helped me perform this study ever so patiently by pressing buttons on command for hours.

# Footnotes

[1] http://www.metacritic.com/game/pc/amnesia-the-dark-descent