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Effects of Anxiety and Exercise-induced Fatigue on Operational Performance

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Epilogue

The goal of the present thesis was to gain insight into the separate and combined effects of anxiety and exercise-induced fatigue on operational performance. In the domains of sports and policing, separate effects of these stressors on the performance of (mostly separate) tasks have received considerable attention. However, despite the potentially serious consequences and the commonality of their occurrence, there is little research on how combinations of anxiety and exercise-induced fatigue affect operational performance. Moreover, little is known about the effects these stressors can have on some of the tasks that are inextricably linked to operational performance, such as endurance tasks. Therefore, in this thesis, we aimed to answer the following questions. Does anxiety affect basic aerobic tasks such as running (whether or not combined with a secondary task, **Chapter 2**)? How is far aiming performance affected by anxiety, a secondary cognitive task, and expertise (**Chapter 3**)? Does shooting behavior change when exercise-induced fatigue gradually increases (**Chapter 4**)? What are the combined effects of anxiety and exercise-induced fatigue on soldier's shooting and cognitive performance (**Chapter 5**)? And can these empirical results be used to build simulation models that can predict soldier performance on military missions (**Chapter 6**)? Answers to these questions are provided in the following summary of the main findings and general conclusion. Next, theoretical and practical implications are discussed.

Summary

Anxiety is known to affect cognitive and perceptual-motor tasks, such as far aiming (e.g., Eysenck et al., 2007, Wilson, 2008; Nieuwenhuys & Oudejans, 2012). However, whether and how anxiety affects tasks that rely heavily on the aerobic system remains unclear. **Chapter 2** investigated the influence of anxiety on running and on the combination of running and far aiming. Participants ran on a treadmill near the ground (low-anxiety) and on a high scaffold (high-anxiety) with and without a concurrent dart-throwing task. After both anxiety conditions, participants were asked to indicate their focus of attention during that condition. Results indicated that participants experienced more anxiety high on the scaffold than near the ground and that participants paid more attention to distracting thoughts and worries about falling off the treadmill in the high-anxiety condition. Moreover, anxiety caused participants to run less efficiently, resulting in smaller and more steps, longer contact times, and a higher oxygen uptake. Also, participants performed the dart throwing task less accurate when anxiety was manipulated. Finally, the condition in which running, dart throwing, and anxiety were combined showed the largest values on all kinematic and metabolic variables (except for stride length which showed the lowest value). Together, findings indicate that anxiety can also affect tasks with a large aerobic component, such as running. Furthermore, running, aiming, and anxiety all seem to compete for attentional resources leading to an accumulating effect on running parameters and suboptimal performance when they are combined.

Next, **Chapter 3** investigated the effects of anxiety and a cognitive secondary task on far aiming. Moreover, in addition to anxiety and a secondary task, a third manipulation of attentional

resources was induced through expertise. Novice and expert dart players performed a dart throwing task low (low-anxiety) and high (high-anxiety) on a climbing wall, and with or without a concurrent counting backwards task. Participants' gaze behavior was assessed as a measure of (visual) attention. Anxiety evoked a decrease in dart performance, but only for the novices. Counting backwards (secondary task) did not affect performance, which is probably because participants preferred to switch between the dart throwing and the counting task instead of performing them simultaneously. Analyses of participants' gaze behavior indicated that performance decrements were accompanied by shorter final fixations on the target and by fixations that deviated off the target earlier. These findings stress the importance of sufficient time to look at a target and to pick-up the (visual) information that is necessary for successful performance as late as possible. Moreover, the finding that anxiety decreased dart throwing accuracy only for novices, and that novices invested more mental effort in the dual task condition, indicates that anxiety, expertise level, and the secondary task all influenced the amount of attentional resources that are consumed. Peoples' attentional capacity is suggested to be limited, leading to a decrease in efficiency and eventually performance when this capacity is exceeded.

In **Chapter 4**, the effect of gradually increasing exercise-induced fatigue on shooting behavior was examined in a pursue-and-shoot task. Participants ran on a treadmill and chased a target in a virtual environment. They were free to choose when to stop the treadmill and shoot at the target. During the 20 minute-pursuit task participants became gradually more physically fatigued. Analyses of the data showed no changes in shooting performance due to exercise. However, the distance to the target at which participants decided to shoot showed a U-shaped relationship with exercise-induced fatigue. The rating of perceived exertion of 6.5 constituted the lowest point of the U curve, that is, the distance closest to the target. As anticipated, participants stopped running sooner, aimed at the target longer and shot less often, at high levels of exercise-induced fatigue. Findings indicate that physiological parameters influence actual transitions between different actions. Thus, the decision when to shoot (distance to the target) altered when exercise-induced fatigue increased gradually.

Next, in **Chapter 5**, we performed a field study to examine to what extent anxiety and exercise-induced fatigue, in isolation and in combination, affected shooting and cognitive performance of soldiers. To that aim, soldiers performed a field track in a military practice village. Anxiety was manipulated by opponents that shot back at the participants with paint bullets, through time pressure, and through ego-stressor methods such as an audience and a video camera. Exercise-induced fatigue was induced by a 10-minute intense running exercise. Soldiers' shooting accuracy, decision making, and mathematical performance decreased significantly under anxiety. Whether exercise-induced fatigue was beneficial or detrimental to task performance depended on the task at hand. The increased arousal levels due to exercise prevented shooting accuracy from deteriorating in the decision task. In the decision task, participants had to distinguish hostile from friendly opponents and shoot at a target in case the opponent was hostile. In contrast, decision making suffered from the increased arousal. Participants more often failed to return fire when they were shot at by an opponent. Also, math performance tended to decrease. In sum, anxiety can negatively affect soldier performance, and exercise-induced fatigue may improve or deteriorate performance in combination with anxiety depending on the nature of the task.

Finally, in **Chapter 6**, we made a first step in validating the Capability-based Human-performance Architecture for Operational Simulation (CHAOS). This framework can simulate complex human behavior and is used to predict performance in circumstances that are hard to measure in practice, such as military missions. We implemented the data of **Chapter 2** in the CHAOS framework and investigated whether the model we built could reproduce the data. Results showed that in the model anxiety affected task performance just as in the actual experiment. Moreover, the model results matched the empirical data very closely, which suggests that the resource based modeling approach in CHAOS has merit.

Conclusions

All three types of tasks relevant to operational performance that were investigated in the current thesis (cognitive, perceptual-motor, endurance) appear susceptible to anxiety. More precise, decrements were found in very attention demanding cognitive tasks, such as math (**Chapter 3 & 5)** and decision making (**Chapter 5**), as well as in far aiming tasks (dart throwing and rifle shooting, **Chapter 2, 3, & 5**), and even running, a task that is considered highly automated and thus requiring little attention, showed decreased efficiency due to anxiety (**Chapter 2**). Moreover, negative effects on performance generally seem to become larger when the attentional demands of the task increase. **Chapter 2** and **3** showed negative effects of anxiety to be larger when several tasks were performed concurrently, and for novices compared to experts. Whenever possible, people preferably seem to switch between tasks to cope with the increased attentional demands. When the secondary task was self-paced (counting backwards while dart throwing, **Chapter 3**) participants switched between tasks enabling them to maintain performance. In contrast, in **Chapter 2**, people threw darts while running on a treadmill. Consequently, they were not able to switch between tasks as then they would fall off the treadmill. Dart accuracy decreased in the combined running and dart-throwing condition.

With respect to exercise-induced fatigue, the current thesis suggests that the degree to which task performance is affected by acute bouts of exercise depends on the attentional demands of the task. Highly attentional demanding cognitive tasks seem more susceptible to negative effects of exercise-induced fatigue than perceptual-motor tasks. Cognitive tasks (e.g., shooting decisions) were (negatively) affected by exercise-induced fatigue (**Chapter 4 & 5**). However, **Chapter 4 and 5** indicate that shooting performance is rather resistant to exercise. Higher arousal levels due to exercise even prevented shooting accuracy from decreasing under anxiety, demonstrating that effects of anxiety and exercise-induced fatigue do not simply add up (**Chapter 5**). Results with fatigue are not as straightforward as with anxiety and further research is warranted. Recommendations for future research are provided later on in this epilogue.

Finally, simulation models, such as the CHAOS framework, can provide a valuable tool in simulating (and predicting) soldier performance under circumstances that are hard or even impossible to create in an experimental setting (**Chapter 6**). These simulation models may increase soldiers' safety and increase their effectiveness under stressful and physically exerting circumstances.

Theoretical implications

Effects of anxiety

With respect to the mechanisms underlying the effects of anxiety on operational performance two types of theories were introduced in this thesis: distraction theories (e.g., Eysenck et al., 2007; Nieuwenhuys & Oudejans, 2012) and explicit-monitoring theories (e.g., Baumeister, 1984; Beilock & Carr, 2001; Lewis & Lindner, 1997). Overall, results presented in this thesis provide support for the central tenets of distraction theories. More precisely, the results seem to fit the three levels within the integrated model of Nieuwenhuys and Oudejans (2012) and provide some useful additions. Recapitulating, Nieuwenhuys and Oudejans suggested anxiety to influence goal-directed performance through: 1) threat-related attention, 2) threat-related interpretation, and 3) threat-related response tendencies (see Figure 7.1).

On an attentional level, anxiety is suggested to shift attention towards threat-related stimuli at the expense of attention directed at perceiving, selecting, and realizing possibilities for action. In line with this suggestion, results from **Chapter 2** show that anxiety can distract attention away from running and dart throwing and towards worries related to falling off the high scaffold. These worries and distracting thoughts were accompanied by decreased dart performance. Moreover, in **Chapter 3,** the assessment of visual attention through gaze behavior indicated shorter final fixations on the target (bulls eye) under anxiety. Shorter final fixations leave less time to perceive the information required for optimal task performance. Shorter final fixations predicted decreased dart throwing performance with anxiety. Most important, whereas previous studies generally focused on the duration of the final fixation, current results also stress the importance of the timing of the final fixation. When gaze deviates off the target too early, people are unable to pick up the information that is closest to dart release, which is the most up-to-date information.

On an interpretational level, anxiety is suggested to cause people to misinterpret information based on current feelings. In line with this suggestion, results of **Chapter 5** indicate that soldiers who were afraid to get shot were more prone to recognize an opponent directing a gun at them, even if the opponent actually surrendered.

On a behavioral response level, anxiety is proposed to lead to changes in amongst others action readiness. In line with this suggestion, people showed higher heart rates when they were anxious about falling off a high scaffold than near the ground (**Chapter 2**). Moreover, running became less efficient. This was shown by the less efficient stride pattern and higher oxygen uptake. These findings interestingly add to the current literature that anxiety affects endurance tasks next to cognitive and perceptual-motor tasks (**Chapter 2**).

Finally, in line with ACT, the current thesis provides support the idea that negative effects on performance generally seem to increase when the attentional load becomes larger. Besides anxiety, concurrent execution of cognitive, perceptual-motor, as well as endurance tasks contributes to the attentional load (**Chapter 2 & 3**). Moreover, for novices task execution is more attention demanding than for experts (**Chapter 3**). Together, the attentional demands of all of these factors seem to add up (**Chapter 2 & 3**).

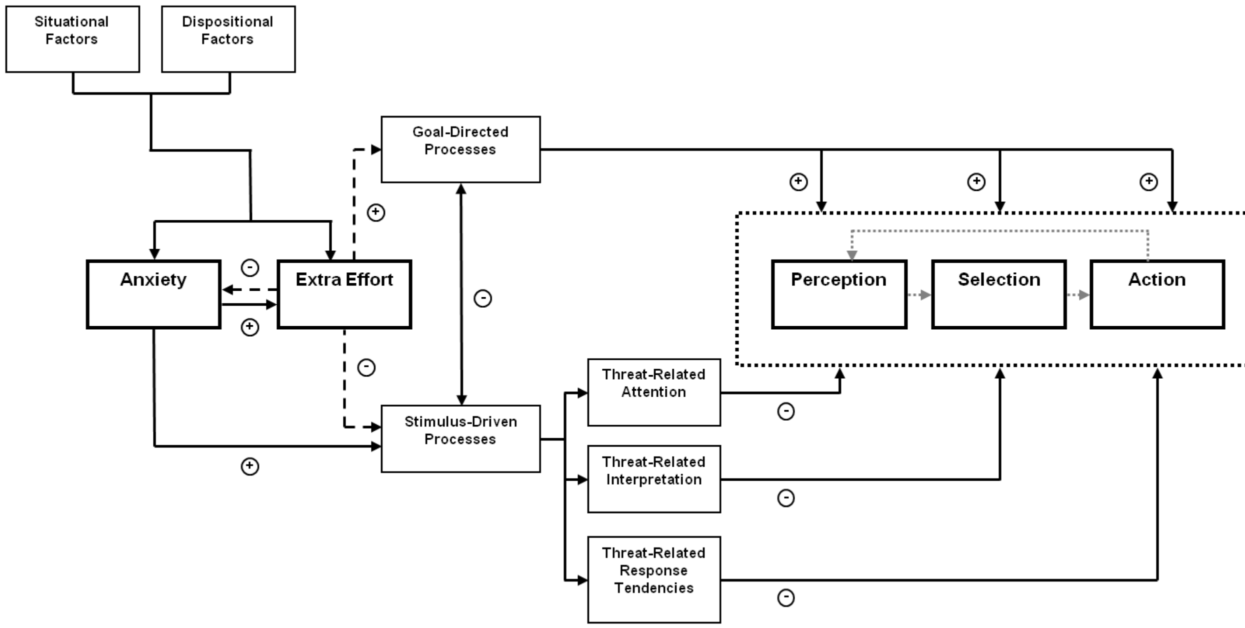

Figure 7.1. An integrated model of effects of anxiety on perceptual-motor performance (Nieuwenhuys & Oudejans, 2012).

Effects of exercise-induced fatigue

Many studies focused on the effects of exercise-induced fatigue on (cognitive and perceptual-motor) performance. However, empirical findings are still scattered and an overarching framework does not exist. Moreover, exercise-induced fatigue is a complex concept. As a result, different definitions and interpretations exist. Knicker et al. (2011) for example, reviewed symptoms of exercise-induced fatigue in sports competition, and they quantified exercise-induced fatigue using performance symptoms, such as technique execution and error rates. This approach assumes however, that if there is no degradation in performance, then there is no exercise-induced fatigue. This approach is clearly flawed; people can indeed experience exercise-induced fatigue without showing performance decrements (e.g., **Chapter 4;** McMorris et al., 1994, 1996, 1997, 1999). On the other hand, defining exercise-induced fatigue as a sole physiological process does not hold either. Following Noakes (2012), there is no doubt that motivation is necessary to achieve VO_2max. “For if exercise is regulated purely by physiological failure there is no need for any motivation to reach that inevitable state of biological failure; one simply continues to move the legs until they fail. Secondly, then there is no need for the symptoms of fatigue whose principal function must be to forestall homeostatic failure” (Noakes, 2012, p.4). Experiments in the current thesis support the view of exercise-induced fatigue as a combination of self-perceived (RPE) and physiological changes (e.g., heart rate, oxygen uptake).

With regard to the mechanisms that underlie the effects of exercise-induced fatigue on different types of performance, the inverted-U hypothesis is often proposed (Yerkes & Dodson, 1908). Davey (1973) was the first to present a theoretical explanation for a direct exercise-cognition interaction. He saw exercise as a stressor that would induce increases in arousal as exercise intensity increased, resulting in an inverted-U shaped relationship. However, the inverted-U hypothesis is merely a general prediction, not a theory that explains how, why, or precisely when arousal affects performance. Studies that provide an explanation for the effects of exercise on human behavior often suggest behavior to be affected through changes in attention (e.g., Arcelin, Delignières, & Brisswalter, 1998; Lambourne & Tomporowski, 2010; Noakes, 2012; Tomporowski, 2003). Interestingly, this line of thought is similar to that adopted in the large body of literature that already consists on the theoretical underpinnings of anxiety effects. Consequently, it would be interesting to investigate whether parallels can be drawn between the concepts of anxiety and exercise-induced fatigue. Although somewhat speculative, in the following section, we therefore discuss whether exercise-induced fatigue would fit into the integrated model of anxiety by Nieuwenhuys and Oudejans (2012). This might provide a first step towards building one model to explain combined effects of anxiety and exercise-induced fatigue. Therefore, findings on exercise-induced fatigue are discussed in the light of the integrated model of anxiety Nieuwenhuys and Oudejans (2012) (see Figure 7.1). Similarities and differences are highlighted. First, the suggestion that exercise-induced fatigue can affect human behavior on different levels (effects on attention, interpretation, and response tendencies) is addressed. Thereafter, we discuss whether central tenets of ACT are also in line with findings on exercise-induced fatigue, such as the suggestions that task efficiency is affected to a larger degree than task effectiveness, and that the investment of additional mental effort may compensate for negative performance effects.

Effects of exercise-induced fatigue on attention

It is important to distinguish between task execution *during* and *after* exercise. Just as with anxiety, inducing exercise-induced fatigue *during* task execution changes the performance setting from a single-task into a dual-task setting. Performing exercise consumes attention, even if it considers strongly automated movements such as walking or running (e.g., **Chapter 2**). Consequently, one would consider fewer resources to be available for cognitive performance. Indeed**,** cognitive performance appears to be negatively affected when performed during exercise (for a review, see Lambourne & Tomporowski, 2010). Moreover, reduced cognitive performance seems to be especially prominent for participants with relatively low fitness, providing another indication that exercise affects attentional capacity (Chang et al., 2012). Chang et al., (2012) argue that people with low fitness need to invest more attentional resources in conducting exercise. Consequently, they are also thought to have fewer resources available for cognitive performance. A viable explanation for these performance effects is provided by the hypofrontality hypothesis (Dietrich, 2003). The hypofrontality hypothesis states that the brain has a limited and constant metabolism and that performance of exercise and cognitive processing require similar neural structures and metabolic activity. Consequently, during exercise, available neural resources are drawn from cognitive processes towards the control and maintenance of motor movements in for example running.

On the other hand, when tasks are performed *after* exercise, a small positive overall effect on (cognitive) performance can be observed (Chang et al., 2012; Lambourne & Tomporowski, 2010). This positive effect is independent of exercise intensity. However, the duration of exercise might be particularly important. Performing tasks after exercise of relatively short duration appeared beneficial for performance (Chang et al., 2012). In line with Yerkes and Dodson (1908), it can be argued that tasks were performed in an aroused state rather than a fatigued state, which might explain the positive effects on performance (Chang et al, 2012). Theoretically, cognition should be facilitated by the increase in brain concentrations of the neurotransmitters dopamine and norepinephrine that arises during and following moderate intensity exercise (catecholamines hypothesis, Cooper, 1973; McMorris et al., 2008). The few studies that reported decreases in performance after exercise, required their participants to exercise for at least 2 hours (Cian et al., 2000; Grego et al., 2004). Thus, only after prolonged exercise, exercise-induced fatigue seems to consume attention to the detriment of task performance.

Together, in line with findings on anxiety, results indicate that exercise can affect (cognitive) task performance through changes in attentional processes. Whether and to what extent these effects occur is dependent on the mode (during or prior to task execution) and duration of the exercise that is performed. Future research is warranted to further investigate how and to what extent exercise affects attentional capacity. Future research could for example investigate the effects of exercise-induced fatigue on dual-task performance. It is discussed that there are indications that the more demanding the task, the larger the performance effects. Moreover, findings are compatible with the view that attentional resources are limited (Eysenck et al., 2007). Thus, attentional resources seem to be consumed by both anxiety and exercise-induced fatigue. Moreover, just as anxiety, exercise-induced fatigue seems to be able to trigger stimulus-driven attention at the cost of goal-directed attention. Noakes (2012), for example, indicates that exercise-induced fatigue can distract attention away from task execution towards feelings of fatigue in marathon runners, thereby negatively affecting their performance outcome.

Exercise-induced fatigue-related interpretations

Similar to anxiety, exercise-induced fatigue has been found to change the way that people perceive their environment. Previous studies indicate that peoples' perceived action possibilities decrease when they are subjected to moderate or intense exercise (Bhalla & Proffitt, 1999; Pijpers et al., 2007; Proffitt et al., 1995). Pijpers et al. (2007), for example, instructed people to climb to exertion on a climbing wall and asked them to judge their maximum reaching distance at low and high levels of perceived exertion. Higher perceived exertion was associated with decreases in perceived maximum reaching distance. Similarly, inducing fatigue by having people complete an exhausting run resulted in people perceiving a hill to be steeper than when people were rested (Bhalla & Proffitt, 1999; Proffitt et al., 1995). Also, participants who wore a heavy backpack judged the hill to be steeper than their counterparts without a backpack (Bhalla & Proffitt, 1999).

On the other hand, **Chapter 5** shows an interesting difference between effects of anxiety and exercise-induced fatigue on shooting decisions. Soldiers interpreted the intended action of their opponent differently when they were anxious than when they were physically fatigued. In line with previous findings for police officers, anxiety caused soldiers to shoot too fast and consequently shoot more surrendering suspects (Nieuwenhuys et al., 2011). Nieuwenhuys et al. (2011) argued that people who are afraid to get shot are more prone to recognize an opponent's weapon even when there is none. In contrast, in **Chapter 5**, physically fatigued participants were too slow and more often failed to shoot when they were supposed to. Threat-related expectancies caused police officers to react even before visual information on the presence of a gun was available. Future research should elucidate what caused the soldiers in **Chapter 5** to fail to shoot. It would be interesting to conduct a follow-up study in which gaze behavior is assessed to investigate whether the soldiers look too late or too short to pick up crucial information. Or did they pick up the available information but were they too slow to react? In sum, in line with the integrated model of Nieuwenhuys and Oudejans (2012), exercise-induced fatigue, just as anxiety, seems to influence the way that we perceive our environment.

Exercise-induced fatigue induced behavioral changes

Obviously, exercise-induced fatigue induces physiological changes, such as increased heart rate and oxygen uptake. Anxiety-evoked physiological changes are suggested to reflect an increase in action readiness, thereby enabling an individual to quickly respond to a threat. In first instance, exercise-evoked physiological changes might also increase action readiness. Similar to anxiety, a warm-up period or a relatively short acute bout of exercise (as induced in **Chapter 5**) heightens one's state of physiological arousal, which might prepare soldiers to quickly respond to the upcoming tasks. Whether exercise-induced fatigue also evokes other behavioral responses, such as increased avoidance tendencies, remains to be determined.

Performance efficiency vs effectiveness and the investment of mental effort

Similar to anxiety, exercise-induced fatigue does not always negatively affect performance. Especially after exercise, various studies report maintained performance and even a small overall positive effect on cognitive performance (see reviews by Chang et al., 2012, Lambourne & Tomporowski, 2010). However, these reviews do not distinguish between task efficiency and effectiveness as suggested by Eysenck et al. (2007). Eysenck et al. (2007) proposed that the investment of more time or more mental effort to achieve the same performance indicates a decrease in task efficiency. Actually, cognitive performance is measured through response times in many of the studies that were included in several meta-analyses (e.g., Chang et al., 2012, Lambourne & Tomporowski, 2010). These response time tasks assessed the elapsed time between the detection of a sensory stimulus on a computer screen and a behavioral response (press the correct key) (Al-Yahya, Dawes, Smith, Dennis, Howells, & Cockburn, 2011). In general, during exercise, response times seem to increase, providing an indication of reduced efficiency (Lambourne & Tomporowski, 2010). Moreover, higher mental effort ratings at higher levels of exercise-induced fatigue have also been reported in previous studies (e.g., Eaves et al., 2008). People seem to try to compensate for possible negative effects of exercise-induced fatigue by investing extra effort.

On the other hand, after exercise, reductions in response time appear, which suggests that exercise can also disengage additional resources. In line with this suggestion, the current thesis shows that perceptual-motor performance (shooting accuracy) is not necessarily negatively affected by acute bouts of exercise, even at high intensity **(Chapter 4 and 5)**. In **Chapter 5**, the increased arousal level due to an acute bout of exercise even seems to protect shooting accuracy against the negative effects of anxiety. However, although shooting accuracy did not decrease in these studies, in **Chapter 4**, efficiency of task execution clearly suffered. People took more time to take the shot and invested more mental effort at higher levels of exercise-induced fatigue. The increase in invested mental effort indicates that, just as anxiety, exercise-induced fatigue can also serve a motivational function. Thus, just as with anxiety, people seem to become less efficient as exercise-induced fatigue increases, they invest more effort or need more time to perform the same task. These effects are most prominent when tasks are performed during exercise.

In sum, the majority of findings on effects of exercise(-induced fatigue) are compatible with the integrated model of the effects of anxiety on performance by Nieuwenhuys and Oudejans (2012). Exercise(-induced fatigue) can affect attention and interpretation, and can induce behavioral changes. Moreover, people compensate for the negative effects of exercise(-induced fatigue) on performance by investing more mental effort and/or time. However, task performance during exercise should be distinguished from task performance after exercise. When tasks are performed *during* exercise, exercise(-induced fatigue), just as anxiety, changes a single-task into a dual-task situation and competes with the task at hand for limited attentional resources. Cognitive tasks in an operational context (e.g., communicating coordinates, decision making, vigilance) often have to be performed during walking or running over heavy terrain. On the other hand, *after* exercise, the task is generally performed in an 'aroused' state which is mostly beneficial to performance and is particularly important for perceptual-motor tasks such as shooting that are generally performed after exercise.

Practical implications

Performing under threatening and physically exerting circumstances is inherent to soldier performance. Recent research in the International Security Assistance Force for Afghanistan (2009-2010) on Dutch soldiers for example stresses the unpredictable character of modern military operations and the consequent variety of stress burdens that soldiers carry (Boermans, Kamphuis, Delahaij, Korteling, & Euwema, 2013). Moreover, soldiers are confronted with situations in which they have to carry heavy loads or cross heavy terrain. The current thesis demonstrates that these stressors can negatively affect performance on tasks and combinations of tasks that are important in soldier practice.

In **Chapter 2-4**, anxiety has been shown to negatively affect shooting accuracy, shooting decisions, and to cause less efficient running through less efficient gait patterns and higher energy expenditure. Effects are suggested to be larger when the attentional demands become larger, for example through dual-tasking. In military practice, soldiers have to monitor the ground for obstacles and safe locations for foot placement while simultaneously communicating with members of their squad, scan the environment for the enemy, and attending to information from communication networks (Mahoney et al., 2007). Moreover, in these settings, aiming tasks are often combined with cognitive tasks, such as strategic decision making. Furthermore, the current thesis suggests that soldiers benefit from the highest possible skill level. Negative effects of anxiety were larger for participants that were novices in far aiming than for experts. For novices, dual tasking appeared more effortful, and far aiming accuracy was more susceptible to anxiety. Novices need to allocate more attention to task execution. Consequently, a high skill level would leave soldiers with more attention available to cope with anxiety or dual tasking.

In addition to anxiety, the current thesis suggests that exercise-induced fatigue can also alter shooting decisions. More precise, the distance from which people decide to shoot is suggested to increase at high levels of physical exertion. As a possible consequence, soldiers might decide to shoot from too far away to get a clear shot, thereby increasing the risk of missing the target and consequently increasing the risk of unintended casualties.

Although the findings described above highlight some interesting points of interest for military practice, they did not measure soldiers. As such, results do not automatically generalize to soldier performance and more research is warranted to verify these findings for soldier practice. The experiments in **Chapter 2-4** were designed to further our understanding of separate and combined effects of anxiety and exercise-induced fatigue on tasks that are important to operational performance. **Chapter 5** meets the demand for test circumstances that are more representative of the real world (e.g., Dicks et al., 2010; Mann et al., 2010; Nieuwenhuys et al., 2012). The most important practical implications are therefore provided by the field study in **Chapter 5**. Results of this chapter indicate that infantry soldiers shoot less accurately under anxiety. Although soldiers are expected to perform well under heightened levels of anxiety, results indicate that shooting accuracy decreased with 20-40% which is comparable to police officers (drop around 32%, Nieuwenhuys & Oudejans, 2010; around 16%, Nieuwenhuys & Oudejans, 2011; around 22%, Oudejans, 2008).

Moreover, following **Chapter 5**, soldiers are suggested to make more errors in decision making and in math performance in threatening situations. The latter is suggested to have serious consequences for tasks that include fast calculations, such as communicating coordinates or counting rifle magazines. Effects of exercise-induced fatigue on soldier performance appear more complex and seems to depend on exercise duration, mode (task performance during or after exercise), and the attentional demands of the task. However, moderate arousal levels induced through exercise are suggested to negatively affect soldiers' shooting decisions, but be beneficial for their shooting accuracy.

All in all, the current thesis indicates that the debilitative effects of anxiety and exercise-induced fatigue on operational performance should not be overlooked. Moreover, the current thesis supports the notion that theories and methods from sport psychology might be applied successfully to the domain of human factors (e.g., Eccles et al., 2011). Finally, future research is suggested to continue the development of computer simulations that might allow us to predict human performance under circumstances that are hard or sometimes even impossible to create in an experimental setting. Accurate predictions of soldier performance on the battlefield may help to prevent casualties in the future.