MARTINA NAVARRO

EFFECTS OF STRESS AND TRAINING ON LATENCY AND ACCURACY OF MOTOR RESPONSES TO VISUAL STIMULI

Thesis of Doctor of Philosophy presented to Institute of Biomedical Science of University of São Paulo to obtain Degree of PhD in Sciences.

São Paulo
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Area: Human Physiology

Supervisor: Ronald D. P. K. C. Ranvaud

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A Comissão Julgadora dos trabalhos de Defesa da Tese de Doutorado, em sessão pública realizada a ..../................/................, considerou

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São Paulo, 24 de março de 2008.

PARECER 827/CEP

Prezada Senhora,

Atendendo sua solicitação, a *Comissão de Ética em Pesquisas com Seres Humanos do ICB*, em sua 82ª reunião realizada em 19.03.08, analisou o projeto de sua responsabilidade intitulado: "*Os Efeitos do treinamento sobre o desempenho motor em condições de estresse e de fadiga*".

Informo a V.Sa. que, após análise e discussão, o referido projeto foi **aprovado por esta Comissão.**

Lembramos que cabe ao pesquisador elaborar e apresentar a este Comitê, relatórios anuais (parciais ou final), de acordo com a resolução 196/06 do Conselho Nacional da Saúde, item IX.2 letra c.

O primeiro relatório deverá ser encaminhado à Secretaria deste CEP em **24 de março de 2009.**

Atenciosamente,

Prof. Dr. LUIZ VICENTE RIZZO
Coordenador da Comissão de Ética em
Pesquisas com Seres Humanos - ICB/USP

Ilma. Sra.
MARTINA NAVARRO
Departamento de Fisiologia e Biofísica
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ABSTRACT

Navarro M. Effects of stress and training on latency and accuracy of motor responses to visual stimuli. [Ph. D. thesis (Human Physiology)]. São Paulo: Instituto de Ciências Biomédicas, Universidade de São Paulo; 2013.

The aim of the current thesis was to investigate the effects of high-pressure on latency and accuracy of motor responses to visual stimuli during the execution of two experimental protocols, and to examine the efficiency of task-specific practice intervention in managing these effects. The theoretical framework adopted was Attentional Control Theory (ACT), which argues that high-pressure increases situational stress and state anxiety and thus impairs the goal-directed attentional system. The penalty kick in football, a task with tight time constraints to motor response and an example par excellence of high-pressure situation in real life, was adopted as paradigm. The series of experiments performed revealed that when stressed by the high-pressure situation, participants either required more time to respond to the visual stimulus or were unable to inhibit automatic responses, resulting in consistent errors with very short latencies. Such effects were in part successfully reverted by practice. However, significant individual differences were revealed that seem to relate to the individual's tendencies for attentional control. Furthermore, the results showed that the mere presence of a threatening non-target object impaired shooting accuracy, with a tendency of responses towards the threatening non-target. The findings provide a better understanding of how high-pressure and non-target objects affect motor performance under stress and how task-specific practice may revert such effects.

Keywords: Attentional control theory. Choking under pressure. Anxiety. Automatization. Motor control. Penalty kick.

RESUMO

Navarro M. Efeitos de estresse e treino na latência e acurácia de respostas motoras a estímulos visuais. [tese (Doutorado em Fisiologia Humana)]. São Paulo: Instituto de Ciências Biomédicas, Universidade de São Paulo; 2013.

O objetivo da presente tese foi de investigar os efeitos de situações de pressão (causadoras de estresse) na latência e acurácia de respostas motoras a estímulos visuais, e verificar a eficiência de sessões de treinamento na reversão de tais efeitos. O embasamento teórico adotado foi o *Attentional Control Theory* (ACT), teoria que prediz que em situações de estresse psicológico e estado de ansiedade aumentada, o sistema atencional *goal-directed* fica prejudicado e sobrepujado pelo sistema *stimulus-driven*. O pênalti no futebol, por ser uma tarefa de controle motor com fortes vínculos temporais e um excelente exemplo de situação causadora de estresse na vida real, foi adotado como paradigma experimental para o presente trabalho. A série de experimentos relatados revelaram que, quando estressados, os participantes precisaram de mais tempo para responder ao estímulo visual ou então eram incompetentes em inibir respostas automáticas incompatíveis com a tarefa. Tais efeitos foram em parte revertidos, revelando porém, grandes diferenças individuais que parecem estar relacionadas com diferenças individuais no controle atencional. Os resultados também revelaram que a simples presença de um estímulo ameaçador (a priori irrelevante) prejudicou a resposta motora. Os achados ofereceram uma melhor compreensão de como estresse, ansiedade e estímulos irrelevantes afetam o controle motor e de como treinamento pode reverter tais efeitos.

Palavras-chave: Controle atencional. Desempenho sob pressão. Ansiedade. Automatização. Controle motor. Pênalti.

LIST OF ILLUSTRATIONS

LIST OF TABLES

CONTENTS

1 INTRODUCTION

1.1 General context and motivation

Basic function of the nervous system is the fundamental capacity to select the most relevant information at precise moments from the wealth of information available in a complex environment (Fitts, Posner, 1967; Schall, Thompson, 1999). The mechanisms of attention, responsible for selecting, focussing on and processing visual information are key determinants of successful motor execution (Knudsen, 2007; Williams et al., 1999, 2002a). Just as significant is the ability to re-program, adjust or even inhibit a given motor plan as function of novel online information, clearly enhancing the adaptive power of human behaviour in a dynamic environment (Logan, Cowan, 1984; Sakai et al., 2000). A distinguishing feature of these skills is the dependency on the time needed for contemplation prior and within the execution of a skill, during which the neural networks involved must be organized (Milton et al., 2007). This time required to process and adjust (when necessary) response might vary according with circumstances and rely on action complexity (Morya et al., 2003a).

In our daily activities, both attentional and motor control are essential to achieve optimal response. Particularly, the moment beyond which a response can no longer be adjusted, altered or even inhibited is an important variable. Less time needed to respond to a stimulus means more time available to select and process information correctly, providing faster responses. Particularly in sports, knowledge of the constraints on time needed to adjust responses appropriately may provide a crucial advantage when elaborating training strategies. Practice on a task leads to ‘automaticity’, the ability to perform a skilled task using minimal or no processing resources (Brown, Carr, 1989; Logan, 1988, 1989). Automatization occurs because the task is so well-practiced that many of its components become automatic and no longer require conscious awareness, thereby reducing capacity demands (Laberge, Samuels, 1974). Nonetheless, even after practice and achieving highly automatized behaviour, athletes’ performance often decreases during important tournaments. Considering a circumstance of high-pressure, a phenomenon known as choking under pressure may occur. It is best defined by the following statement: “it is performing more poorly than expected, given one’s skill level, in situations where performance pressure is at a maximum (Beilock, Gray, 2007).”

Surprisingly, the effects of high pressure and of practice on the time needed to reliably respond to visual events are largely unknown. It is extremely valuable to understand how high-pressure affects attentional and motor control in order to develop specific training strategies that assist athletes to cope with high-pressure conditions. The current thesis tries to shed some light on high-pressure effects on attentional and motor control, particularly on the time needed to respond appropriately, and elaborate successful strategies that revert such effects.

1.2 Structure of the thesis

Chapter 2 provides a literature overview of the fields relevant to this thesis: motor control, cognitive psychology and cognitive neuroscience, especially in sport context. This overview covers topics such as the dynamics of motor responses to visual stimuli and motor programming, high-pressure and anxiety-stress theories and finally task automatization, including explicit and implicit learning concepts. Chapter 3 provides an overview of research questions. Chapters 4-6 provide an introduction, objectives, methods, results, discussion and conclusion for the three studies completed, two published (Navarro et al., 2012, 2013) and one submitted (Navarro et al., Submitted). Finally, Chapter 7 provides a general discussion and summary of all findings, considering theoretical and practical implications.

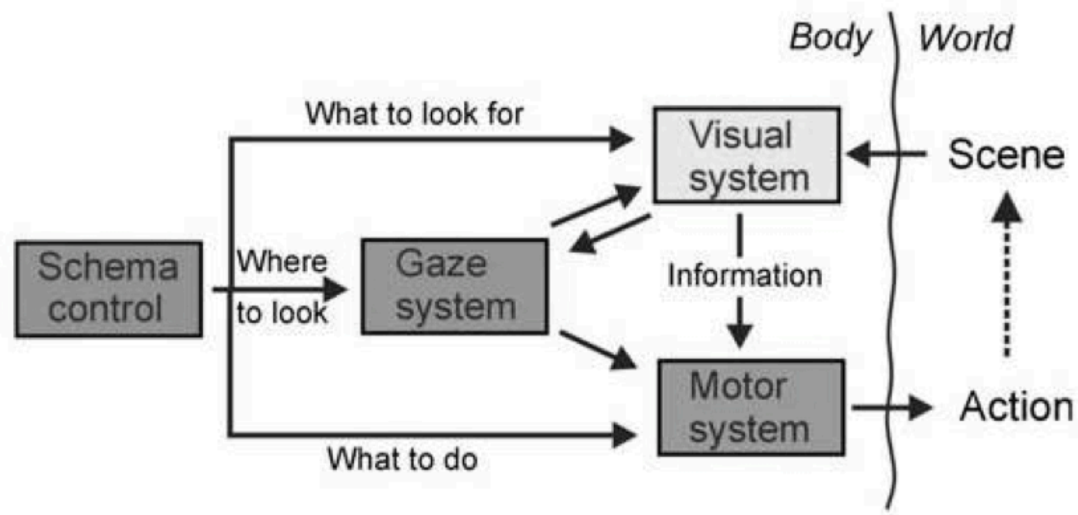
2 REVIEW OF THE LITERATURE

2.1 Dynamics of motor response

2.1.1 Visual system and attentional functions

Vision plays a keyhole in guiding action responses (Land, 2009). The visual system, located in the occipital lobe and much of the temporal lobe, acts to provide information to the motor system to ensure accurate and finely tuned movements (Figure 1). Hence, knowing where and when to look is crucial to plan appropriate motor responses, yet the visual display can be large and full of relevant and irrelevant information for the task.

Figure 1 - The relationship between vision and motor system during visually guided movements.



The relationship between vision, composed by the visual and gaze systems, and motor system during visually guided movements.
Source: Land (2009).

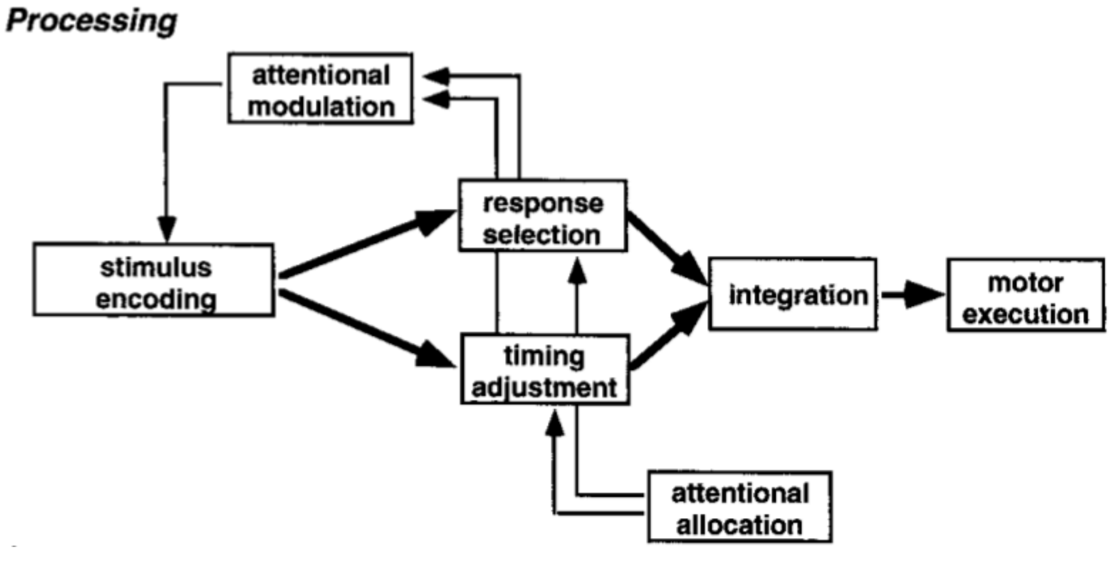
Attention can be defined as a cognitive system that facilitates the selection of relevant information and inhibits the rest for further processing. Moreover, the perceptual ability of focussing on task-relevant information while ignoring potential distractors that compete for our attention is called selective attention. Selective attention is important especially in sports in which athletes should be able to rapidly identify relevant information and ignore the irrelevant cues. Several studies in a variety of sports indicated that directing attention can be very useful (Abernethy, 1996; Williams et al., 1999; Williams, Grant, 1999). As an example, Abernethy et al. (1999) improved squash anticipatory skills instructing participants to focus on particular areas of the visual field. Video clips filmed from the perspective of the defensive squash player were presented and participants, from the opposing squash player point of view, executed a particular stroke. Savelsbergh et al. (2010a) used the same method to improve anticipatory skills of football goalkeepers when saving penalties. In this case they presented video clips filmed from the goalkeepers' perspective and also added transparent ellipses during these films to orient attention to relevant areas at different and crucial moments. In another study, Hagemann et al. (2006) used in a badminton task a transparent red patch to orient athletes' attention to relevant areas of information at different moments before racket-shuttle contact. Like in the study of Abernethy et al. (1999) and Savelsbergh et al. (2010a), participants learned both the location and timing of the focus of attention, which resulted in significant improvement in anticipatory skill. Thus, it is important to emphasise that selective attention is not exclusively a matter of learning to focus on the most useful information, but it also involves the learning of accurate timing of attention to moments at which the most useful sources are available.

Corbetta and Shulman (2002) scrutinized how attention works and showed evidence for two attentional systems that carry out different attentional functions in partially segregated brain networks. They distinguished between two systems, one influenced by expectation, knowledge, and current goals and the other system responding maximally to salient or conspicuous stimuli. The former system, called goal-directed attentional system, includes parts of the intraparietal cortex and superior frontal cortex and is involved in the top-down control of attention, preparing and applying goal-directed selection for stimuli and responses. The second system, called stimulus-driven attentional system includes the temporoparietal cortex and inferior frontal cortex, and is largely lateralized to the right hemisphere. This system is involved in the bottom-up control of attention and is specialized in the detection of default relevant stimuli, particularly when they are salient or unexpected. In practice, both the goal-directed and stimulus-driven attentional systems often interact during their functioning (see Pashler et al., 2001, for a review).

2.1.2 Motor response and point of no return

After processing by visual system the relevant information is utilized in processing the output motor response. Psychological studies suggested that the response selection (i.e. what action to take) and timing adjustment (i.e. when to act) are performed serially in separate stages (Frowein et al., 1981; Posner et al., 1973; Sanders, 1977). The response is selected based on visuomotor mapping rules, timing adjustment being related to activity in the posterior part of the cerebellum. More specifically, the timing-related area is localized bilaterally in the lateral part of the cerebellar posterior lobe (Sakai et al., 1998, 2002). According to the model shown in Figure 2 (Sakai et al. 2000), the response selection and timing adjustment processes are performed in parallel, but their integration starts only after both processes are completed. The latency of a response would then be determined by the slower of the two processes and the additive effect of reaction time would be attributable to the time required for the integration of the two kinds of information.

Figure 2 - Model of motor response processing.



Source: Sakai et al. (2000).

Morya et al. (2003a) developed a computer-based simulated penalty kick task in which they examined the so-called point of no return (i.e., PNR), this being the moment beyond which alterations to motor decisions cannot be made, at least not reliably. The simulated penalty task involved a computer monitor that displayed a goalmouth with three dots that represented goalkeeper, ball and kicker. The ‘kicker’ moved upwards, towards the stationary ‘ball’, while in the upper half of the screen the ‘goalkeeper’, inititially in the middle of the goalmouth, moved randomly to the right or left at different times (≤ 459 ms) before the ‘kicker’ coincided with the ‘ball’. In some (catch) trials, the ‘goalkeeper’ did not move. Participants were instructed to tilt a lever to the left or to the right, exactly at the moment the 'kicker' and the 'ball', were superposed and in the direction opposite to the side the goalkeeper moved. The PNR for this simulated penalty task (the time for which the probability to direct the ball to the opposite side of the goalkeeper is half way through the transition between random response, i.e., 50% correct, and perfect response, i.e., 100% correct[1]) was found to be approximately 250 ms.

Van der Kamp (2006; see also van der Kamp, 2011) performed a similar study adapting it to a field situation, and requiring more complex motor response. In this study instead of tilt a lever, participants had to actually kick a ball at one of two targets, in the right or in the left upper corner corners of a football goalmouth, depending on which of two lights near the goal centre was switched on. The results showed that if goalkeepers make their move within approximately 400 ms prior to foot-ball contact, kickers are less likely to succeed in placing the ball to the opposite side and/or their accuracy is decreased. Particularly, it was found that with less than 600-700 ms available between the start of goalkeeper dive and foot-ball contact risk of choosing the wrong side was actually enhanced. In other words, penalty kickers require a minimum amount of time to be able to determine the side to which to direct the ball and accurately perform the kicking action.

Some studies also have shown that humans are able to make fast corrections in ongoing movements (Day, Lyon, 2000; Paulignan et al., 1991). The minimum time needed for visual information to influence fast responses has been estimated to be 200–300 ms (Beggs, Howarth, 1970; Keele, Posner, 1968) or less, 100–150 ms (Carlton, 1981; Paulignan et al., 1990, 1991; Prablanc, Martin 1992; Soechting, Lacquaniti, 1983; Zelaznik et al., 1983). Sondersen et al. (1989) surprisingly revealed that first motor adjustments on fast responses as function of a second visual stimulus start within 30-60 ms after movement onset. Considering such short-latency, Day and Lyon (2000; see also Castiello, Jeannerod, 1991; Castiello et al., 1991; Goodale et al., 1986; Pelisson et al., 1986; Prablanc, Martin, 1992) proposed that the early correction is generated by an automatic motor system that is under direct visual control (i.e., stimulus driven).

[1]Determination of PNR is based on standard psychophysical procedures (see e.g., Regan, 2000). For a more detailed explanation of this procedure, see section 4.6.3 below.

2.2 High-pressure in sport

One of the factors that may affect the time needed to make (or alter) motor decisions (i.e. the PNR) is high pressure. Baumeister (1984, p. 610) defined pressure as "any factor or combination of factors that increases the importance of performing well on a particular occasion". In sport tournaments with high degree of perceived importance it is common that the desire to perform as well as possible creates pressure (Hardy et al., 1996). It is commonly assumed that this pressure to perform at an optimal level provokes an increase in situational stress and state anxiety, which leads to decrements in performance (Beilock, Carr, 2001; Lewis, Linder, 1997; Masters, 1992; Wang et al., 2004). The term "choking under pressure" has been used to describe this phenomenon. Beilock and Carr (2001, p. 701) defined choking as "performing more poorly than expected given one's level of skill". Specifically, high level of anxiety is considered an aversive emotional state that occurs in threatening circumstances. In fact, state anxiety (the currently experienced level of anxiety) is determined interactively by trait anxiety (individual propensity towards anxiety) and by situational stress (see Eysenck, Calvo, 1992). Situational stress also can be defined, in a psychological perspective, as the individual's perception of the balance between the physical or psychological demands, and their competence in an activity that is regarded important at that specific moment.

The following sections outline physiological responses related to situational stress and the main attentional theories that have been used to described performance decrements under pressure situations. It should be noted that, although the majority of such research concentrates on how pressure situations modify the mechanics of attentional systems, there are also investigations associating less-than-optimal performance with biomechanical processes (Pijpers et al., 2003).

2.2.1 Autonomic nervous system

Physiological responses to high levels of perceived stress (induced by high-pressure conditions) include changes in autonomic nervous and endocrine systems. Two main pathways by which these changes occur are the hypothalamic-pituitary-adrenal axis (HPAA), the neuroendocrine route that results in release of glucocorticoids – cortisol, and the sympathetic nervous system (SNS), the neural route that results in release of catecholamines – noradrenaline/adrenaline and neuropeptides. Dysregulation of these stress systems can consequently trigger multiple physiological systems, including the cardiovascular system, metabolic function and behaviour. There are two major physiological responses to stress that can be easily assessed (Lundberg, Frankenhauser, 1980). They involve increase in heart rate (HR; e.g., Beuter et al., 1989) and increase in hormonal cortisol levels that can be measured in saliva samples (Salvador et al., 2003).

Variability of heart rate is easily assed by commercial heart rate monitors. Increase in heart rate is one of the autonomic nervous system (ANS) responses to stress. The sympathetic branch of the ANS plays an important role in the regulation of the cardiovascular system response to stress. Summarizing, the locus coeruleus and other noradrenergic cell groups of the medulla and pons, known as the LC/NE system, become active and use epinephrine to execute autonomic and neuroendocrine responses. This neural hormone accelerates the depolarization of the sinoatrial node, which increases heart rate.

Salivary cortisol also has been routinely used as a biomarker of psychological stress. Salivary cortisol levels are considered a reliable measure of an important response of HPAA adaptation to stress. Lundberg (2005, p. 5) suggested, "the most important psychological factors triggering the cortisol response are uncertainty, novelty, lack of control, distress, anxiety, and helplessness [...]" The HPAA is an important pathway by which social and psychological factors influence human physiology. On a neuroanatomical level, it is worth emphasizing that there are close links between the HPAA and cortical and limbic structures, which are important mediators of subjective-psychological stress responses (Buijs, Van Eden, 2000; Feldman et al., 1995; Heckmann et al., 2005; Herman et al., 2005; Lopez et al., 1999; Wang et al., 2005). Stressful situations activate hypothalamus—pituitary—adrenal function by predominantly activating corticotrophin releasing factor/arginine vasopressin (CRF/AVP) neurons in the paraventricular nucleus of the hypothalamus (see Chrousos, Kino, 2007 for a review). The hypothalamus releases CRF that then travels to the pituitary gland, where it triggers the release of adrenocorticotropic hormone (ACTH). Finally, ACTH is released into the bloodstream and causes the cortex of the adrenal gland to release the stress hormones, particularly cortisol. Cortisol results in physiological changes in most organ systems, helping to provide energetic resources normally useful in facing the stressor (Sapolsky et al., 2000). As an example, HPAA activity is initiated with the function of allocating glucose to brain areas where energy requirements are highest.

Since saliva is an easily obtainable biofluid and provides a noninvasive sample for evaluating the HPAA activity, collecting saliva has been a widely applied method in field-related research settings. Yet, it is important to mention that the degree of activation varies not only with perceived stress but also on other factors, such as circadian oscillations (Kudielka et al., 2007; Mason, 1968). Several additional variables, such as adrenal sensitivity, capacity and cortisol binding may affect total and free cortisol levels in the blood, and, subsequently, in saliva. Thus, careful proceedings should be adopted to collect saliva and sometimes, salivary cortisol may be expected to be only moderately correlated with perceived stress.

The HPAA and the LC systems are linked to the hypothalamus and also to the limbic system. Activity of the limbic system is correlated with emotions and memory thus allowing to discriminate whether the current stress is of a sort that has been mastered in the past and successfully adapted to, or not represent a threat at all, or is a clear and present problem.

2.2.2 Explicit monitoring theories

Explicit monitoring theories are a part of the attentional theories that seek to describe the cognitive processes governing pressure-induced failure. Attentional theories focus particularly on how pressure changes the attentional mechanisms and memory structures during performance. Explicit monitoring theories (Beilock, Carr, 2001; Gray, 2004; Jackson et. al., 2006; Masters, 1992) have suggested that anxiety raises self-consciousness, which turns attention inward toward an explicit focus in the execution of movements. Consequently, automatized motor processes that previously ran efficiently outside of consciousness, become explicitly controlled in a step-by-step fashion. This theory does well in explaining choking under pressure in skilled athletes, because an explicit step-by-step approach makes control performance more liable for errors. Masters' (1992) reinvestment theory suggests that the specific mechanism governing explicit monitoring is "dechunking." Pressure-induced attention to execution causes an integrated or proceduralized control structure that normally runs off without interruptions to be broken down into a sequence of smaller and independent units, similar to how performance was organized in early learning stages.

2.2.3 Processing efficiency theory

The Processing Efficiency Theory developed by Eysenck and Calvo (1992) in order to explain the adverse effects of high-pressure situations on motor performance primarily distinguished effectiveness and efficiency. They defined effectiveness as: “refers to the quality of task performance indexed by standard behavioural measures (generally, response accuracy)” (p. 336); and efficiency as: “refers to the relationship between the effectiveness of performance and the effort or resources spent in task performance, with efficiency decreasing as more resources are invested to attain a given performance level" (p. 336). These authors proposed two major assumptions that lead to the Processing Efficiency Theory. First, in order to deal with aversive high anxiety levels there is an increase in task effort and use of auxiliary processing resources. Hence, performance effectiveness is maintained if auxiliary processing resources are available, albeit at the expense of processing efficiency. Second, anxiety reduces working memory capacity, depleting processing resources that would normally be available to perform concurrent tasks and, thereby, resulting in performance decrements. From this perspective it is predicted that adverse effects of anxiety are much greater on processing efficiency than on performance effectiveness. Some studies on visual search behaviour under pressure corroborated this theory (Janelle, Singer, 1999; Williams, Elliott, 1999; Williams et al., 2002b; Wilson et al., 2006).

2.2.4 Attentional control theory

An increasingly influential theoretical model explaining the adverse effects of high-pressure on sporting performance is the attentional control theory (ACT; Eysenck et al., 2007; see also Derakshan, Eysenck, 2009; Oudejans, Nieuwenhuys, 2009; Wilson et al., 2009a,b). This theory, a major extension of the Processing Efficiency Theory discussed in the previous section, claims that stress-inducing high-pressure situations, or the presence of a threat-stimulus (which may be more conspicuous when anxiety increases), reduce the efficiency of the goal-directed attentional system (i.e., attention to worrying thoughts is associated with the use of more resources to maintain performance accuracy) and increase in reliance on the stimulus-driven attentional system. This relationship is bidirectional, in other words each system has influence on the other. On the one hand, anxiety affects the stimulus-driven attentional system via automatic processing of threat-related stimuli, thereby decreasing the influence of the goal-directed attentional system. On the other hand, the reduced influence of goal direction on attentional processes means that such processes are more affected by salient and conspicuous stimuli.

Attentional Control Theory also extends the theoretical approach by focusing on how lower level functions that are directly related to the goal-directed attentional system are affected. First, Miyake et al. (2000) identified three basic major control functions of the central executive:

1) inhibition: “One’s ability to deliberately inhibit dominant, automatic, or prepotent responses when necessary” (p. 57); this implicates in use of attentional control to resist disruption or any possible interference of task-irrelevant stimuli;

2) shifting: “Shifting back and forth between multiple tasks, operations, or mental sets” (p. 55); in other words this includes adaptive changes in attentional control based on task demands;

3) updating: “Updating and monitoring of working memory representations” (p. 56).

Second, Miller and Cohen (2001) showed that the brain areas most associated with the inhibition and shifting functions of the central executive are common to those associated with the goal-directed attentional system. Not coincidently, either inhibition and/or shifting were the most affected functions under increased pressure situations (Graydon, Eysenck, 1989; Lavie et al., 2004). Once more, this indicates that the notion that anxiety decreases the influence of the goal-directed attentional system and increases the influence of the stimulus-driven attentional system.

2.3 Motor skill acquisition

It is know that practice of motor responses improve performance. Fitts and Posners (1967) proposed a three-stage model to explain motor skill acquisition. In the initial phase, dubbed as the *cognitive phase*, novices learn by using explicit cognitive processes to control motor execution in a step-by-step fashion. In the next phase, *the associative phase,* learners already are familiar with the task and start to develop associations between stimulus situations and corresponding action responses. Finally, after extended practice, performance reaches the last *autonomous phase*, in which conscious attentional control is no longer required and execution of a particular action is to a large extent automatic.

Masters and Maxwell (2004) extended this model to a more detailed cognitive view based on two pathways. First, they argued that in a usual motor learning situation learners build up declarative (i.e. explicit) knowledge as a consequence of hypothesis testing behaviour. Hypothesis testing behaviour involves the generation of movement strategies and appraisal of the results, relying on working memory (Baddeley, Hitch, 1974). As a consequence, learners acquire a highly specialized set of declarative knowledge relevant to the motor skill. Second, they argued that in parallel with the accumulation of explicit knowledge, learners also build up a large set of procedural knowledge, which is complex and difficult to verbalise or monitor consciously (Masters, Maxwell, 2004). Once skilled, the performer executes complex responses with minimal attention to this declarative knowledge, due to automatic processing of information. However, declarative knowledge may sometimes come under attentional control (voluntarily or not) and is then manipulated via working memory, interfering with the delicate balance of the two attentional systems. Hence, strategies that minimize or circumvent contributions of working memory during motor skill acquisition may prevent, or diminish, the accumulation of declarative knowledge.

2.3.1 Implicit learning

In contrast with explicit processing of skill acquisition, implicit learning basically tries to remove the verbal and/or analytical systems, preventing the use of working memory during learning (Reber, 1967). Whereas implicit motor learning is designed to minimize the use of working memory, explicit motor learning tends to promote reliance on working memory. Thus, implicit motor learning tends to cause absence of awareness of the acquisition period and the acquired skill is difficult to describe verbally (Berry, Dienes, 1993; Cleeremans et al., 1998; Frensch, 1998). Furthermore, learning with limited dependence on working memory has been shown to improve the ability to maintain consistent performance when facing stress situations (Jackson, Farrow, 2005; Masters, 1992, 2000; Masters, Maxwell, 2004; Maxwell et al., 2003; Poolton, Zachry, 2007). Under pressure, performers that learned with implicit strategies do not seek to recover declarative knowledge (since they did not build up on it) when attempting to improve performance. This prevents the balance of attentional systems from being disrupted. An overview of key concepts of implicit and explicit motor learning is shown in Chart 1.

Chart 1 - Characteristics of implicit and explicit motor learning.

Implicit Motor Learning	**Explicit Motor Learning**
Limited Dependence on Working Memory	Increased Dependence on Working Memory
Limited Declarative Knowledge Accrual	Increased Declarative Knowledge Accrual
Stable Performance under Psychological Stress	Deteriorated Performance under Psychological Stress
Stable Performance under secondary-task conditions	Deteriorated Performance under Secondary-Task Conditions

Source: Poolton and Zachry (2007).

There are many techniques used to induce implicit motor learning. Errorless learning is one of these techniques and apparently is the most practical way to learn implicitly. Conversely to what the term suggests, errorless learning does not literally mean that no errors are made, but simply that errors are kept to a minimum, especially early in the learning process. To kept errors at a minimum, a method used for centuries to teach people new skills, is to start easy and gradually increase the difficulty. It is supposed that learners accumulate declarative knowledge even from their own trial-and-error attempts to find successful ways to complete a task. Hence, the errorless learning technique attempts to constrain the learner's environment such that errors are prevented or at least minimized. Reduced number of errors reduces propensity to form and test hypotheses that would lead to a build up of declarative knowledge. Studies have confirmed that when errors were prevented, or considerably reduced, an implicit mode of acquisition was adopted and this led to robust performance under pressure conditions (Maxwell et al., 2001; Poolton et al., 2005; Prather, 1971).

Other techniques that include the use of an external focus of attention (via concurrent secondary tasks, Poolton et al., 2006a; Wulf et al., 1998, 1999, 2001, 2002; Wulf, Prinz, 2001) and learning by analogy (Liao, Masters, 2001; Poolton et al., 2006b) can be used to promote implicit learning. Assuming that implicit processes operate relatively automatically, learning should be largely implicit under dual-task conditions because learners have to share attentional resources between the two tasks, which limits the resources available for testing hypotheses and formulating rules about the primary task. For cases in which some explicit information is necessary, at least to explain the task to the learner, analogy learning may help. This technique reduces the amount of information consciously processed in working memory by packing task-relevant knowledge into a single biomechanical metaphor. As example, Liao and Masters (2001), teaching a table tennis forehand showed robust performance for novices that were instructed to draw a right angle triangle with the bat when compared to novices that were instructed with a set of twelve rules adapted from table tennis coaching manual.

Overall, motor skill acquisition via implicit learning seems to be a promising approach to avoid the use of working memory and attentional resources, particularly under pressure conditions, thus preventing performance decrements under pressure.

2.3.2 Automatization and attenuation effect

Alternatively, another method that may help maintain the efficiency and/or effectiveness of the goal-directed attentional system under high pressure, is increasing automaticity of task performance. It is well known that with practice, a task, or at least some of its components, become automatic so that less conscious, or goal-directed, control is required for task execution (Abernethy et al., 2007). This freeing of attention can already be achieved by repetitive practice of the task or one its essential components (Brown, 1998, 2008; Brown, Bennett, 2002), and may be accelerated by limiting the amount of declarative task-relevant knowledge that is accumulated during practice (Jackson, Farrow, 2005; Masters, 1992).

Brown (1998) showed that a spatial, non-temporal task (e.g., pursuit rotor tracking) may interfere with the execution of a temporal, non-spatial task (e.g., pressing a mouse button every 5 s) as shown by the production of less accurate and consistent time judgments. In fact, for tasks that require both timing and spatial precision, it is presumed that both aspects of the task share the same attentional pool of resources. Brown and Bennett (2002; Brown, 1998, 2008) found that practice of the spatial, non-temporal task attenuates the interference. That is, practicing one aspect of the task (e.g., timing) reduces its attentional demands on the first aspect of the task, thereby increasing the availability of resources for the second aspect of the task (e.g., spatial). ACT holds that situations of high-pressure require a higher fraction of available attentional resources than normal situations. Yet, if the attentional resources are limited, then a point is reached in which supply becomes insufficient and performance suffers. In line with the attenuation effect, practicing for example on the timing aspect of the task would reduce the attentional demands for it, freeing resources for the spatial aspects of the task.

2.4 Penalty kick

In penalty kicks, a player takes a free kick to the goal from approximately 11 m (formally, 12 yards) facing only the opposing goalkeeper. This situation offers an excellent paradigm to study the effects of high-pressure and practice on latency and accuracy of responses to visual stimuli. It is a well-defined task with beginning and end precisely specified and with a high level of perceived stress (see section 2.4.1. below). Furthermore, on the one hand, the penalty kicker during the run-up has time constraints to use (or not) visual information from goalkeeper's actions to decide which side to shoot the ball. On the other hand, the goalkeeper also has limited time to choose which side to dive, using visual clues that kickers offer during the run-up.

2.4.1 Penalty kick and stress

The penalty kick has become a regular and decisive event in professional association football; in one out of five matches during the elimination stages of international tournaments such as the World Cup, the South American Copa Libertadores and the European Champions League, the winner is determined with a series of penalty kicks or penalty shootout (Armatas et al., 2007; Jordet et al., 2007a). Due to its decisive nature, the penalty kick is an example par excellence of a high-pressure situation in sports. Michael Owen, former English national team player recounts the Euro 2004 match between England and Portugal (Owen, 2004, p. 98):

> So we staggered on to penalties, and here I will make a declaration: there is nothing so nerve-racking as a penalty shootout, except maybe stepping into a boxing ring, which I did twice as a boy. Fighting for your life, one on one, or taking a penalty in a big game - in both instances your body simply doesn't belong to you.

Hence, notwithstanding the blatant advantage for the penalty taker, a surprising 20-35% of penalty kicks are not converted (Armatas et al., 2007; Jordet et al., 2007a; Morya et al., 2003b).

Often this high failure rate is attributed to situational high pressure. Thus, Jordet et al. (2007a) examined match statistics to estimate the relative importance of psychological factors (e.g., coping with stress), perceptual-motor skill (e.g., kicking skill) and physiological factors (e.g., level of fatigue) for success in penalty kicking. They found that the importance of the kick (i.e., the significance of the match and tournament, and the time within the match the kick is taken) is negatively related to the outcome of penalty kicks (see also McGarry, Franks, 2000). They concluded that psychological factors, such as coping with stress, are more important than physiological factors and perceptual motor skills for success in penalty kicking (see also Jordet, 2009; Jordet et al., 2007b; Jordet, Hartman, 2008).

These studies did not clarify how high-pressure situations lead to suboptimal penalty kick performance. Recently, however, Wilson et al. (2009a; see also Wood, Wilson, 2010a) have examined participants taking penalty kicks in a laboratory situation in order to uncover the adverse effects of high pressure. To ensure high levels of pressure a monetary prize was awarded and a leader board with the scores was circulated among the participants. Eye-tracking recordings revealed that under high pressure, penalty kickers looked at the goalkeeper significantly longer than in the absence of pressure, and this correlated with more centralized shots, within goalkeeper’s reach (see also Bakker et al., 2006). In line with attentional control theory (Eysenk et al., 2007), Wilson et al. (2009a) argued that in high-pressure situations attention is more stimulus-driven than goal-directed, and hence, kickers are more likely to focus on the threat-inducing goalkeeper with the result of a bias in favour of shots in the direction of the goalkeeper.

Since the outcomes of important football matches (e.g., most recently the 2012 European Champions League final) are progressively more likely to be decided by penalty kicks, many studies focus on delineating the most favourable strategy for taking a penalty kick (van der Kamp, 2011; Wood, Wilson, 2011). Considering that penalty kickers are supposed to have an overwhelming advantage over goalkeepers, adopting and training the more favourable strategy (or one that is superior to the kicker's current strategy) may significantly improve success rate, which on average seems conspicuously low (Jordet et al., 2007a).

2.4.2 The kicker: penalty kick strategies

Kuhn (1988; see also Morya et al., 2003a) was the first to investigate the strategies that penalty kickers adopt. He distinguished two strategies that are now identified as the ''keeper-independent'' (originally dubbed "open loop" by Kuhn) and "keeper-dependent" (first called "closed loop") strategies (van der Kamp, 2006). In the former strategy, the penalty kicker chooses where to aim the ball before the run-up and holds to that choice during the run-up and kick. Any action of the goalkeeper during the run-up is ignored. Alternatively, in the second strategy, the penalty kicker intends to kick the ball to the side opposite to which the goalkeeper dives. To this end, he tries to anticipate the direction of the goalkeeper dive by obtaining information from the goalkeeper's action during the run-up.

At first glance, a shot to the side opposite to the goalkeeper's dive prevents the goalkeeper from intercepting the ball and lessens the requirement for kicking accuracy. After all, the ball is shot to the empty half of the goal. Yet, research has indicated that the keeper-dependent strategy can only be successful if the information about the direction of the goalkeeper's dive can be picked up relatively early in the run-up. Van der Kamp (2006, 2011; see also Morya et al., 2003a) showed that if goalkeepers make their first move within approximately 400 ms prior to foot-ball contact, kickers are less likely to succeed in placing the ball to the empty half of the goal, and furthermore kick accuracy tends to be poor. In other words, penalty kickers need a minimum amount of time to be able to determine the side to which to direct the ball and accurately perform the kicking action. Recent work by Navarro et al. (2012) suggests that these effects are further exacerbated under high-pressure. The keeper-dependent strategy may also be challenging due to constraints related to visual attention. It is well-established that focussing on and fixating a target prior to and during the movement is essential in far aiming tasks in general (Vickers, 2007). Fixation not only allows the pickup of visual information necessary for accurate control of movement parameters such as direction and force of the aiming action (e.g., Vickers, 1996), but eye movements also makes non-visual information available (e.g., efference copy, or eye muscle propriocepsis) that can be exploited for accurate spatial control of the aiming action (Land et al., 1999; Land, Hayhoe, 2001; Wilson et al., 2007). In penalty kicking a focus on (or eye movements toward) the goalkeeper rather than the target area jeopardizes accuracy (Bakker, Oudejans, Binsch, van der Kamp, 2006; Noël, van der Kamp, 2012; van der Kamp, 2011; Wilson et al., 2009a). Notwithstanding the risks associated with it, it is likely that penalty kickers at times adopt the keeper-dependent strategy, and according to some authors more often than not (Kuhn, 1988; Wood, Wilson, 2010b).

In contrast to the keeper-dependent strategy, the keeper-independent strategy seems the more cautious and powerful approach for taking penalty kicks. First, descriptive analyses from international competitions reveal that goalkeepers never saved shots that are directed at one of the two upper corners of the goal (Armatas et al., 2007; Morya et al., 2003b), suggesting that aiming at these areas is favourable for achieving success. Moreover, a few biomechanical studies (Graham-Smith et al., 1999; Kerwin, Bray, 2006) measured the time that goalkeepers take to dive and reach different areas of the goal. Based on these measurements it is clear that if penalty kickers choose to kick at one of the upper corners with moderate force (i.e., with a speed > 22 m/s), then it would be impossible for a goalkeeper to intercept the ball. This is true, even if the goalkeeper anticipates the direction of the ball with a movement onset at approximately 300 ms before the kicker -ball contact. Finally, the goalkeeper independent strategy also permits a more efficient pattern of gaze fixations (Noël, van der Kamp, 2012; Wood, Wilson, 2011), a prerequisite to be successful in aiming tasks. Without focusing on the goalkeeper, penalty kickers can direct their attentional focus to areas that are more important for the accurate execution of the kick, such as the target and the ball (Noël, van der Kamp, 2012).

2.4.3 The penalty kicker's perceptions are implicitly influenced by the goalkeeper

Based on the pros and cons of the two strategies it seems clear that to adopt a keeper-independent strategy is the more favourable choice. However, it may be difficult for penalty kickers to completely ignore the goalkeeper. That is, previous work has suggested that penalty kickers can be influenced unwillingly by the actions (and possibly the mere presence) of a goalkeeper, with performance suffering as a consequence. Masters, van der Kamp and Jackson (2007) demonstrated that if goalkeepers simply stand marginally off-center, even if the penalty kicker is not consciously aware of this, there may be an influence on the kicker's shot direction. Furthermore, van der Kamp and Masters (2008) demonstrated that a goalkeeper's posture influences the perception of their size, resulting in subtle influences on the location to which the penalty kicker shoots the ball. Finally, Wood and Wilson (2010a) showed that if a goalkeeper waves his arms, this attracts visual attention of the penalty kicker, leading to sub-optimal gaze patterns and impaired shot accuracy.

Taken to its extreme, it might be that the mere presence of the goalkeeper may affect shot accuracy. An analogy can perhaps be found in the literature on the role of visual non-target objects (that are not necessarily physical obstacles) in reaching and grasping tasks (Howard, Tipper, 1997; Tipper, Howard, Jackson, 1997; Welsh, Elliott, Weeks, 1999). These studies have reported that visual non-target objects that surround the target influence the trajectory of the target-directed hand movement by either veering away from (Howard, Tipper, 1997; Tipper et al., 1997) or towards the visual non-target object (Welsh et al., 1999; Welsh, Elliott, 2004). To explain these effects, the response activation model (Welsh, Elliott, 2004; for an alternative explanation, see Howard, Tripper, 1997) proposes that prior to the execution of an action attention is distributed *throughout* the environment. As a result, both target and non-target objects activate automatic independent and parallel action response processes. Both action response processes race toward activation (see McGarry, Franks, 1997). It is the resulting combined activation of these independent processes that in the end determines the details of the action response directed to a target object. Inhibitory processes are responsible for eliminating competing action responses to non-target objects. The influence of the inhibitory processes is dependent on the moment (relative to the onset of the action response) that the visual non-target is presented and on its saliency. In the case of a visual non-target object that is present very early and is indistinct, inhibitory processes will result in negative activation, affecting the combined activation such that the movement veers away from the non-target object. However, the response activation process for a visual non-target object that is presented late and/or is very salient is much more difficult to inhibit. The response toward the non-target object will be incorporated in the combined action for the final action response, resulting in the movement being attracted toward the non-target object. In the penalty kick, if the kicker adopts a goalkeeper-independent strategy, the goalkeeper may be considered as a visual non-target object. In this scenario, the response activation model predicts that even the mere presence of the goalkeeper can affect, involuntarily, the placement of the ball relative to the target (i.e., corner). The direction of this effect (i.e., away from or closer to the goalkeeper) will depend, in large part, on the degree of saliency of the goalkeeper (e.g., arm waving may make the goalkeeper more salient, resulting in closer shots, Wood, Wilson, 2010). In sum, the mere presence of the goalkeeper may affect ball placement, even when a goalkeeper-independent strategy is adopted. .

3 OBJECTIVES

3.1 Overall objective

The principal aim of the current thesis was to investigate the effects of high pressure and of practice on accuracy and on the time needed to reliably respond to a visual stimulus relevant in guiding an on-going task.

3.2 Detailed objectives

In a series of three studies, focussing the penalty kick as paradigm specific objectives were:

1) to investigate the effects of high-pressure on latency and accuracy of motor responses to visual stimuli;
2) to investigate the effects of practice on latency and accuracy of motor responses to visual stimuli, in particular whether the effects of pressure can be reverted or minimized;
3) to investigate the influence of a probably threatening, but non-target object on attentional control and on accuracy of motor responses when a strategy of totally ignoring this object is adopted.

In order to achieve these objective, three experiments were performed, each addressing one of the above items.

Study 1 and 2 employed the validated simulated penalty task developed by Morya et al. (2003a), to uncover the effects of high-pressure and practice, respectively, on the accuracy and on the PNR of motor responses. Based on ACT, it is expected that high-pressure would cause participants to take a longer time than in low-pressure situations to respond to goalkeeper movement, and/or would lead to a decrease in performance accuracy. Furthermore, it is expected that practice in this simulated penalty kick task can revert or at least diminish such adverse effects.

Study 3 investigated in a field setting whether a non-target object such as a goalkeeper might implicitly influence penalty kickers' attentional control when a strategy of totally ignoring his presence is adopted. In particular, based on ACT, the goalkeeper would be interpreted as a threat-stimulus, disrupting the balance between goal-directed and stimulus-driven systems.

4 EXPERIMENT 1: THE EFFECTS OF HIGH PRESSURE ON THE POINT OF NO RETURN IN SIMULATED PENALTY KICKS

Experiment 1 employed the validated simulated penalty task developed by Morya et al. (2003a) to uncover the effects of high-pressure on the PNR in penalty kicking. The results of this experiment were published in Navarro et al. (2012).

Recently, Wilson et al. (2009a) have shown that under high-pressure, penalty kickers focussed more on the goalkeeper than in a low-pressure situation, compromising kick accuracy. This attentional shift is consistent with the ACT that proposed increased influence of the stimulus-driven attentional system in high-pressure situations. In the present study, it was examined the stress-induced decrease in efficiency of the goal-directed attentional system. Eysenck et al. (2007) argue that the time to respond is an important measure for this efficiency: the more time spent to achieve similar levels of performance accuracy, the less efficient the goal-directed system is. It has been reported for a variety of cognitive tasks that in high-pressure situations performance accuracy can be maintained, but with increased response times relative to low-pressure situations (e.g., Ansari et al., 2008; Derakshan, Eysenck, 2009; Eysenck et al., 2007), although the converse sometimes also occurs: response times are maintained, but accuracy decreases (e.g., Beilock et al., 2004a). For motor tasks, high-pressure leads the goal-directed system to invoke a step-by-step control mode, making performance not only significantly slower as in cognitive tasks, but also more prone to error (e.g., Beilock et al., 2004b; Masters, Maxwell, 2008).

In the current experiment, high-pressure was created by having the volunteers, divided in two opposing teams, perform the simulated penalty task in front of a large participative audience. A participative audience has been shown to be a reliable method to promote pressure and induce high levels of stress in laboratory experiments. That is, previous studies have confirmed a clear association of participative audiences with significant performance decrements, often labelled choking under pressure (e.g., Baumeister, Steinhilber, 1984; Butler, Baumeister, 1998; Carver, Scheier, 1978). Stress was assessed by measuring heart rate and cortisol levels in saliva. Cortisol hormone is considered the “golden standard” physiological method to measure acute stress (Gunnar et al., 2009; Hellhammer et al., 2009). Based on attentional control theory, it was hypothesised that the participative audience would induce high levels of stress, which in turn would result in participants needing more time than in the low pressure situation to respond to goalkeeper movement in the simulated penalty task, or conversely, would lead to a decrease in performance accuracy.

4.1 Objectives

The main goal of this first experiment was to investigate the effect of high-pressure on performance of a simulated soccer penalty kick task (see Morya et al., 2003a). In particular, it scrutinized whether the minimum time needed (i.e., PNR) to make motor decisions (i.e., to respond to goalkeeper movements) increases in high-pressure compared to low-pressure situations.

4.2 Participants

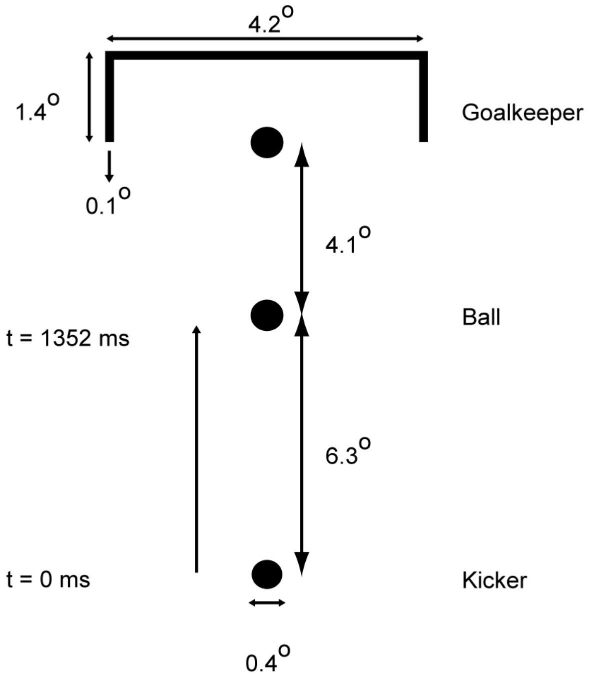
Thirty-one right-handed undergraduate students (20 males and 11 females, mean age 21.2 years, SD = 3.2) with normal or corrected-to-normal vision volunteered to perform the simulated penalty task in low- and high-pressure situations. The approval of the local ethical committee was obtained before the experiments were carried out, and participants provided informed consent prior to testing.

4.3 Apparatus

A computer-based simulated penalty kick task developed by Morya et al. (2003a) was used in the current experiment. MEL Professional 2.01 (Psychology Software Tools, PST Inc., Pittsburgh, PA, USA) software generated white visual stimuli on a black background on the screen. Three lines represented the posts and the cross bar of a goalmouth, while three dots represented a goalkeeper (within the goalmouth area), a ball and a kicker. In each trial, the 'kicker' moved vertically upwards towards the stationary 'ball', located at the centre of the display (Figure 3). In the majority of trials the 'goalkeeper' either moved to the left or right at different times before kicker-ball contact. Participants responded to the stimuli by manual inclining a vertical lever to the right or to the left, tripping off optical sensors connected to the game port (Figure 4). Participants sat with their eyes centrally placed 0.57 m in front of a 17" computer screen (60 Hz), resting their head against an adjustable chin and forehead support.

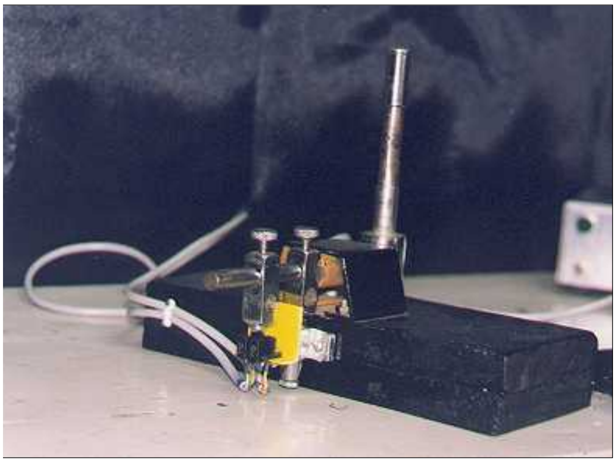
A Suunto T3 heart rate monitor (Suunto Oy, Vantaa, Finland) was used to register the heartbeats, and saliva samples were collected and stored to measure cortisol levels using a commercial radioimmunoassay (i.e. RIA) according to the procedure of Hellhammer et al. (2009).

Figure 3 - The stimulus display.



The three dots represent the 'goalkeeper', the 'ball' and the upward moving 'kicker'. The vertical and horizontal lines represent the goalposts and the crossbar.
Source: Morya et al. (2003a).

Figure 4 -Vertical lever with optical sensors for register responses.



4.4 Pressure manipulation

The experiment took place under two conditions: a low-pressure and a high-pressure situation. For the low-pressure condition participants performed the task alone in a small, dimly lit isolated booth to favour maximum concentration on the task (Figure 5).

Figure 5 – Participants performing the task in low-pressure condition.

Participants performing the task alone in a small, acoustically isolated booth with dimmed lights (i.e. low-pressure condition).

For the high-pressure condition they were tested in a large lecture hall in front of a loud participative audience (Figure 6) that watched their performance projected on a large screen in (1.90 m x 2.00 m). The audience was composed of more than 70 classmates of the participants, who were enrolled in two different curricula (i.e., physical education and sports science). The audience was encouraged to openly support or boo the participants according to curriculum in which they were enrolled.

Figure 6 – Participants performing the task in high-pressure.

Participants performing the task in a large lecture hall in front of a loud participative audience (i.e. high-pressure condition).

4.5 Procedure and design

Each participant faced 100 trials. They were instructed to tilt the lever to the opposite side of the 'goalkeeper' motion at the exact moment the 'kicker' contacted the 'ball', which occurred 1352 ms after trial onset. On 90% of the trials the 'goalkeeper' moved either to the right or to the left at a speed of 4.7 $cm.s^{-1}$. The 'goalkeeper' remained stationary on the remaining 10% of trials, for which participants were free to choose the side to which they moved the lever. 'Goalkeeper' sideward motion started at 51, 102, 153, 204, 255, 306, 357, 408, or 459 ms before 'kicker-ball' contact, resulting in nine available time intervals (i.e., AT).

Measurements for the low-pressure and high-pressure conditions took place on different days. On both days, participants were first instructed and received 10 familiarization trials. They subsequently performed the 100 randomised trials. The order of presentation of the two conditions was counterbalanced across participants. Trials with temporal errors larger than 42 ms (i.e., tilting the lever before 1310 ms or after 1394 ms from the beginning of the trial) were discarded and replaced until participants performed all 100 trials with the required timing accuracy. Participants were told that failing to comply with these temporal constraints would be equivalent to missing the goalmouth altogether. They received feedback after each trial, where these temporal errors were flagged with a message on the screen that they had tilted the lever too early or too late.

At three moments, immediately before, immediately after, and 45 min after completing the experiment, samples of saliva were collected to measure cortisol levels. The heart rate was monitored throughout the experimental sessions. Measurements in the low-pressure and high-pressure conditions were conducted at the same time of the day between 14:00h-16:00h to avoid confounds with circadian cortisol variations.

4.6 Data analysis

4.6.1 Stress measures

To assess the effect of the protocol in promoting stress, first the average heart rates under low-pressure and high-pressure were submitted to a paired samples *t* test analysis. Secondly, considering the high variability in cortisol production across the population (Hellhammer et al., 2009), the salivary cortisol levels were individually normalized by calculating a percentage of difference score between the measurement taken immediately after completion of the task and the measurement taken 45 min after task completion (i.e., baseline levels) for both the low-pressure and the high-pressure condition. These percentages were also submitted to a paired samples *t* test analysis.

4.6.2 Performance scores

Performance scores were obtained for each participant by calculating the percentage of correct responses for each available time interval (AT). These percentages were submitted to a 2 (condition: low-pressure situation, high-pressure situation) by 10 (AT: 51 ms, 102 ms, 153 ms, 204 ms, 255 ms, 306 ms, 357 ms, 408 ms, 459 ms, catch trials) analysis of variance with repeated measure (RM-ANOVA).

4.6.3 Point of no return

The percentages of correct responses for each AT were individually fitted to a logistic curve model (Equation 1) as proposed by Morya et al. (2003; see also van der Kamp, 2006). This model considered average performance for each available time and adjusted the best logistic curve starting with chance performance for the short available times (i.e., 50% of the shots correctly directed to the opposite side of goalkeeper movement) and reaching perfect performance for long available times (i.e., 100% of the shots correctly directed to the opposite side of goalkeeper movement). The fitted model was then used to determine the minimum time needed for 75% of the shots being directed to the correct side of the goal (i.e., PNR). In psychophysics, the logistic curve model is typically chosen to describe the relationship between a stimulus varied along a certain dimension (e.g., weight, size, time) and response. The model presumes that for values of the stimulus (i.e., in the present study, the time the goalkeeper starts moving) above some threshold participants' responses are accurate (i.e., 100% correct responses), while below the threshold participants' responses are random (i.e., 50% correct responses, participants are just guessing)(for an overview, see Regan, 2000). To identify the threshold (i.e., in the present study, the minimum time needed to respond or PNR), the average performance (i.e., % of correct responses) for each available time to respond to a stimulus is fitted to a S-shaped logistic curve, presuming chance performance (50%) for the lowest stimulus values and perfect performance (100%) for the highest stimulus values. The stimulus threshold for a reliable correct response is mostly defined as the stimulus value at the mid-point (i.e., 75%) between chance performance (i.e., 50%) and perfect performance (i.e., 100%)(Regan, 2000). Adhering to these psychophysical conventions, in the present study we define reliable performance (i.e., above chance, but not necessarily always correct), as the time at which in 75% of the attempts the lever is tilted to the correct side (i.e., derived from the fitted logistic curve). It is this mid-point between random and perfect performance that is labelled the point of no return (PNR, see Morya et al., 2003a). The individual PNR values for the low-pressure and high-pressure conditions were compared.

Equation 1 – Logistic curve model for analysis of correct responses as function of available time.

$$p(\mathrm{TD}) = \frac{e^{\beta*(\mathrm{TD}-\mathrm{TD}_0)}}{1+e^{\beta*(\mathrm{TD}-\mathrm{TD}_0)}}$$

$$\therefore \log\left[\frac{p(\mathrm{TD})}{1-p(\mathrm{TD})}\right] = \beta*(\mathrm{TD}-\mathrm{TD}_0)$$

$$\hat{\mathrm{TD}}_\pi = \frac{1}{\hat{\beta}} * \{\log\left(\frac{\pi}{1-\pi}\right) - \hat{\beta} * \mathrm{TD}_0\}$$

4.6.4 Temporal errors

Finally, the temporal errors were analyzed. To this end, the percentages of replaced trials (i.e., trials in which the lever was moved 42 ms before or after the kicker-ball superposition) were compared using a 2 (condition: low-pressure situation, high-pressure situation) by 10 (AT: 51 ms, 102 ms, 153 ms, 204 ms, 255 ms, 306 ms, 357 ms, 408 ms, 459 ms, catch trials) RM-ANOVA. For the remaining valid 100 trials, the constant error (i.e., 1352 ms minus the signed temporal error, with minus signs indicating an early response and plus signs indicating delayed responses) was calculated. These variables were submitted to separate 2(group: logistic, linear), by 2(condition: low-pressure, high-pressure) by 2(test: pretest, posttest) RM-ANOVA on the last two factors.

For all data analysis, in case of a violation of the sphericity assumption, Huyn-Feldt corrections to the degrees of freedom were applied. Post-hoc comparisons were carried out with *t*-tests using the Bonferonni correction procedures. Effect sizes were calculated using partial eta squared (η_p^2) for analysis of variance comparisons and Cohen's *d* for pairwise comparisons.

4.7 Results

4.7.1 Stress measures

Heart rate and cortisol measures indicated that the high-pressure situation indeed induced higher levels of stress than the low-pressure situation. This was confirmed by a significant difference on average heart rate, $t(30) = 9.5$; $p < .001$, $d = 1.1$, which indicated that the heart rate in high-pressure situation (i.e., M = 89 beats·min^{-1}, SD = 10.37) was significantly higher than in the low-pressure situation, (i.e., M = 76 beats·min^{-1} , SD = 13.09), and by a significant difference on percentage increase in cortisol level, $t(30) = 3.2$, $p < .05$, $d = 0.85$, which indicated that the increase in cortisol in the high-pressure situation (i.e., M = 16%, SD = 20.36) was significantly higher than in the low-pressure situation (i.e., M = 2%, SD = 10.86). The order of presentation of the two conditions was counterbalanced across participants and no order effect was found.

4.7.2 Performance scores

Perusal of the individual curves for the percentage of correct responses as function of available time intervals suggested large inter-individual differences between participants, in particular under high-pressure. That is, for the low-pressure situation, all individual curves showed the typical S-like shape of a logistic model. Yet, in the high-pressure situation, there were individual curves that had a shape that suggested that a linear model would be more appropriate. In addition, there was a strong suggestion that for some individuals the curves for the two pressure conditions nearly overlapped, whereas for others there was a clear shift to the right for the high-pressure situation. Therefore, the participants were classified into three groups:

1) 'logistic shift' (n =11: participants for whom the S-shape curve for the high-pressure situation was clearly shifted to the right relative to low-pressure situation);
2) 'logistic no shift' (n = 6: participants for whom the S-shape curves for both conditions [nearly] overlapped);

3) 'linear' (n = 14; participants for whom a linear model better fitted the data in the high-pressure situation than a S-shape logistic model as indicated by r^2-values)(see Figure 7).

Table 1 reports the average r^2-values for the logistic and linear models for all three groups for both pressure conditions. These r^2-values were submitted to a 3 (group: logistic no-shift, logistic shift, linear) by 2 (condition: low-pressure situation, high-pressure situation) by 2 (model: logistic, linear) RM-ANOVA on the last factors. This revealed significant effects for various (combination) of factors that were all modulated by a significant interaction effect for model by group by condition, $F(2,60) = 13.18$, $p < .001$, $\eta_p^2 = 0.57$), which is of crucial importance here. *Post-hoc* comparison indicated that the logistic model provided a better fit in the low-pressure situation than the linear model for all three groups (t's > 3.61, p's < 0.01). This was also found for the high-pressure situation (t's > 2.45, p's < 0.05), with the exception of the linear group, which showed a better fit for the linear model ($t(13) = 3.94$, $p < 0.01$) .

Hence, group was used as a between-participant factor in the subsequent analyses that scrutinized the effects of pressure on the performance scores, point of no return (PNR) and the temporal errors (i.e., percentage of replaced trials and constant errors). Condition (i.e., low-pressure situation, high pressure situation) served as within-participant factor. No effects for the order of presentation of the two conditions were found on the performance scores.

Table 1 - Mean (SD) r^2-values for the logistic and linear models for all three groups for the low-pressure and the high-pressure situation.

Group	Low-pressure		High-pressure	
	Logistic	Linear	Logistic	Linear
Logistic no-shift	.82 (.10)	.76 (.11)	.63 (.14)	.49 (.15)
Logistic shift	.69 (.11)	.59 (.18)	.54 (.14)	.46 (.15)
Linear	.69 (.09)	.60 (.10)	.31 (.18)	.43 (.12)

Source: Navarro et al. (2012)

The percentages of correct responses were submitted to a 2 (condition: low-pressure situation, high-pressure situation) by 10 (AT: 51 ms, 102 ms, 153 ms, 204 ms, 255 ms, 306 ms, 357 ms, 408 ms, 459 ms, catch trials) RM-ANOVA. The results revealed main effects for condition $F(1, 30) = 25.54$, $p < .001$ and time available $F(8, 240) = 243.74$, $p < .001$, η_p^2 =

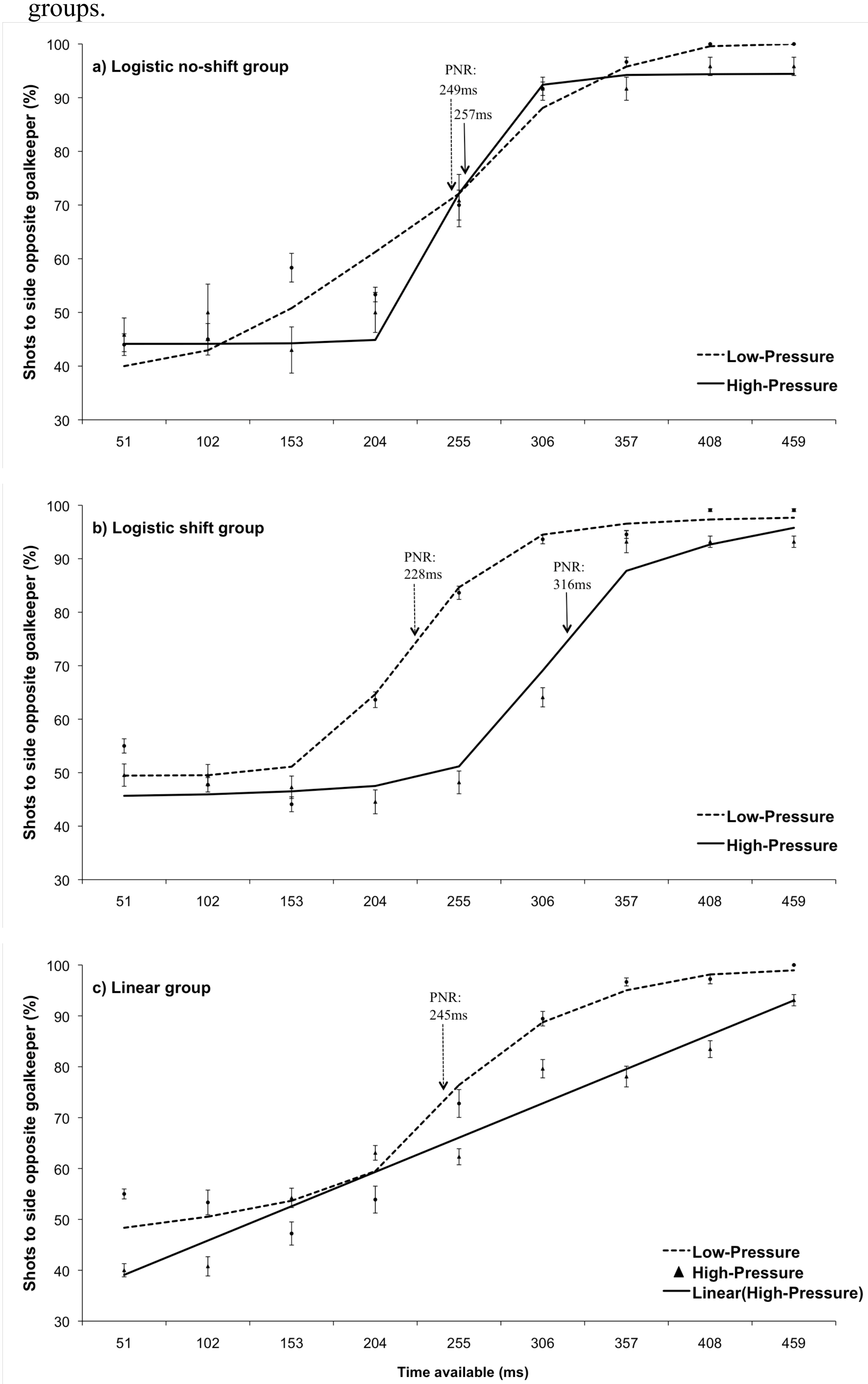
0.90. Importantly note that for the linear group the percentages of correct responses for the two shortest times available in high-pressure appeared to be below 50%. *T*-tests were used to explore whether these percentages were significantly below 50%. As expected, results revealed significant differences in percentage of correct answer in high-pressure condition only for the linear group at 51 ms time available (M = 40%, SD = 16.8; $t(13) = 2.14$, $p < .05$) and at 102 ms (M = 41%, SD = 17.6; $t(13) = 1.35$, $p < .05$)(see Figure 7c). No such differences were found for the two other groups.

4.7.3 Point of no return

The PNR is defined as the 75% point on the logistic curve and represents the minimum time needed for a participant to reliably direct the ball to the side opposite to which the goalkeeper moves. However, the logistic model appeared an inappropriate description for the performance of the linear group in the high-pressure situation (see Table 1). The PNR could therefore not be obtained for this group. Hence, we first compared the PNR for the different groups in the low-pressure situation only. An ANOVA showed that the PNR for the linear group (M = 245 ms, SD = 54.8) was not significantly different from the PNRs in the logistic no-shift (M = 249 ms, SD = 37.6) and the logistic shift (M = 228 ms, SD = 28.8) groups, $F(2,30) = 2.29$, $p > .05$, $\eta_p^2 = 0.05$ (Figure 7).

Secondly, we assessed differences in the effects of pressure on the PNR for the two logistic groups using a 2 (group: logistic no-shift, logistic shift) by 2 (condition: low-pressure situation, high-pressure situation) RM-ANOVA on the last factor. This revealed a significant main effect for condition, $F(1,16) = 18.59$, $p = .001$, $\eta_p^2 = 0.55$, indicating that the PNR increased from the low-pressure to the high-pressure situation. Yet, as can be seen by comparing Figures 7a and 7b, this increase in PNR only occurred for the logistic shift group. This was confirmed by a significant effect for group, $F(1,16) = 2.126$, $p = .05$, $\eta_p^2 = 0.15$ and for group by condition, $F(1,16) = 12.77$, $p < .05$, $\eta_p^2 = 0.46$). *Post-hoc* tests indicated that the logistic shift group showed a clear difference in the PNR values between the low-pressure (M = 228 ms, SD =28.8) and the high-pressure situations (M= 316 ms, SD = 38.2), $t(10) = 5.79$, $p < .001$ (Figure 7b), whereas for the logistic no-shift group no differences occurred between low-pressure (M = 249 ms, SD =37.4) and high-pressure situations (M = 257 ms, SD =26.1), $t(5) = 0.75$, $p > .05$ (Figure 7a).

Figure 7 - Percentage of correct responses as a function of available time and condition for groups.



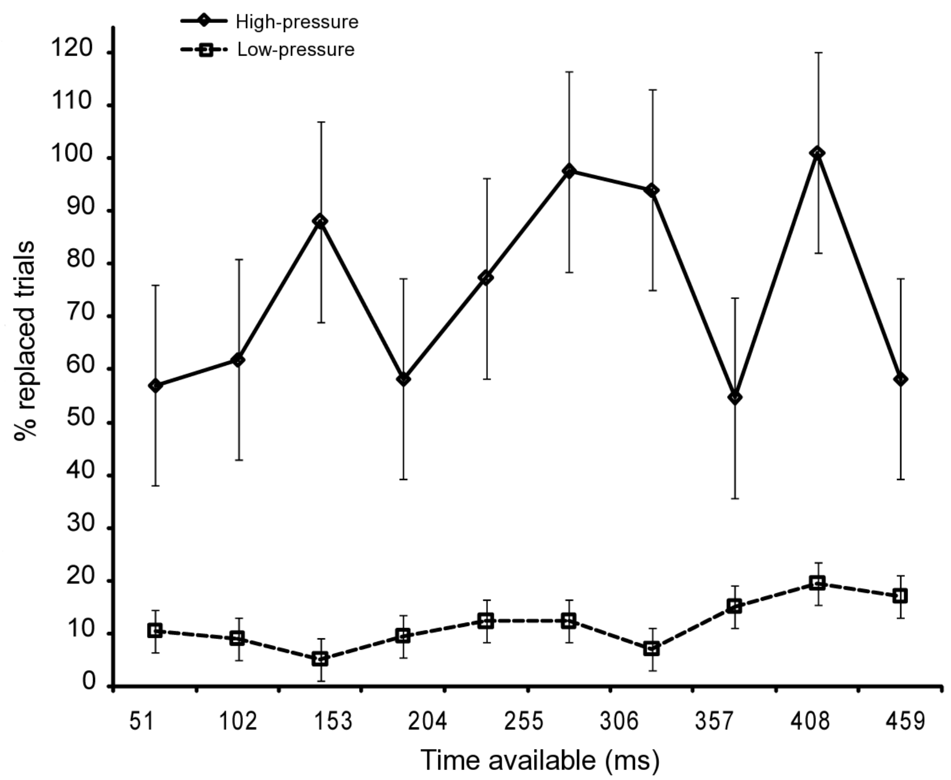
Percentage of correct responses as a function of available time and condition for the logistic no-shift group (A), the logistic shift group (B), and the linear group (C). Plain lines represent the curves for the best fitting models in the low-pressure and high-pressure situations.
Source: Navarro et al. (2012).

4.7.4 Temporal errors

Percentage of replaced trials. A 3 (group: logistic shift, logistic no-shift, linear) by 2 (condition: low-pressure situation, high-pressure situation) RM-ANOVA on the percentage of replaced trials only revealed a main effect for condition, $F(1,30) = 32.49$, $p < .001$, $\eta_p^2 = 0.60$ (Figure 8), indicating that the participants made significantly more temporal errors in high-pressure situation (M = 75%, SD =18.84) than in low-pressure situation (M = 12%, SD =4.47) irrespective of group.

Constant error. In order to analyze and to compare these temporal errors between groups, the average constant (i.e., logistic shift, M = - 20.1 ms; logistic no-shift, M = -16.8 ms; linear group, M = -16.2 ms) and variable errors (logistic shift, M = 105.5; logistic no-shift, M = 108.5; linear group, M = 112.1) for the high-pressure condition were submitted to separate one-way ANOVAs. The results did not reveal differences between groups for the constant error, $F(2,30) = 0.08$, $p > .05$, $\eta_p^2 = 0.01$, nor for the variable error, $F(2,30) = 0.16$, $p > .05$, $\eta_p^2 = 0.01$.

Figure 8 - Percentage of replaced trials as function of available time and condition.

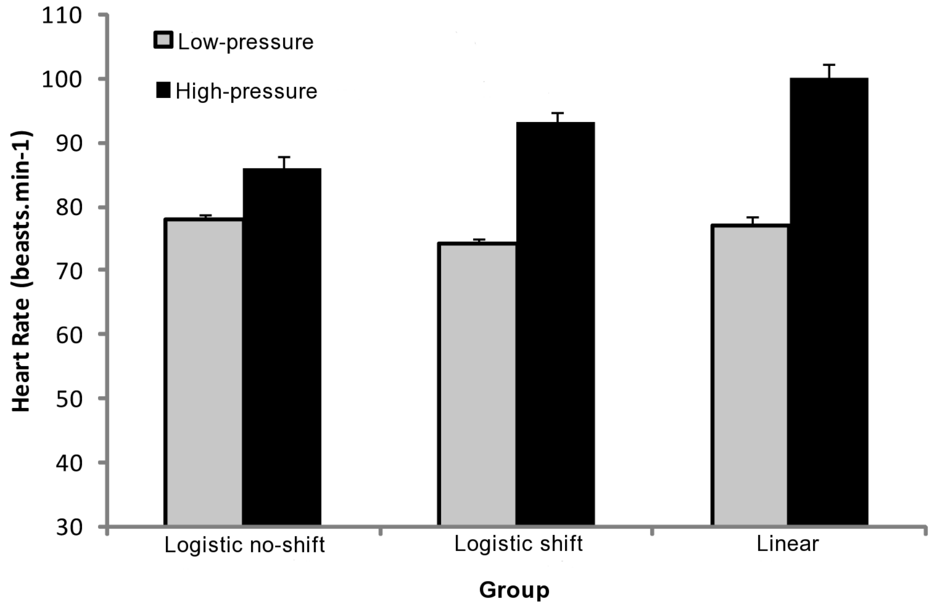


Source: Navarro et al. (2012).

4.7.5 Revisiting stress measures

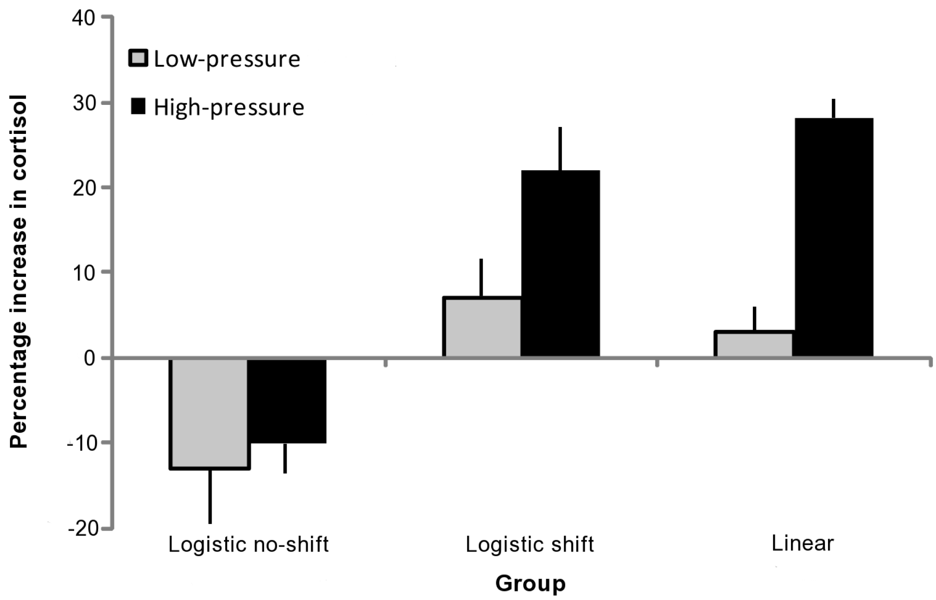
To examine whether the performance differences between groups were associated with different stress levels, average heart rate and percentage increase in cortisol levels were submitted to separate 3 (group: logistic no-shift, logistic shift, linear) by 2 (condition: low-pressure situation, high-pressure situation) RM-ANOVA's on the last factor. Figure 9 illustrates the findings for heart rate, and suggests higher heart rates for the logistic shift and linear groups as compared to the logistic no-shift group in the high-pressure situation only. However, neither the main effect for group, $F(1,30) = 3.05$, $p = .059$, $\eta_p^2 = 0.17$ nor the group by condition interaction, $F(2,60) = 2.2$, $p < .10$, $\eta_p^2 = 0.13$ was significant. The percentage increase in cortisol level showed a similar pattern (Figure 10). The analysis of variance revealed significant main effect for group, $F(2,60) = 10.92$, $p < .001$, $\eta_p^2 = 0.29$ indicating higher increases in cortisol for the logistic shift and linear groups than for the logistic no-shift group, but no significant group by condition interaction $F(2,60) = 1.82$, $p < .10$, $\eta_p^2 = 0.06$. Finally, we used independent t-tests to examine whether the percentages increase in cortisol level in the high-pressure condition were significantly higher than zero (i.e., no increase). This revealed a significant increase in cortisol levels for both the linear (M =28%, $t(13) = 22.33$, $p < .01$) and the logistic shift groups (M = 22%, $t(10) = 3.02$, $p < .05$), but not for the logistic no-shift group (M = -10%, $t(5) = 1.24$, $p > .05$, Figure 10). For the low-pressure condition the percentage increase in cortisol level did not differ from zero*;* linear (M = 3%, $t(13) = 0.36$, $p > .05$), logistic shift (M = 7%, $t(10)=0.76$, $p > .05$) and logistic no shift group (M = -13%, $t_5=1.91$, $p > .05$). Together, these results indicate that stress levels in the high-pressure condition were raised in the linear and logistic shift group, but not in the logistic no-shift group.

Figure 9 - Mean heart rate as function of condition and group.



Source: Navarro et al. (2012).

Figure 10 - Percentage increase of salivary cortisol levels between post-task and baseline levels as function of condition and group.



Source: Navarro et al. (2012).

4.8 Discussion

The Experiment 1 investigated the effect of high-pressure on the performance of a simulated soccer penalty kick task (see Morya et al., 2003a). In particular, it scrutinized whether the minimum time needed (i.e., PNR) to make motor decisions (i.e., to respond to goalkeeper movements) increases in high-pressure compared to low-pressure situations. Unexpectedly, this was only confirmed for one-third of the participants. In these participants (i.e., the logistic shift group), the high-pressure situation indeed led to increased stress and a lengthening of the PNR. Yet, there were considerable inter-individual differences in how participants responded to the high-pressure. Almost half of the participants (i.e., the linear group) showed high stress levels, but rather than affecting the PNR, the increased stress resulted in a qualitatively different relationship between the time available to respond to goalkeeper motion and proportion of correct motor decisions.[2] Finally, for the remaining participants (i.e., the logistic non-shift-group), high pressure did not result in significant increase in stress, and the PNR did not change. In the remainder, we will discuss the observations for these three groups of participants separately.

About one-third of the participants behaved as expected based on attentional control theory. This group (i.e., the logistic shift group) showed a significant lengthening of the PNR in the high-pressure situation as compared to the low-pressure situation. That is, the minimum time that this group of participants required to respond to the goalkeeper movement increased under high-pressure by more than 30%, from 228 ms to 316 ms. Since cortisol and heart rate measures for this group showed that the high-pressure protocol indeed provoked reliably higher levels of stress, this lengthening of the PNR points to a stress-induced reduction of the efficiency of the goal-directed attentional system (cf. Eysenck et al., 2007). Intriguingly, Eysenck et al. (2007) argued that a key function of the goal-directed system is the deliberate inhibition of automatic or prepotent behaviours. In this respect, it may be useful to compare the current simulated penalty kick task with investigations on anti-pointing (e.g., Day, Lyon, 2000). In these investigations, targets are shown that unpredictably move to the left or right while participants point at the target. Upon target displacement, however, participants are required to follow the target (i.e., pointing) or to point to the opposite direction (i.e., anti-pointing). Contrary to task instructions, during anti-pointing trials participants often show early corrections in the pointing movement that are in the direction of the target displacement and only after a delay a correction opposite to the target displacement is initiated. Day and Lyon (2000) proposed that the early correction is generated by an automated motor system that is under direct visual control (i.e., stimulus driven). This fast visuo-motor system is under

[2] In fact, I cannot rule out that in the linear group high-pressure did affect the minimum time needed to respond to a goalkeeper's movement. However, the definition of PNR as a property of a logistic curve on fitting a logistic curve precludes a valid comparison. Anyhow, I deem the qualitative change more important.

conscious control of a slower goal-directed or supervisory attentional system, which inhibits the early correction and reverses the direction of pointing (Day, Lyon, 2000; Johnson et al., 2002). Similar findings are reported from the anti-saccade paradigm (e.g., Ansari, Derakshan, 2010; Derakshan, Eysenck, 2009), in which the goal-directed attentional system must inhibit a reflexive saccade toward to a stimulus. It has been found that high-anxious individuals show significantly longer anti-saccade latencies (i.e., take longer to inhibit the initial reflexive saccade) compared to low-anxious individuals. The current simulated penalty task is comparable to the anti-pointing and anti-saccade tasks: participants are instructed to use a goalkeeper dependent strategy and kick the ball opposite to the side the goalkeeper moves. Hence, the lengthening of the PNR under high pressure may be understood as an impairment of the inhibition function of the goal-directed attentional system (see Eysenck et al., 2007).

A second group of participants (i.e., the linear group) was differently affected by the higher levels of stress provoked in the high-pressure situation. Rather than a lengthening of the PNR, this group showed a qualitative change in the relationship between the time available to respond to the goalkeeper movement and the percentage of correct responses under high-pressure. Performance for the shortest times available was below chance (i.e., < 50), while even for longest times available performance remained suboptimal (i.e., < 100%). The fact that these participants appear to systematically err, that is, more often incorrectly directed the ball to the side the goalkeeper moved when little time was available to respond is particularly intriguing. In terms of the anti-pointing and anti–saccade tasks, this seems analogous to the supervisory system being unable to inhibit the behaviour of the automatic visuo-motor system. As a result, performance becomes stimulus-driven. In other words, in line with the attentional control theory we find two distinct effects of increased stress levels. First, the high-pressure-situation decreases the efficiency of the goal-directed attentional system, which slowed down performance (i.e., the logistic shift group). Secondly, high-pressure adversely affects performance effectiveness, supposedly because the goal-directed system suffered a disruption, impairing its effectiveness in inhibiting automatic or stimulus-driven behaviours. For very short times available, this paradoxically led to automatically and unwittingly tilting the lever exactly to the side the goalkeeper moved (i.e., the linear group).

Finally, a relatively small number of participants did not show a difference in the PNR between the two pressure conditions (i.e., the logistic no shift group). As can be inferred from the cortisol and heart rate measures, it is likely that these participants were not significantly stressed in the high-pressure-situation. This indicates that apart from situational constraints (i.e., different situation may affect athletes in different ways) there may be inter-individual differences in susceptibility to high-pressure situation associated with factors such as personality (Adam, van Wieringen, 1983; Masters, 1992) and self-regulation strategies (Masters et al., 1993; Mor, Winquist, 2002) or degree of practice and experience (Mellalieu et al., 2004). Mellalieu et al. (2004) for instance, demonstrated that situational stress can be effectively controlled with practice and experience. Finally, it must be noted that although the participants in this group did not show increased levels of stress in the high-pressure-situation, they (like the participants in the other groups) did make more temporal errors with the participative audience present. It might be that these errors merely reflect distractions by the noisy environment.

Approximately 25% of penalty kicks in official games are wasted (Morya et al., 2003b). Typically, this is attributed to situational stress. Explicit monitoring theories (Beilock, Carr, 2001; Gray, 2004; Jackson et al., 2006; Masters, 1992; Pijpers et al., 2003) have suggested that anxiety raises self-consciousness, which turns attention inward toward an explicit focus on the execution of movements. Consequently, automatized motor processes that previously ran efficiently outside of consciousness become explicitly controlled in a step-by-step fashion. This theory does well in explaining choking under pressure in skilled athletes, because an explicit step-by-step slows down of and makes control performance more liable for errors. Explicit monitoring theories can easily incorporate the finding that more time is needed in the high-pressure-situation to respond to the goalkeeper movement. (Although, it is perhaps neither entirely trivial that the discrete movement of tilting the lever can be explicitly controlled in a step-by-step fashion, nor to what degree the tilting movement is proceduralized.) Yet, it is perhaps more difficult to incorporate for explicit monitoring theories that people make consistent errors rather than performance breaking down (i.e., performing at chance level). This is much easier reconciled with attentional control theory, where disruption of the goal-directed system can go together with a lack of inhibition of the stimulus driven system.

5 EXPERIMENT 2: INDIVIDUAL DIFFERENCES IN THE EFFECT OF PRACTICE ON PERFORMANCE OF A SIMULATED PENALTY KICK UNDER HIGH-PRESSURE CONDITIONS

Based on the results of Experiment 1, Experiment 2 employed the same computer-based simulated penalty task to investigate whether task-specific practice can indeed moderate the negative effects of high pressure. That is, whether it can increase the efficiency and/or effectiveness of the goal-directed attentional system. The results of this experiment have been submitted for publication after incorporating the suggestions of the editor and reviewers, which were very constructive (Navarro et al., Submitted).

In an attempt to reverse the adverse effects of high pressure, researchers have explored different interventions. One intervention method is to accustom participants to the pressure inducing situation, for instance by have them practice under increased levels of pressure, although not necessarily at the same levels as encountered in competition (Beilock, Carr, 2001; Nieuwenhuys, Oudejans, 2011; Oudejans, 2010; Oudejans, Pijpers, 2009). A second method seeks to increase automaticity of task performance as previously described (in Introduction, section 2.3.2).

In the current experiment, participants practiced the computer-based simulated penalty task (Morya et al., 2003a) in eight sessions over a period of three weeks to automatize task execution. In order to investigate whether task-specific practice can indeed moderate the negative effects of high pressure, participants were tested on the simulated penalty task before and after practice under high-pressure in the presence of a large participative audience (Navarro et al., 2012). The task required the participants to tilt a lever in the direction opposite to the displacement of the ‘goalkeeper’ exactly at the moment the ‘kicker’ superposed the ‘ball’. During practice, augmented feedback was provided about timing errors (i.e., whether the lever was tilted too early or too late). It was presumed that, next to improvements in the direction of the response, task-specific practice would induce improvements in coincidence timing, that is, tilting the lever closer to the exact moment that the ‘kicker’ and ‘ball’ superposed. By improving the coincidence timing component of the task, practice may free some of the attentional resources initially committed to timing. These can then be exploited by the goal-directed system for selecting the appropriate response to the ‘goalkeeper’s’ sideways motion. Especially under high-pressure this may prevent a decrease in the efficiency and/or effectiveness of the system. Hence, it was hypothesized that practice in the simulated penalty kick task may increase the attentional resources available for the goal-directed system. Consequently, the goal-directed system can count on more resources, such that after practice either the increase in the time needed to respond to goalkeeper motion under high-pressure is diminished (i.e., smaller shift in PNR), or the breakdown of the goal-directed system is avoided (i.e., preventing that the lever is unwillingly tilted to the same side as the 'goalkeeper' motion).

5.1 Objectives

The main goal was investigate whether higher levels of automatization obtained with practice would prevent performance decrements observed as a result of high-pressure.

5.2 Participants

Fifteen right-handed male undergraduate students (mean age 19.8 years, SD = 4.2) that were enrolled in Sports Science or Physical Education curricula volunteered to practice and perform the simulated penalty task in low- and high-pressure conditions. They were all relatively experienced sportsmen, and had normal or corrected-to-normal vision. Local ethical committee approval was obtained prior to testing, and participants provided informed consent before taking part.

5.3 Apparatus and pressure manipulation

The experimental protocol used in the current experiment was exactly the same computer-based simulated penalty kick task used in Experiment 1 (for more details please check section 3.3).

In this case, additionally to the heart rate monitor used to measure heartrate and saliva samples collected to measure cortisol levels, participants' propensity to be stressed and participants´ subjective perceptions of the situational stress were obtained using IDATE (appendix A; Biaggio, Natalício, 1979; Gorenstein, Andrade, 1996; Spielberger et al., 1979), which is Brazilian Portuguese version of the STAI (i.e., the State -Trait Anxiety Inventory, Spielberger et al., 1983). The IDATE consists of 20 questions addressing trait anxiety and 20 questions regarding state anxiety on a 4-point ranking scale. The results of experiment 1 revealed that there might be inter-individual differences in susceptibility to high-pressure situation, which perhaps would be pointed out in these questionnaires.

5.4 Design

The experiment 2 consisted of a pretest (including a low-pressure and a high-pressure condition, the sequence of which was counterbalanced across participants), a 3-week practice period (2-3 sessions per week, total of 8 sessions under low-pressure; cf. Brown, Bennett, 2002) and a posttest (including a low-pressure and a high-pressure condition, with the low-pressure condition always being conducted first). The measurements for pretest and posttest and the practice sessions took place on different days. The low-pressure posttest took place the day immediately following the final practice session and the high-pressure posttest the next day. As in experiment 1, participants faced 100 trials during each test and practice sessions, 10 trials for each of nine AT in randomized order. Participants were instructed to tilt the lever at the exact moment the 'kicker' superposed the 'ball', which always occurred 1352 ms after trial onset, to the side opposite of the 'goalkeeper' motion. Trials for which participants had a temporal error larger than 42 ms were replaced and they were told that failing to comply with these temporal constraints would be equivalent to missing the goalmouth altogether. These temporal errors were flagged with a message on the screen that they had tilted the lever too early or too late.

5.5 Procedure

Each participant performed the pretest, posttest and practice sessions individually. The pretest and posttest started with instructions to the participants about the experiment, who then completed the IDATE. The heart rate monitor was then attached, and participants warmed up with 10 familiarization trials of the simulated penalty task. They then performed the 100 test trials. Immediately after completion of the test and 45 min later, samples of saliva were collected again. The heartrate and samples of saliva, however, were not collected for the low-pressure condition of the posttest. Measurements in the test sessions were conducted at the same time of the day between 14:00h-16:00h to avoid confounds with circadian cortisol variations.

The eight practice sessions took place under low-pressure in the isolated booth, and participants were simply required to perform the task with the objective of trying to improve performance. No saliva samples were collected, nor was heart rate registered in these practice sessions.

5.6 Data analysis

According with the results found in Experiment 1 (i.e. the logistic model did not fit the data of all participants, which implied in a group classification), the first step was classified participants into three groups based on the same analysis procedures. Then, all subsequently analysis followed the procedure in experiment 1, but now including test(pretest, posttest) as within-participant factor in RMANOVAs.

5.6.1 Model fits

The *r*-values for model fits were submitted to a 2(group: logistic shift, linear) by 2(model: logistic shift, linear) by 2(test: pretest, posttest) by 2(condition: low-pressure, high-pressure) RMANOVA on the last three factors to determine whether practice affected the best fitting model.

5.6.2 Performance scores

Performance scores were obtained for each participant by calculating the percentage of correct responses for each available time interval (AT). These percentages were submitted to a 2 (condition: low-pressure situation, high-pressure situation) by 10 (AT: 51 ms, 102 ms, 153 ms, 204 ms, 255 ms, 306 ms, 357 ms, 408 ms, 459 ms, catch trials) by 2 (test: pretest, postest) by 2 (group: logistic shift, linear) RMANOVA.

5.6.3 Point of no return

Because PNR cannot be obtained meaningfully from a linear model, the PNR of groups only in the low-pressure conditions were compared by submitting it to a 2(group: logistic shift, linear) by 2(test: pretest, posttests) RMANOVA. In addition, it was assessed changes in PNR for the logistic shift group only as a function of practice and condition by submitting the PNR to a 2(condition: low-pressure, high-pressure) by 2(test: pretest, posttest) RMANOVA on both factors.

5.6.4 Temporal errors

The number of replaced trials and the constant error were submitted to separate 2(group: logistic shift, linear), by 2(condition: low-pressure, high-pressure) by 2(test: pretest, posttest) RMANOVA on the last two factors.

5.6.5 Stress measures

The percentage difference in cortisol level, the average heart rate and the STAI state anxiety scores were submitted to separate 2(group: logistic, linear) by 3(test-condition: pretest low-pressure, pretest high-pressure, posttest high-pressure) RMANOVAs on the last factor. The trait-anxiety scores were compared by an independent *t*-test between groups.

5.7 Results

5.7.1 Model fits

As in experiment 1, visual inspection of the individual graphs depicting the relationship between the percentage of responses to the correct side as function of AT, suggested that for the low-pressure conditions a logistic model best described the data for all participants. In the high-pressure conditions, however, several of the individual graphs followed a model with a linear fit to the data (Navarro et al., 2012). These inter-individual differences were not altered by practice (see Table 2 for a concise view).

Table 2 - The best model fit of the data for logistic and linear group.

	Low-pressure before	High-pressure before	Low-pressure after	High-pressure after
Logistic shift group	Logistic fit	Logistic fit[a]	Logistic fit	Logistic fit[b]
Linear group	Logistic fit	Linear fit[b]	Logistic fit	Linear fit[b]

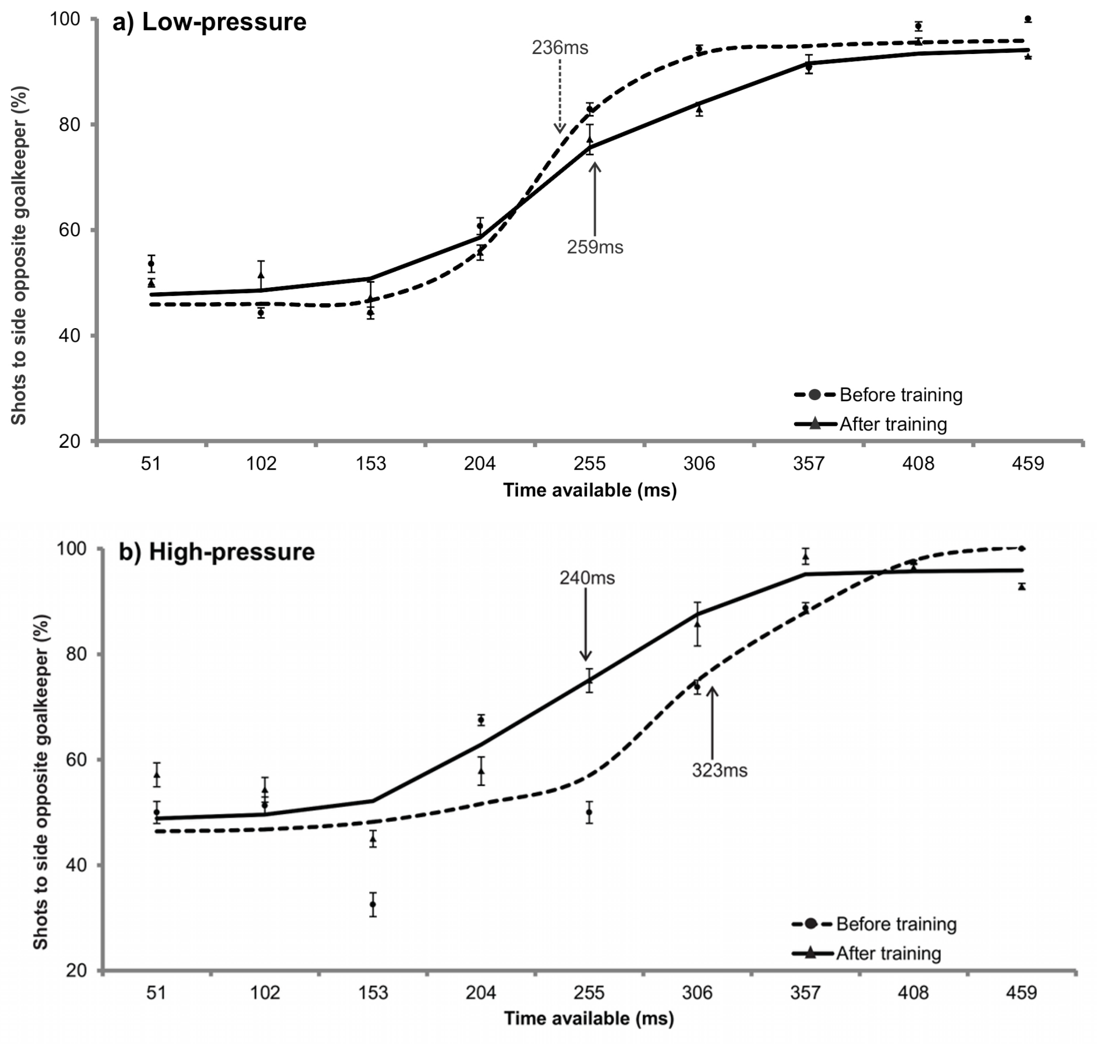
Note that after practice the model with lowest p-value did not change for both groups .

More specifically, under the high-pressure condition eight participants performed according to the logistic model and were thus classified as ‘logistic group’ (see Figure 11a,b), whereas the remaining seven participants performed according to the linear model (Table 3) and were therefore classified as 'linear group' (Figure 12a,b). In fact, experiment 1 discerned a third group ('logistic no-shift group'), pattern that was not observed among the current participants. The subsequent ANOVA revealed significant effects in *r*-values for model, $F(1,14) = 6.26$, $p < .05$, $\eta_p^2 = 0.36$, group, $F(1,14) = 5.53$, $p < .05$, $\eta_p^2 = 0.33$, model by group, $F(1,14) = 10.4$, $p < .01$, $\eta_p^2 = 0.48$, condition by test, $F(1,14) = 33.2$, $p < .001$, $\eta_p^2 = 0.75$, condition by test by group, $F(1,14) = 6.30$, $p < .05$, $\eta_p^2 = 0.36$ and model by condition by group $F(1,14) = 4.76$, $p = .05$, $\eta_p^2 = 0.30$. Yet, these effects were all subordinate to a significant model by group by condition by test interaction, $F(1,14) = 13.18$, $p < .05$, $\eta_p^2 = 0.52$. *Post-hoc* comparison indicated that in both groups in the low-pressure condition the logistic model provided a better fit than the linear model both before and after practice. This was also found for the high-pressure conditions for the logistic group; yet, the linear model showed a better fit for the linear group in the high-pressure condition both before practice and after practice. Importantly, this indicates that practice did not result in qualitative changes in the relationship between percentages of responses to the correct side and AT (as would have been the case if the goal-directed system were to have regained control over the stimulus-driven system).

Table 3 - Mean (and Standard Deviation) of logistic shift and linear model *r*-values for logistic and linear groups under low- and high-pressure conditions before and after practice.

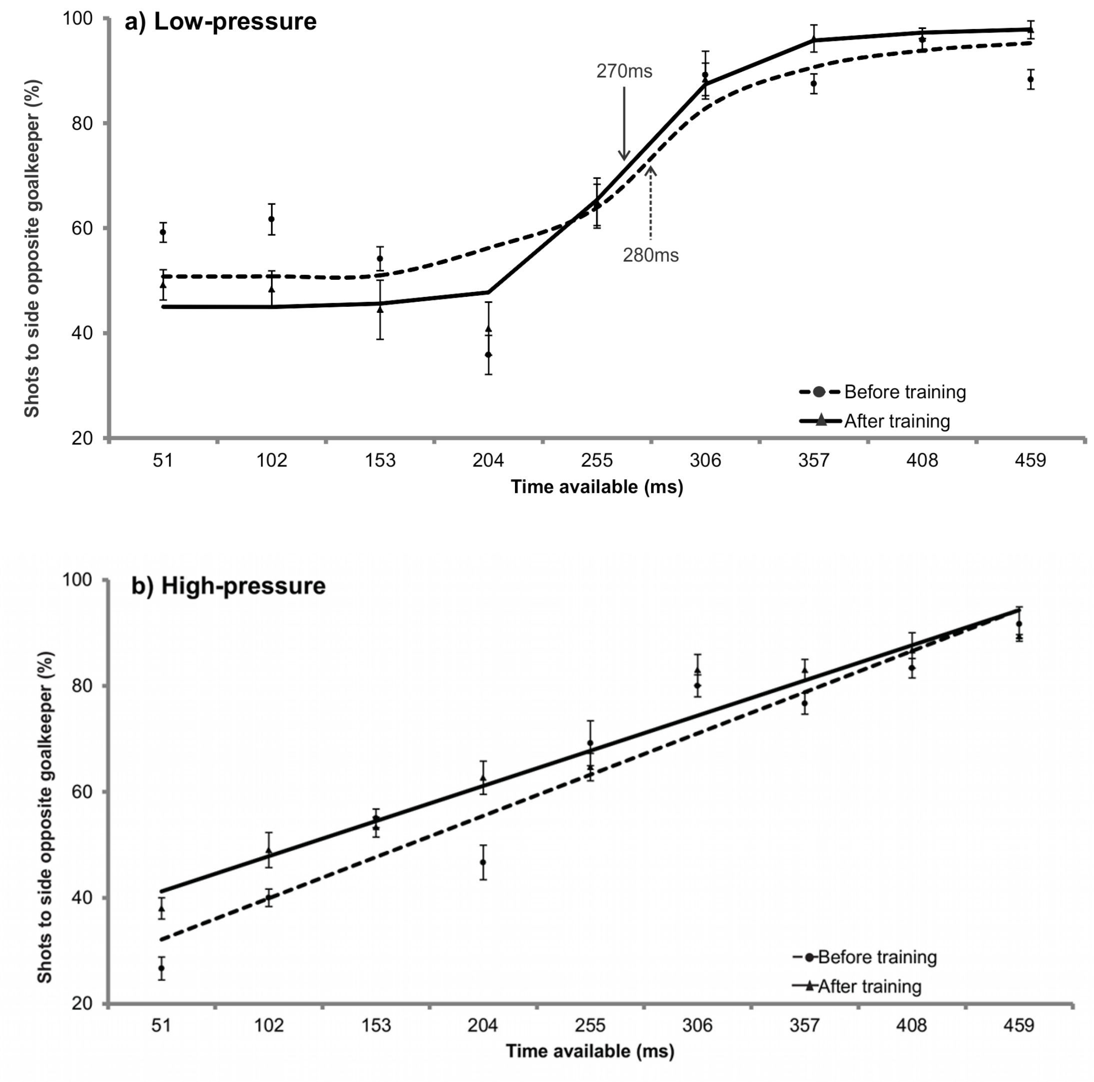
	Low-pressure before		High-pressure before		Low-pressure after		High-pressure after	
	Logistic model	Linear model	Logistic model	Linear model	Logistic model	Linear model	Logistic model	Linear model
Logistic group	.82 (.09)	.75 (.14)	.79 (.09)	.64 (.10)	.92 (.06)	.79 (.09)	.73 (.13)	.64 (.16)
Linear group	.83 (.30)	.70 (.24)	.65 (.10)	.79 (.10)	.91 (.04)	.79 (.07)	.63 (.20)	.71 (.22)

Figure 11 - Percentage of correct responses as a function of available time for the logistic in (a) low-pressure and (b) high-pressure conditions.



Continuous lines refer to performance before practice and dashed lines refer to performance after practice. (Note that practice fully reversed the effect of high-pressure on the PNR).

Figure 12 - Percentage of correct responses as a function of available time for the linear group in (a) low-pressure and (b) high-pressure conditions.



Continuous lines refer to performance before practice, dashed line refer to performance after practice. (Note that under high-pressure, practice did not induce changes in performance).

5.7.2 Performance scores

The percentages of correct responses submitted to a RMANOVA revealed main effects for condition $F(1, 14) = 4.76$, $p < .05$, $\eta_p^2 = 0.30$, time available $F(8, 112) = 101.11$, $p > .001$, $\eta_p^2 = 0.90$ and a for various combination of factors that were all modulated by a significant interaction effect for group by time available $F(8, 112) = 2.62$, $p < .05$, $\eta_p^2 = 0.19$, but not for test $F(1, 14) = 1.59$, $p > .05$, $\eta_p^2 = 0.12$, which means that percentages were not altered by practice.

As in experiment 1, for the linear group the percentages of correct responses for the two shortest times available in high-pressure condition were below 50%. *T*-tests revealed significant differences in percentage of correct answer only for the linear group at 51 ms time available (M = 26%, SD = 4.8; $t(6) = 7.59$, $p = .001$) and at 102 ms (M = 40%, SD = 6.8; $t(6) = 2.51$, $p < .05$) in pretest, and only at 51 ms (M = 38%, SD = 6.9; $t(6) = 2.93$, $p < .05$) in posttest.

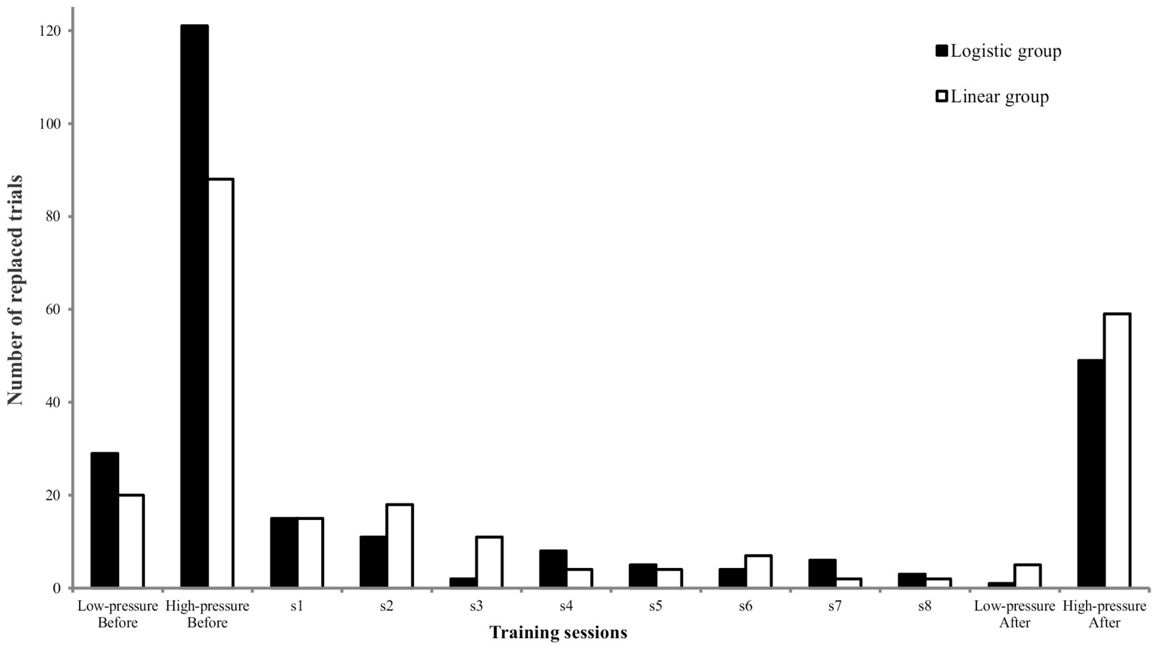
5.7.3 Point of no return

The PNR for the linear group in the high-pressure conditions could not be obtained, because the logistic model did not provide an appropriate description of the data. The RMANOVA comparing the PNR of both groups under low-pressure before and after practice did not reveal a main effect for group, $F(1,14) = 3.23$, $p = 0.10$, $\eta_p^2 = 0.23$, test, $F(1,14) = 0.18$, $p > .05$, $\eta_p^2 = .02$, nor for the group by test interaction, $F(1,14) = 1.05$, $p = 0.33$, $\eta_p^2 = .09$. Hence, the PNRs in the low-pressure conditions before and after practice did not significantly change (Figure 11a and 12a), either for the linear group (i.e., before: M = 280 ms, SD = 52.1, and after: M = 270 ms, SD = 16.8) or for the logistic group (i.e., before: M = 236 ms, SD = 32.4 and after: M = 259 ms, SD = 15.5). A second ANOVA comparing the PNR only for the logistic group revealed a significant main effect for condition, $F(1,14) = 7.34$, $p < .05$, $\eta_p^2 = 0.55$, and for condition by test interaction $F(1,14) = 35.2$, $p < .001$, $\eta_p^2 = 0.85$. The main effect for test $F(1,14) = 2.66$, $p > .05$, $\eta_p^2 = 0.31$, was not significant. *Post-hoc* comparisons indicated a shorter PNR in the low-pressure (M = 236 ms, SD =32.4) than in the high-pressure condition before practice (M = 323 ms, SD =16.1), but after practice, PNR in high-pressure condition (M = 240 ms, SD =19.4) had decreased to the same value as in the low-pressure condition (M = 259 ms, SD = 51.2). In other words, for the logistic group the practice sessions fully reversed the effect of high pressure on the PNR (as would be expected if the goal-directed system had gained more attentional resources).

5.7.4 Temporal errors

Percentage of replaced trials. As can be seen in Figure 13, the number of replaced trials in the low-pressure condition gradually decreased during practice sessions. Moreover, the number of replaced trials also decreased from pretest to posttest in the high-pressure condition, but nonetheless remained higher than in the low-pressure condition. The ANOVA on the number of replaced trials revealed main effects for condition, $F(1,14) = 45.69$, $p < .001$, $\eta_p^2 = 0.80$, and test $F(1,14) = 39.41$, $p < .001$, $\eta_p^2 = 0.78$, but not for group, $F(1,14) = 0.26$, $p > .05$, $\eta_p^2 = .02$. In addition, significant interactions were found for test by group, $F(1,14) = 5.77$, $p < .05$, $\eta_p^2 = 0.34$ and condition by test $F(1,14) = 20.27$, $p < .05$, $\eta_p^2 = 0.65$, which were all subordinate to a significant interaction for group by condition by test, $F(1,14) = 6.50$, $p < .05$, $\eta_p^2 = 0.37$. *Post hoc* comparisons indeed pointed to a decrease in the number of replaced trials with practice both in the high- and in the low-pressure condition; yet, for the linear group the difference between pretest and posttest in the low-pressure condition, failed to reach significance.

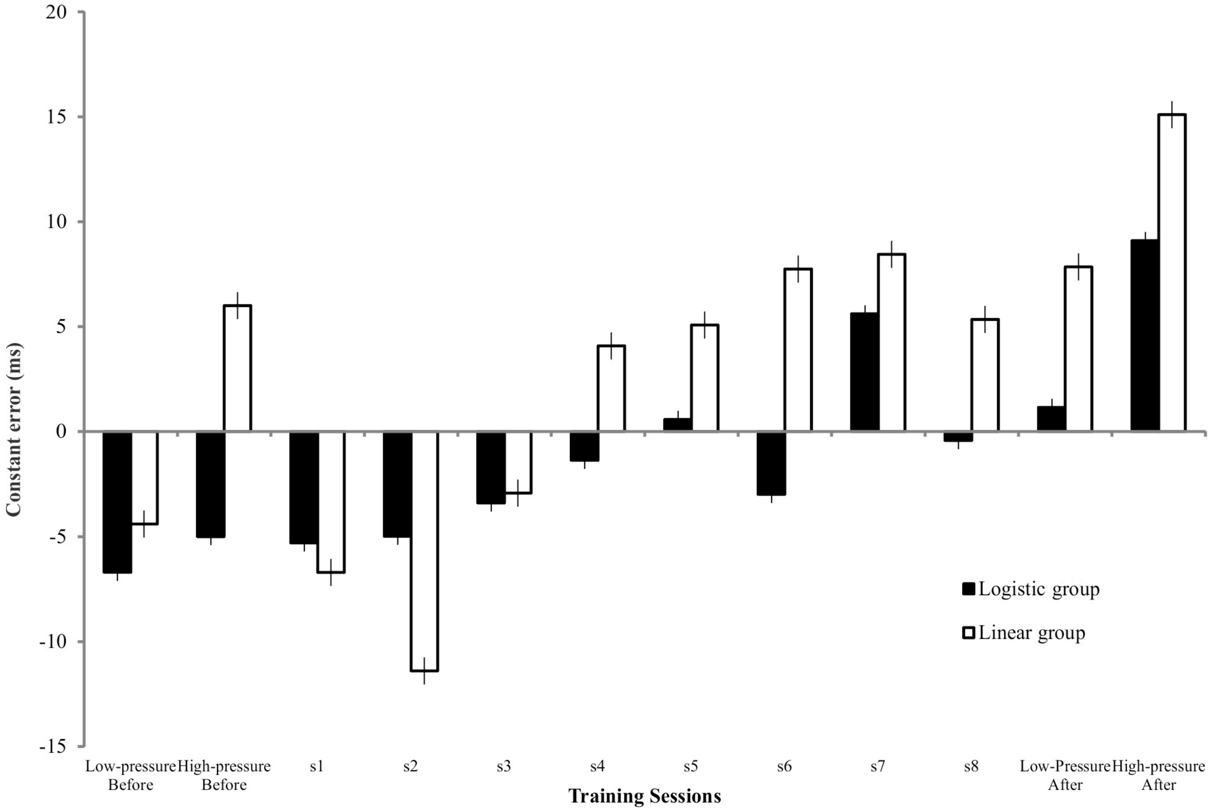
Figure 13 - Number of replaced trials (i.e. timing errors) for the logistic and linear groups before, during and after practice in the low- and high-pressure conditions.



Note that for both groups high-pressure condition increased the number of replaced trials before and after practice. Practice lowered the number of replaced trials equally for both groups and conditions.

Constant error. Figure 14 shows how the constant error changes from pretest to postest in the low-pressure and in the high-pressure conditions. The change in constant error points to the lever being tilted later in the high-pressure than in the low-pressure condition, and later in the posttest than in the pretest. This was confirmed by main effects for condition, $F(1,14) = 10.90$, $p < .01$, $\eta_p^2 = 0.49$, and test $F(1,14) = 7.23$, $p < .05$, $\eta_p^2 = 0.39$. There was no main effect for group, $F(1,14) = 3.94$, $p >.05$, $\eta_p^2 = 0.26$, nor were there any interactions.

Figure 14 - Constant errors (ms) (and standard error) for the logistic and linear groups before, during and after practice in the low- and high-pressure conditions.



Note that for both groups there's a trend in slightly delayed responses.

5.7.5 Stress measures

Table 4 shows the increase in cortisol level, heartrate and STAI scores, which indicates higher stress in both high-pressure conditions than in the low-pressure condition in the pretest (at least for the increase in cortisol level and heart rate). Accordingly, for the cortisol levels ANOVA revealed a significant main effect for test-condition, $F(2,28) = 5.72$, $p = .01$, $\eta_p^2 = 0.34$, but not for group $F(2,28) = 0.76$, $p > .05$, $\eta_p^2 = .06$. *Post-hoc* comparisons indicated that for both groups the difference in cortisol level in the high-pressure conditions of both the pretest and posttest was significantly higher than in pretest low-pressure condition, but not different from each other. Similarly, for the heart rate significant effects were found for test-condition, $F(2,28) = 33.34$, $p < .001$, $\eta_p^2 = 0.75$, and group $F(2,28) = 15.59$, $p < .01$, $\eta_p^2 = 0.58$, but not for the group by test-condition interaction. *Post-hoc* comparisons indicated that for both groups the high-pressure conditions provoked higher levels of stress than in the pretest low-pressure condition, even after practice. Further, the linear group had higher heart rates than the logistic group. Finally, the ANOVA for the state-anxiety scores did not show a significant effect of test-condition, $F(2, 28) = 1.5$, $p > .05$, $\eta_p^2 = 0.12$, nor for group, $F(2,28) =$

0.11, p > .05, η_p^2 =.01, and also trait-anxiety scores did not differ between groups (t(14) = 0.41, p > .05).

Table 4 - Mean (and Standard Deviation) of cortisol levels (% increase), heartrate (beats per min^{-1}) and state and trait anxiety scores for logistic and linear groups under low- and high-pressure conditions before and after practice.

	Group	Before practice		After practice
		Low-pressure	High-pressure	High-pressure
Cortisol level (%)	Logistic	2 (9)	28 (17)	20 (14)
	Linear	5 (8)	39 (20)	23 (13)
Heartrate (beats per min^{-1})	Logistic	66 (16)	85 (8)	96 (15)
	Linear	77 (4)	110 (11)	109 (15)
State-anxiety scores	Logistic	42 (5)	45 (5)	46 (7)
	Linear	46 (2)	46 (5)	48 (3)
Trait-anxiety scores	Logistic	47 (2)	46 (3)	-
	Linear	45 (3)	46 (4)	-

5.8 Discussion

The Experiment 2 investigated whether task-specific practice, which presumably increases automatization, would help prevent performance decrements observed as a result of high-pressure in experiment 1. The present experiment found similar detrimental effects of increased pressure and similar inter-individual differences as those reported in experiment 1. Basically, in dealing with high-pressure condition, participants showed one of two responses: logistic shift or linear. The third group, where participants also showed a logistic curve under both low- and high-pressure; however, they did not show a difference in PNR between low- and high-pressure conditions was not observe among the current participants. On the one hand, participants of the logistic group showed a shift in the PNR under high-pressure, indicating that the minimum time they needed to correctly respond to the 'goalkeeper's' motion was increased. Building on the ACT framework (Eysenck et al., 2007), in last experiment (see also Navarro et al., 2012) it was argued that this reflects a decline in the efficiency of the goal-directed attentional system, which either results from a decrease in attentional resources or an increase in effort to maintain performance under high-pressure. On the other hand, participants that made up the linear group were prone to systematically err under high-pressure. That is, when time pressure was rigorous (i.e., the 'goalkeeper' moved very late) they tended to respond to the same side as the 'goalkeeper', rather than to the opposite side. In terms of ACT, this may be understood as the goal-directed system becoming ineffective in inhibiting the automatic stimulus-driven system (Navarro et al., 2012).

Most significantly, however, the present experiment demonstrates that practice to enhance task automatization had differential effects on the two groups under high-pressure, but not under low-pressure. However, before discussing the differential effects of high-pressure after practice, it is important to briefly discuss the relationship between practice and automatization of task execution. The simulated penalty kick task requires that two conditions be fulfilled for a participant to be successful: the participant must tilt the lever to the side opposite to 'goalkeeper' movement and they must do this at the right time. Presumably, both aspects of the task share the same attentional resources. Brown (1998, 2008; Brown, Bennett, 2002) demonstrated that for this type of task the so-called attenuation effect may occur. That is, practicing one aspect of the task (e.g., timing) reduces its attentional demands, thereby increasing the availability of resources for a second aspect of the task (e.g., spatial). Accordingly, participants practiced the simulated penalty kick task with feedback on timing to attenuate the attentional task demands, at least for the temporal component of the task. It must be noticed, however, that it was not directly assessed whether the practice indeed resulted in the freeing of attentional resources. It would be important for future work to verify this contention, for example, by implementing dual task probes during practice (see e.g. Brown, Bennett, 2002). For now, it may be presumed that practice indeed automatized task execution and hence resulted in making more attentional resources available (see also Abernethy et al., 2007).

ACT holds that situations of high-pressure call for a higher fraction of available attentional resources. Yet, if the attentional resources are limited, then a point is reached in which supply becomes insufficient and performance suffers. In line with the attenuation effect, practicing the simulated penalty kick task with feedback on timing would reduce the attentional demands for this aspect of the task, freeing resources for the spatial aspects of the task. This would allow for the allocation of more resources under high-pressure to decide on the side to direct the 'ball'. In other words, practice would increase the efficiency of the goal-directed system relative to pre-practice.

The logistic group in the low-pressure condition indeed benefited from practice in the temporal aspects of the task (i.e. less replaced trials and smaller constant error), pointing to automatization. Under high-pressure the same timing improvement occurred. Although practice did not lead to improvement in PNR (i.e., minimum time needed to respond correctly) in low-pressure, in high-pressure it did bring the PNR to low-pressure levels. Apparently, the additional resources that were freed during practice allowed the goal-directed system to more fully focus on moving the lever in the direction opposite to the 'goalkeeper', such that the stimulus-driven system could be inhibited more effectively.

For the linear group, however, practice effects were less obvious. Although there were clear indications that during practice these participants altered timing (i.e., they also slightly delayed their response), they did not show a significant decrement in the number of temporal errors under low-pressure. (In fact, it cannot be rule out that this is simply a 'ceiling effect', the number of errors already being very small before practice). Under-high pressure, however, timing significantly improved from pretest to postest. Intriguingly, even after practice the performance of the linear group was still affected by high-pressure. With little time available, the participants were still inclined to systematically err, that is, to move the lever to the same side as the 'goalkeeper'. It thus seemed that the goal-directed system remained unable to inhibit the stimulus-driven system. The main hypothesis to explain this lack of improvement would be that the goal-directed system did not have access to sufficient additional attentional resources, necessary to inhibit the stimulus-driven system. This may be due to insufficient improvements in automatization following practice (e.g., there was no significant decrease in the number of temporal errors). Moreover, counteracting a breakdown of the goal-directed system under high-pressure may require the freeing of a considerable larger pool of resources than merely improving its efficiency (cf. the logistic group). Alternatively, it might be argued that, given their reliance on the stimulus-driven system, practice may have further increased the speed of this system among the participants of the linear group, making it even more difficult for the goal-directed system to inhibit the stimulus-induced response. Yet, this explanation is unlikely for two reasons. First, the stimulus-driven system is an automatized system, which would require huge amounts of practice to increase the degree of automatization even further. In addition, it would also follow that the percentage of errors would increase, which was not the case. Finally, heart rate measures also suggested that levels of anxiety were somewhat higher among participants of the linear group compared to participants of the logistic group, although the increases in heart rate from the low- to the high-pressure conditions were of similar magnitude (i.e., 40%). To shed light on these issues, further investigations of longer and/or more specific training strategies are needed, to examine why the linear group responded differently to practice than the logistic group.

Considering the effects of practice, especially the delay in responding to 'goalkeeper' motion in both the low- and high-pressure conditions, it may be useful to make a comparison with prior reports on quiet eye practice (see e.g., Behan, Wilson, 2008; Causer et al., 2011; Harle, Vickers, 2001; Vickers, Williams, 2007; Williams et al., 2002a; Wood, Wilson, 2011). Quiet eye (QE) refers to a long final fixation on a relevant target prior to the execution of the critical phase of movement (Vickers, 2007). In the simulated penalty kick task, this would be equivalent to the duration of the final fixation on the goalkeeper prior to tilting the lever. Vickers (1996) proposes that QE reflects the organization of visual attention to optimize control of the movement, while minimizing environmental distraction. Hence, the longer the QE, the better the performance. Thus, practice of QE may not only improve task relevant gaze control, but also enhance attentional control under high pressure (Vine, Wilson 2010; Vine, Wilson, 2011). In the current task, the logistic group might have learnt to slightly delay their response, enabling them to focus longer on the 'goalkeeper', which, analogous to QE, improved the ability to inhibit the stimulus-driven system, that is, to better use information to aim to the side opposite 'goalkeeper' motion. Yet, others have argued that longer fixations on the goalkeeper (relative to the target location and/or ball) may actually impede performance (e.g., Wilson et al., 2009a; Wood, Wilson, 2010a). Possibly, this is not simply due to a longer fixation, but a combination with the inability to inhibit the pre-potent stimulus-driven response. Participants of the linear group may have encountered the same problem, since they seem to more heavily rely on the stimulus-driven system (already before practice). It is important to evaluate these conjectures using gaze recordings.

6 EXPERIMENT 3: THE PRESENCE OF A GOALKEEPER INFLUENCES EVEN THE KEEPER-INDEPENDENT STRATEGY IN FOOTBALL PENALTY KICKS

As already described (see Introduction, section 2.4.2), penalty kickers may adopt one of two strategies when taking penalties (Kuhn, 1998; Morya et al., 2003a; van der Kamp, 2006). In the keeper-independent strategy, the penalty kicker chooses a target location to aim the ball before the run-up and holds that choice during the run-up and kick. Any action of the goalkeeper during the run-up is to be ignored. Alternatively, in the keeper-dependent strategy, the penalty kicker intends to kick the ball to the side opposite to the goalkeeper dive. To this end, kickers try to anticipate the direction of the goalkeeper dive by obtaining information from the goalkeeper's action during the run-up. Also, according with studies previously discussed (see Introduction, section 2.4.3, particularly the response activation model), it seems that penalty kickers' perceptions might be implicitly influenced by the goalkeeper. The results of this experiment have been published (Navarro et al., 2013).

With reason enough to suspect that even when a goalkeeper-independent strategy is adopted, the mere presence of the goalkeeper may affect kickers' performance, the current experiment examined whether penalty kickers are able to adopt a strategy in which they totally ignore the goalkeeper. Although previously researchers have shown that this is the more favourable strategy, the question whether the simple presence of a goalkeeper may jeopardize kicking accuracy and speed has not been addressed. This effect may be present even though kickers are fully aware that a goalkeeper is incapable of intercepting a ball directed to one of the two upper corners (at least when the kick is sufficiently powerful). Thus, in the current study, participants where required to shoot the ball hard enough, aiming at a specified area of the goal, located in the upper corners, with and without the presence of a goalkeeper. Comparing shot accuracies in these conditions should uncover whether the presence of a goalkeeper can indeed be fully ignored (as is presumed with a goalkeeper-independent strategy) or whether his or her presence as a visual non-target object affects shot placement along the lines suggested by the response activation model. In addition, a third condition was created to enhance any effect that might be present by increasing the saliency of the goalkeeper. To this end, the kicker informed the goalkeeper on the intended target before taking the kick. Knowing that the goalkeepers know the target location should not be relevant to the outcome, if kickers shoot with sufficient accuracy and power, but it may increase the goalkeeper's saliency or threat. On the one hand, if a kicker can ignore the presence of the goalkeeper, as is required for the goalkeeper-independent strategy, then ball placement should not depend whether or not a goalkeeper is present. This means that the number of target hits and the distance between the target and where the ball intersects the goalmouth should not differ across conditions. On the other hand, if a kicker can not fully ignore the presence of the goalkeeper, that is, if the presence of a goalkeeper functions as a visual non-target object, then shots may be biased away or towards the goalkeeper, depending on the goalkeeper's salience.

6.1 Objectives

The main goal of Experiment 3 was to investigate the performance of penalty kickers when employing the keeper-independent strategy in a field experiment. In particular, whether penalty kickers are able to adopt a strategy in which they totally ignore the goalkeeper after being instructed about the benefits of the keeper-independent approach, and explicit requested that they should try to aim at a particular area of the goal shooting with enough force.

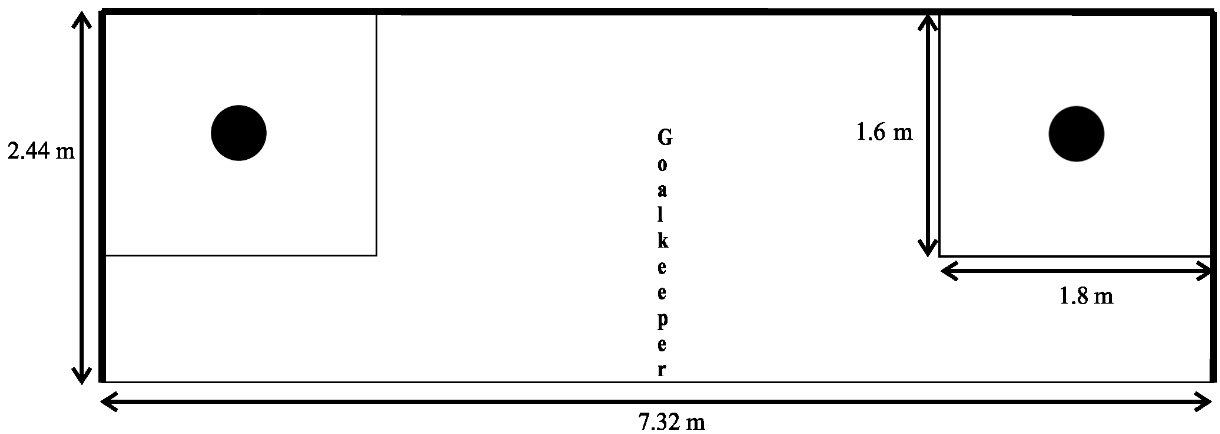
6.2 Participants

Twenty-seven male skilled university footballers, who played competitively in Dutch amateur leagues, volunteered to take part. The pretest consisted of 20 shots aimed at a 1m by 1m target straight in front of them, placed on a wall at a distance of 11m. The pretest was conducted to ascertain that the participant were sufficiently skilled to aim the ball in one of the two top corners during the main experiment. The first ten participants (mean age = 19.1, SD = 1.9) who hit the target at least 18 times (i.e., 90% success) were selected to participate in the main study. In addition, two amateur goalkeepers (26 and 29 years in age) participated in the experiment. The approval of the local ethical committee was obtained before the experiments were carried out, and participants provided informed consent prior to testing.

6.3 Apparatus

Participants took penalty kicks on an official grass pitch. The size of the goal, the distance of the penalty spot from the goal and the ball were in accordance with FIFA (1997) laws. Two pieces of orange PVC canvas measuring 1.8 m in width and 1.6 m in height were attached between crossbar and each goalpost, indicating the two target areas (Figure 15). The size and location of these target areas were chosen based on descriptive analyses from international competitions (Morya et al., 2003b), showing that in these areas it is very difficult if not impossible for goalkeepers to save a penalty kick. At the centre of each PVC canvas, there was a target, consisting of a black circle 22 cm in diameter (i.e., the same as the ball diameter) was painted. Participants were explicitly instructed to aim for the circle (although all kicks landing within the target area were counted as a success, see below). The placement of the target was to preserve the difficulty for the goalkeeper to defend the shot, but reduce the risk of missing the goal altogether. The centre of the target areas (i.e., at 80 cm from the crossbar and 90 cm from the goalpost) was considered optimal for aiming a penalty kick: it is beyond a goalkeeper's reach, but reasonably safely within the goalmouth in case kicking accuracy is somewhat jeopardized.

Figure 15 - Schematic representation of the experimental set-up



It shows a front view of the goal with a PVC canvas in the goalmouth with the two target areas.
Source: Navarro et al. (2013).

A CREATIVE VADO digital video camera (25Hz; Creative Technology Ltd, Jurong East, Singapore) was positioned 1 m behind and 1 m to the side of the penalty mark, and recorded the goalmouth. The video recordings were analysed off-line for shot accuracy. To measure ball flight times, a pinhead microphone was placed 50 cm to the right of the ball to register the foot-ball contact, while two microphones were attached to the PVC canvas to register the impact of the ball. The continuous signals of the microphones were amplified and fed into a computer (1000Hz). A LabVIEW software package (National Instruments, Austin, Texas, USA) was used to synchronize the signals of the microphones.

6.4 Design

A repeated measurements design was used. Participants took six blocks of penalty kicks in three conditions: without the presence of a goalkeeper ('No Goalkeeper' condition), with the presence of a goalkeeper who was unaware of the direction of the shot ('Goalkeeper' condition), and in the presence of a goalkeeper who was informed by the kicker before taking the penalty kick to which side the ball would be placed ('Knowledgeable Goalkeeper' condition). Participants performed 20 kicks per condition in two blocks of 10. For each condition there was an equal number of shots to the right and left target areas. The sequence of these shots was randomized. The three first blocks always belonged to different conditions and their order was counterbalanced across participants. The sequence of blocks four to six was identical to the first three blocks. This design allowed for taking any effects of fatigue or learning during the last blocks into account. However, no differences were observed between the first 3 blocks and the last 3 blocks, which indicated that participants did not get fatigued or were otherwise affected in the course of the experiment.

6.5 Procedure

After providing informed consent, participants were instructed about the characteristics of a keeper-independent strategy, particularly the importance of disregarding the goalkeepers' actions when taking the penalty kick, since it would in any case be impossible for the goalkeeper to defend a well-placed ball. Immediately before the start of the experiment, participants were instructed to aim for the centre of the target with enough power (i.e., ball speed at least approximately 22 m/s). It was emphasised that with these requirements met, it would be impossible for the goalkeeper to save the ball (Graham-Smith et al., 1999), even if they would correctly anticipate the direction of the kick and dive to that the ball went. Furthermore, participants were instructed that they should ignore the goalkeeper's actions (whenever the goalkeeper was present) and simply kick the ball to the designated target area with enough force. Before each penalty kick, they were told which target area to aim towards (i.e., left or right side of the goal).

Goalkeepers were instructed to try to save the penalty kick as they would normally do. However, they were instructed not to start their dive during the early portion of the run-up. More specifically, they were told not to start moving until the kicker started his last step (i.e., approximately at 250 ms before kicker-ball contact, see Franks, Harvey, 1997; Lees, Owens, 2011). In addition, goalkeepers were also required to standardise their posture at the beginning of each trial by standing directly in the centre of the goal with knees bent, arms by their side and hands in front of their body before each shot (van der Kamp, Masters, 2008).

After instructions, participants warmed up by taking 6 practice kicks aiming at the target area (3 shots to each side) without the goalkeeper. Subsequently, participants started a first block of 10 kicks in one of the experimental conditions, followed by the remaining five blocks.

6.6 Data analysis

Penalty-taking performance was assessed from the video recordings. First, each penalty kick was categorized as either a hit (i.e., the ball hit the 1.82 m by 1.61 m target area), a miss (i.e., the ball was shot inside the goal, but missed the target area) or a failure (i.e., the ball was shot wide of the posts or over the crossbar). In addition, shots for the Goalkeeper and Knowledgeable Goalkeeper conditions were also categorized as either saved (i.e., the ball was totally blocked by the goalkeeper) or not saved. The frequency of hits, misses and failures per condition, and the frequency of saved shots were submitted to separate Chi-square tests. The frequencies of hits and misses saved by the goalkeeper were counted and categorised relative to the criterion speed (equal or above versus below 22m/s). The frequencies for these categories were submitted to a Chi-square test.

Subsequently, screenshots were made for the moment that the ball passed the goal line or was blocked by the goalkeeper. Kinovea Motion Analysis software was used to determine the absolute and variable error (in cm) for the distance between the ball landing location and the centre of the target area as well as the distance between ball landing location and the centre of the goal. Shots that completely missed the goal were not included in this analysis. Ball flight times was determined measuring the interval between the moment of foot-ball contact and the moment of ball-canvas impact, as indicated by sound signals from the microphones. Differences in distance the ball travelled to reach different points of the goalmouth were taken into account, and ball speed was calculated dividing this distance by the flight time. The individual absolute error, the variable error and the average ball speed were submitted to separate repeated measure analysis of variance (RM-ANOVA) with condition as within factor. Post-hoc pairwise comparisons were conducted using the Bonferroni correction procedure and partial eta squared (η^2_p) was used as the measure of size effect. Finally, the individual correlations between ball speed and absolute error across conditions were calculated to check for speed-accuracy trade-offs.

6.7 Results

Initial perusal of the data showed that of 600 shots taken (200 shots in each condition), there were 295 hits, 171 misses and 134 failures. Of the 400 shots in the two goalkeeper conditions, 83 were saved. Notice that hits, misses and failures refer to where the ball entered (or would have entered) the goalmouth, irrespective of whether or not the goalkeeper blocked or saved the ball.

6.7.1 Performance

Percentages. Table 5 shows the total number of hits, misses and failures for each of three conditions. Chi-square testing revealed that the number of hits, misses and failures were differently distributed across condition, $X^2(4, N = 600) = 26.64$, $p < .001$. *Post hoc* comparisons indicated that in the No-Goalkeeper condition the number of hits was significantly higher and the number of misses was significantly lower than in the Goalkeeper and Knowledgeable Goalkeeper conditions. The number of failures did not differ across conditions. In sum, the presence of the goalkeeper negatively affected the accuracy of the kicks.

Table 6 shows the number of saves in the two goalkeeper conditions. Chi-square testing revealed that the number of saves differed by condition, $X^2(1, N = 400) = 23.76$, $p < .001$. In Knowledgeable Goalkeeper condition more shots were saved. In addition, Chi-square testing also revealed that the number of saved shots for misses (i.e., shots outside the target area) was significantly higher than for hits, $X^2(1, 400) = 54.95$, $p < .001$. Table 6 also reports the number of hits and misses for penalty kicks that were saved by the goalkeeper as a function of ball speed (i.e., speeds equal or above versus below 22 m/s). For kicks outside the target areas (i.e., misses – but not failures) saves occurred irrespective of ball speed. The Chi-square for these kicks revealed a marginally significant difference for saves when ball speed was below 22 m/s, $X^2(1, N = 68) = 3.71$, $p = .054$. Importantly, for the shots within the target area, only kicks with speeds below 22 m/s were saved: for kicks with higher speeds no interceptions were made.

Table 5 - Number of hits, misses and failures, and average ball speed (Standard Deviation) as a function of condition.

	Conditions		
	No Goalkeeper	**Goalkeeper**	**Knowledgeable Goalkeeper**
Hits	127[a]	89[b]	79[b]
Misses	37[a]	69[b]	65[b]
Failures	36[a]	42[a]	56[a]
Ball speed (m/s)	17.5 (2.2)	18.8 (1.5)	18.8 (1.8)

Note: superscripts denote significant effects for condition ([a] p < .01, [b] p <.05).
Source: Navarro et al. (2013).

Table 6 - Total number of saved shots among target hits and misses for ball speeds above and below 22 m/s.

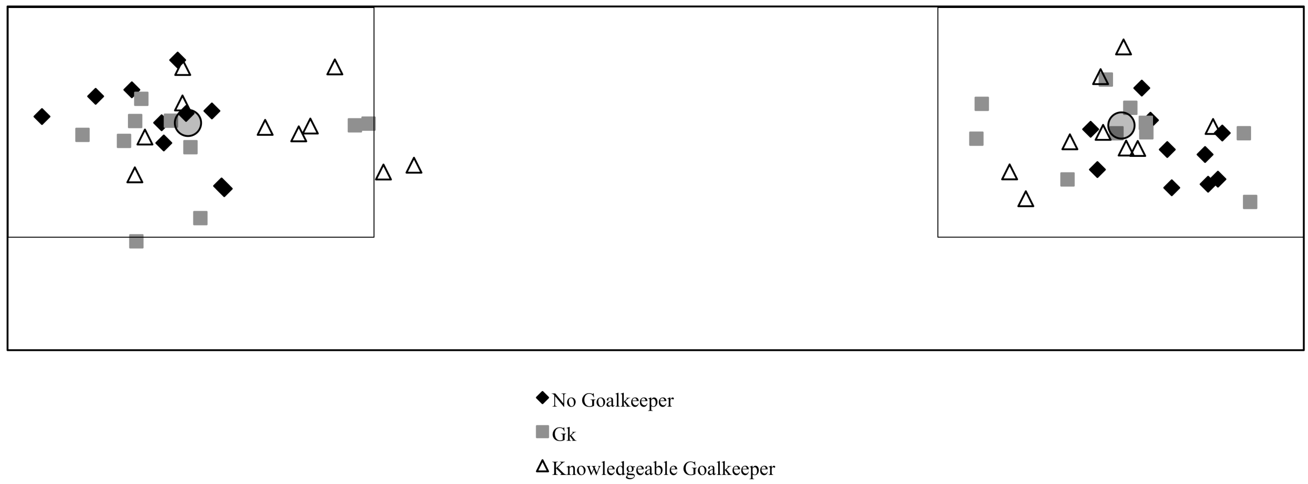
	Goalkeeper		**Knowledgeable Goalkeeper**	
	Hits	**Misses**	**Hits**	**Misses**
Total	5	18	10	50
Below	5	11	10	39
Above	0	7	0	11

Source: Navarro et al. (2013).

Accuracy. As can be seen in Table 7 and in Figure 16, with the goalkeeper present kicks were shot farther from the centre of the target and closer to the centre of the goal (i.e., more centralized). This was confirmed by significant effects for absolute error relative to target centre $F(2,18) = 7.87$, $p < .01$, $\eta_p^2 = 0.49$. *Post hoc* comparisons revealed a larger absolute error for the Knowledgeable Goalkeeper compared to the Goalkeeper and No-Goalkeeper conditions (t's(9) > 2.45, p's < .05), while the latter two conditions did not differ significantly ($t(9) > 2.01$, $p = .07$). A significant effect for condition was found for the distance to the goal centre $F(2,18) = 14.68$, $p < .001$, $\eta_p^2 = 0.65$. *Post hoc* comparisons revealed significant differences between conditions (t's(9) > 2.71, p's < .05), with the

Knowledgeable Goalkeeper resulting in the most centralized and the No-Goalkeeper condition resulting in the least centralized shots.

Figure 16 - Distribution of shots to the right and left targets taken in the three conditions for each participant.



Only individual averages are shown and shots that completely missed the goal were not included.

Table 7 - Mean (and Standard Deviation) for absolute and variable errors (cm) relative to target centre and goal centre as a function of condition.

	No Goalkeeper	Goalkeeper	Knowledgeable Goalkeeper
Target centre			
Absolute error (cm)	124.8 (31.3)	148.8 (28.1)	164.2 (29.0)
Variable error (cm)	27.1 (4.6)	22.7 (4.8)	24.2 (4.3)
Goal centre			
Absolute error (cm)	249.0 (22.2)	226.7 (29.0)	208.5 (26.2)
Variable error (cm)	66.4 (33.8)	84.3 (21.1)	85.6 (19.1)

Shots that completely missed the goal were not included in this analysis.
Source: Navarro et al. (2013).

6.7.2 Ball speed

The RM-ANOVA on ball speed revealed main effects for condition $F(2,18) = 5.42$, $p < .05$, $\eta_p^2 = 0.40$ (Table 6). *Post hoc* comparisons revealed that shots were faster for both Goalkeeper conditions in comparison to the No-Goalkeeper condition (t's(9) > 2.15, p's < .05). However, correlations between ball speed and absolute error relative to the target area and goal centre were not significant for any participant (r^2's < 0.15, p's > .05).

6.8 Discussion

Based on the empirical evidence, the risks and limitations associated with the adoption of the keeper-dependent strategy in penalty kicks seem quite substantial (van der Kamp, 2011; for an overview, see Savelsbergh et. al 2011). By contrast, the keeper-independent strategy seems to be more favorable for scoring a goal. Yet, it is unclear whether penalty kickers are actually able to ignore the goalkeeper, as this is one of the requirements for fully adopting the keeper-independent strategy. Hence, the Experiment 3 set out to investigate penalty kickers' performances with and without the presence of a goalkeeper. To this end, amateur footballers were fully informed about the benefits and requirements of the keeper-independent approach. They were then instructed to adopt the keeper-independent strategy, particularly to aim for the indicated target areas with enough force and to ignore the goalkeeper (if present).

The results clearly indicated that the kickers' performance was affected by the presence of the goalkeeper, and even more so when the kickers were aware that the goalkeeper was informed about where the ball would go. Penalty kickers hit the target significantly less often when the goalkeeper was present compared to an empty goal. In fact, with the goalkeeper present, not only the number of hits dropped, but the shots were also more centralized (i.e., closer to the goalkeeper). Although balls were shot more powerfully with the goalkeeper present, the decrement in spatial accuracy was not due to a trade-off between speed and accuracy. Apparently, the presence of the goalkeeper affected ball placement and ball speed independently. Moreover, the finding that variable errors were not influenced by goalkeeper presence indicates that the more centralized ball placement is not a by-product of the kicks being less precise, but rather reflects a genuine bias in aiming. Together, this points to the decrement in shot accuracy with the ball directed more centrally (i.e., closer to the goalkeeper). In sum, this shows that even when instructed to aim for a predefined target, penalty kickers are not able to fully ignore the goalkeeper; instead they show a tendency to kick the ball closer to the goalkeeper (not unlike previous findings for the goalkeeper-dependent strategy; Noël, van der Kamp, 2012; Wood, Wilson, 2010a,b).

These findings are in accordance with the predictions of the response activation model (Welsh, Elliot, 2004) for situations in which the visual non-target objects is relatively salient. During the penalty kick with the goalkeeper present, two independent parallel action response processes are activated: one for the actual target location in the corner of the goal, and one for the non-target goalkeeper. In fact, Welsh and Elliott (2004) observed with neutral stimuli that if the visual non-target object was present before the onset of action, the inhibitory processes had sufficient time to de-activate the associated action response processes. In the current experiment, the goalkeeper is also presented well before the kicker's run-up, however, in all likelihood the goalkeeper is a salient rather than a neutral visual stimulus. Consequently, the action response process toward the non-target goalkeeper is difficult to inhibit entirely, and hence, it is incorporated in the resulting combined action response. As a result, shots are attracted toward the goalkeeper (i.e., further from the target and more centralized). Apparently, saliency of the goalkeeper further increased when the kicker had to inform goalkeepers about the intended shot direction. Consequently, the tendency for a more centralize shots was even further enhanced.

Although the response activation model describes the differences in participants' kicking accuracy according to goalkeeper presence rather fittingly, it is not necessarily the only possible account for the present findings. In particular, ironic processing may have enhanced the salience of the goalkeeper. Wegner (1994) claimed that a deliberate attempt to ignore a thought or action may enhance the inclination to exactly the opposite: engage in the very thought or action. Accordingly, Bakker et al. (2006; see also Binsch et al., 2010a,b; cf. Beilock et al., 2001) required participants to score a goal in lab-based penalty kick task, but using different wordings to convey the same instruction. It was found that a negatively worded instruction *not* to shoot the ball within goalkeepers' reach, resulted, opposite to what was intended, in more centralized shots (i.e., closer to the goalkeeper) than an instruction that told the participants to aim for the empty space. Because the negatively worded instruction was accompanied with increased fixation of the goalkeeper, Bakker et al. (2006) argued that the negative instruction to avoid the goalkeeper ironically increased visual attention to the goalkeeper. This effect was accompanied by a shorter final fixation for the empty goal space (Binsch et al., 2010b). In other words, the negative wording (or even simply making reference to goalkeeper, see Binsch et al., 2010a) may have enhanced the goalkeeper's salience. Clearly, it cannot be ruled out that in the present study a similar ironic effect contributed to tendency to produce more centralized kicks with the presence of a goalkeeper. The present instruction not only contained a positively worded phrase (i.e., try to hit the target area), but was partly expressed negatively (i.e., ignore goalkeepers' actions). Perhaps, the latter part (ironically) increased the goalkeeper's saliency, making it more difficult to (re-)direct visual attention to the target or ball (Bakker et al., 2006; Binsch et al., 2010b). Future work should involve visual search measures to scrutinize this alternative (or additional) account. Moreover, the degree to which instructions regarding the goalkeeper-independent strategy that solely emphasize the *advantages* of attending to the target and ball or only stress the *disadvantages* of not ignoring the goalkeeper would lead to differences in kicking accuracy should be examined.

It is pertinent to discuss ACT (Eysenck et al., 2007; see also Nieuwenhuys, Oudejans, 2012) at this point, because it may offer an explanation for the presence of goalkeeper saliency (or threat), and for why saliency would be further enhanced when the kicker knows that goalkeeper is aware of the target location. In brief, ACT distinguishes two interactive attentional processes involved in action. The first is a top-down goal-directed process that controls attention based on expectations, knowledge and goals. The second is a stimulus-driven process controlling attention in a bottom-up fashion (Corbetta, Shulman, 2002). The latter process tends to direct attention to salient or threatening stimuli. Under some circumstances, such as with increases in anxiety, the delicate interaction between the processes is perturbed and the goal-directed process operates less efficiently, eventually to the point that inhibitory processes become less effective, and action becomes increasingly driven by the stimulus-driven process. For example, Wilson et al. (2009a) revealed that increases in anxiety led penalty kickers' to attend more to goalkeepers (i.e., considered to be the threat-inducing stimulus) than the target or ball, resulting in more centralized shots (see also Navarro et al., 2012). It is proposed that also the mere presence of salient or threat-inducing stimuli (as is the goalkeeper in the penalty kick, Wilson et al., 2009a) can alter the interaction between the two attentional processes, in particular by enhancing the impact of the stimulus-driven process. In penalty kicking, the perceived threat is likely to be provoked by the awareness that a weak shot (i.e., a shot that is insufficiently accurate and powerful) can be saved by the goalkeeper. From the response activation model, increased attention towards the non-target goalkeeper without a concomitant increase in inhibition, would result in the kick being biased toward the goalkeeper. The perceived threat is further increased, if the kicker knows that the goalkeeper is knowledgeable about his or her intentions, because a weak shot is even more likely to be intercepted. Interestingly, since inhibition of the stimulus-driven process by the goal-directed processes becomes less effective under stress (or may even be completely disrupted, see Navarro et al., 2012), these effects are likely to be exacerbated under high-pressure. Perhaps even to the degree that any advantage of the goalkeeper-independent strategy relative to goalkeeper-dependent strategy dissolves. Accordingly, scrutinizing whether the mere presence of the goalkeeper invokes increments in perceived threat and/or anxiety is an important task for future research, just as it is to assess whether this is further exacerbated when the penalty kicker knows that goalkeeper knows where the ball will be placed.

7 GENERAL DISCUSSION

The present thesis allowed scrutinize the effects of high-pressure on latency and accuracy of motor responses to visual stimuli during the execution of experimental protocols that simulate penalty kicks in football, and examine the efficacy of practice in reverting these effects.

The first experiment, completed and published (Navarro et al., 2012), was the first study that experimentally assessed the adverse effects of stress on the time needed to respond to goalkeeper movements. Obviously, a computer simulation certainly is not the same as the "real thing" and it must also be acknowledged that the participants were not professional football players, nonetheless it did allow to create a high-pressure situation that much more closely mimics a game than protocols that are commonly used to induce stress in experimental settings (e.g., Wilson et al., 2009; Wood, Wilson, 2010b). The majority of participants were significantly stressed by the high-pressure situation; it was found that they either required more time to adjust to the goalkeeper movement, as expected, or, unexpectedly, were unable to inhibit automatic responses with short AT, and this resulted in consistent errors. Since in a more ecologically valid in-situ penalty taking task the times necessary to respond to cues were found to be almost twice as long as the simulated penalty task (van der Kamp, 2006), it is not unreasonable to suspect that the adverse effects of high-pressure are magnified for in-situ penalty taking. In sum, the results provide strong experimental evidence that stress has a major influence in penalty kicks failures.

The second experiment (Navarro et al., Submitted) extended the results of the first and assessed the degree to which practice can reduce the adverse effects of high-pressure on the minimum time needed to respond to goalkeeper movement. Before practice, all participants showed significant performance decrements under high-pressure; they either required more time to respond to the goalkeeper or were unable to inhibit stimulus-driven responses. In one group of participants, practice (i.e., automatizing task performance rather than directly addressing anxiety) minimized the debilitating effects of high-pressure; in posttest they needed an equal amount of time to respond to the goalkeeper in low- as in high-pressure. Presumably, timing automatization provided them with the additional attentional resources to increase spatial goal-directed efforts needed under high-pressure. In the second group of participants, however, practice was ineffective to improve performance. They remained unable to inhibit automatic responses when the available time was short. In sum, the results provided strong support for the contention that practice can have a major influence in improving performance in penalty kicks. However, there are large individual differences that seem to relate to the individual's tendencies for attentional control.

The third experiment (Navarro et al., 2013) investigated whether penalty kickers where able to fully adopt the keeper-independent strategy, particularly to aim for the indicated target areas with enough force and to ignore the goalkeeper (if present). The results revealed that the mere presence of a goalkeeper cannot easily be ignored by the kicker, and is likely to adversely affect kicking accuracy. In sum, the advantages for the keeper-independent strategy were thought to clearly outweigh its drawbacks, and it seemed a safe strategy to adopt.

7.1 Practical applications

There are obvious issues on how relevant the protocols here described are for real life penalty kick. Having said this, however, the present thesis does inform further research on penalty kicking in low- and high-pressure situations and in practice effects and strategies.

For practical applications, experiment 1 results suggest that coaches should carefully choose their penalty kickers, as was previously suggested by McGarry and Franks (2000). This should take into account the inter-individual differences to the extent in which high-pressure causes increased levels of stress. Furthermore, these results may offer a method that could be exploited to identify kickers that are less susceptible to pressure, those that are less susceptible to pressure but need more training, and perhaps, even those that should be encouraged not to take a penalty.

Of the two strategies that penalty kickers can adopt (see Morya et al., 2003a; van der Kamp, 2006), the keeper-independent strategy, during which the penalty taker disregards the goalkeeper's action, has been recommended (e.g., van der Kamp, 2011). Yet, it is not unlikely that penalty kickers often attempt to take into account the goalkeeper actions (i.e., keeper-dependent strategy) to kick the ball to the side opposite to the goalkeeper dive. Experiment 2 suggests that penalty takers should only adopt this strategy, if they are able to inhibit stimulus-driven responses. It also shows that there are large individual differences in the capability for a penalty taker to learn to do this, which may be related to the innate tendency to rely on the stimulus-driven rather than on the goal-directed system.

Finally, the present findings refine the present notions on the advantages for penalty kickers in using a strategy that disregards the goalkeeper. The present consensus is that the advantages for the keeper-independent strategy outweigh its drawbacks, and relative to the goalkeeper-dependent strategy, it is considered the more secure. All this was based on the premise that, by ignoring the goalkeeper, attention can be fully dedicated toward the target and ball, thus allowing for optimal kicking accuracy. Yet, Experiment 3 shows that the kicker cannot easily ignore a goalkeeper; even the mere presence of the goalkeeper is likely to adversely affect kicking accuracy. Hence, before adopting the keeper-independent strategy, it seems wise to require penalty kickers not only to automatize the execution of the kick (as they usually do for free kicks, for example), but also to further stabilize kicking accuracy in the presence of a goalkeeper (or another threat-inducing visual non-target). To this end, practice strategies that optimize gaze control should be considered (e.g., quiet eye training, Vickers, 2007; Wood, Wilson, 2011). This should allow penalty takers to learn to direct gaze at the intended target location and the ball before and during the execution of the shot, rather than looking at the goalkeeper (Wood, Wilson, 2011). Possibly, penalty kickers may also benefit to wait longer before actually performing the shot, providing them more time to inhibit response process toward the goalkeeper (Furley et al., 2012). In agreement with this contention, Jordet et al. (2009) reported, based on field observations, that penalty kickers who took penalties very soon after the referee's whistle were less likely to score. By contrast, kickers that waited longer were more often successful. In other words, in order for the goalkeeper-independent strategy to attain all its potential, and thus be highly preferable to the goalkeeper-dependent strategy, requires prospective penalty kickers to practice kicking the ball to one of the upper corners with sufficient force as well as to control visual attention.

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GLOSSARY AND ACRONYSMS

ACTH: adrenocorticotropic hormone

ANS: Autonomic nervous system

Attentional system: cognitive system that facilitates the selection of relevant information and inhibits the rest. It was divided in two systems (Corbetta, Shulman, 2002; for detailed explanation see section 2.1.1):

1) goal-directed: involved in top-down control of attention based on expectations, knowledge and goals and the stimulus-driven system;
2) stimulus-driven: controls attention in a bottom-up fashion by detecting salient or conspicuous stimuli.

AT: available time interval, 'Goalkeeper' sideward motion started at 51, 102, 153, 204, 255, 306, 357, 408, or 459 ms before 'kicker-ball' contact, resulting in nine AT.

Attenuation effect: practice one aspect of the task (e.g., timing) reduces its attentional demands and it increases the availability of resources for the second aspect of the task

Attentional Theories (in the context of the present work): theories that seek to describe the cognitive processes governing pressure-induced failure, for example (mentioned in the text):

1) Explicit monitoring theories: conscious control of movement rather than automatized behaviour;
2) Processing Efficiency Theory: performance effectiveness is maintained if auxiliary processing resources are available, albeit at the expense of processing efficiency;
3) ACT: Attentional Control Theory claims that anxiety decreases the influence of the goal-directed attentional system and increases the influence of the stimulus-driven attentional system.

AVP: Arginine vasopressin

Central executive: is the system responsible for directing attention to relevant information and suppressing irrelevant information and for coordinating cognitive processes when more than one task must be done at the same time.

CRF: corticotrophin releasing factor

HPAA: Hypothalamic-pituitary-adrenal axis

HR: Heart rate

IDATE: Inventário de Ansiedade Traço-Estado

Implicit motor learning: techniques designed to minimize the use of working memory in motor skill acquisition:

1) errorless learning: errors are kept to a minimum, especially early in the learning process.
2) external focus of attention: perform task under dual-task conditions;
3) analogy learning: packs task-relevant knowledge into a single biomechanical metaphor.

Keeper-dependent strategy: the penalty kicker intends to kick the ball to the side opposite to which the goalkeeper dives

Keeper-independent strategy: the penalty kicker chooses where to aim the ball before the run-up and holds to that choice during the run-up and kick

LC: Locus coeruleus

NE: Noradrenergic cell groups of the medulla and pons

PNR: Point of no return is the moment beyond which alterations to motor decisions cannot be made, at least not reliably

Response activation model: final action response is the result of target and non-target objects activate automatic independent and parallel action response processes

SNS: Sympathetic nervous system

STAI: State-Trait Anxiety Inventory (Spielberger et al., 1982)

APPENDIX A – Inventário de Ansiedade Traço-Estado (IDATE)

Inventário de Ansiedade Estado

NOME:.. Reg:................ ..../..../....

Leia cada pergunta e faça um círculo ao redor do número à direita que melhor indicar como você se sente **agora, neste momento**.

Não gaste muito tempo numa única afirmação, mas tente dar a resposta que mais se aproxime de como você se sente **neste momento**.

AVALIAÇÃO

Muitíssimo......... 4	Um pouco................ 2
Bastante.............. 3	Absolutamente não..... 1

1) Sinto-me calmo(a)	1	2	3	4
2) Sinto-me seguro(a)	1	2	3	4
3) Estou tenso(a)	1	2	3	4
4) Estou arrependido(a)	1	2	3	4
5) Sinto-me à vontade	1	2	3	4
6) Sinto-me perturbado(a)	1	2	3	4
7) Estou preocupado(a) com possíveis infortúnios	1	2	3	4
8) Sinto-me descansado(a)	1	2	3	4
9) Sinto-me ansioso(a)	1	2	3	4
10) Sinto-me "em casa"	1	2	3	4
11) Sinto-me confiante	1	2	3	4
12) Sinto-me nervoso(a)	1	2	3	4
13) Estou agitado(a)	1	2	3	4
14) Sinto-me uma pilha de nervos	1	2	3	4
15) Estou descontraído(a)	1	2	3	4
16) Sinto-me satisfeito(a)	1	2	3	4
17) Estou preocupado(a)	1	2	3	4
18) Sinto-me superexcitado(a) e confuso(a)	1	2	3	4
19) Sinto-me alegre	1	2	3	4
20) Sinto-me bem	1	2	3	4

Font: Spielberger et al. (1979), it is the Brazilian Portuguese version of the State-Trait Anxiety Inventory (STAI, Spielberger et al., 1983).

APPENDIX B – Second of part of the Inventário de Ansiedade Traço-Estado (IDATE)

Inventário de Ansiedade Traço

NOME: .... Reg: ..../..../..

Leia cada pergunta e faça um circulo ao redor do número à direita que melhor indicar como você **geralmente** se sente.

Não gaste muito tempo numa única afirmação, mas tente dar a resposta que mais se aproximar de como você se sente **geralmente**.

AVALIAÇÃO

Quase sempre........ 4 Ás vezes.......... 2

Freqüentemente...... 3 Quase nunca..... 1

1) Sinto-me bem	1	2	3	4
2) Canso-me facilmente	1	2	3	4
3) Tenho vontade de chorar	1	2	3	4
4) Gostaria de poder ser tão feliz quanto os outros parecem ser	1	2	3	4
5) Perco oportunidades porque não tomo decisões rapidamente	1	2	3	4
6) Sinto-me descansado(a)	1	2	3	4
7) Sinto-me calmo(a), ponderado(a) e senhor(a) de mim mesmo(a)	1	2	3	4
8) Sinto que as dificuldades estão se acumulando de tal forma que não as consigo resolver	1	2	3	4
9) Preocupo-me demais com coisas sem importância	1	2	3	4
10) Sou feliz	1	2	3	4
11) Deixo-me afetar muito pelas coisas	1	2	3	4
12) Não tenho muita confiança em mim mesmo(a)	1	2	3	4
13) Sinto-me seguro(a)	1	2	3	4
14) Evito ter que enfrentar crises ou problemas	1	2	3	4
15) Sinto-me deprimido(a)	1	2	3	4
16) Estou satisfeito(a)	1	2	3	4
17) Às vezes idéias sem importância me entram na cabeça e ficam-me preocupando	1	2	3	4
18) Levo os desapontamentos tão a sério que não consigo tirá-los da cabeça	1	2	3	4
19) Sou uma pessoa estável	1	2	3	4
20) Fico tenso(a) e perturbado(a) quando penso em meus problemas do momento	1	2	3	4

Source: Spielberger et al. (1979), it is the Brazilian Portuguese version of the State-Trait Anxiety Inventory (STAI, Spielberger et al., 1983).

APPENDIX C – Form filled by participants providing informed consent

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

ESTUDO: OS EFEITOS DO TREINAMENTO SOBRE O DESEMPENHO MOTOR EM CONDIÇÕES DE ESTRESSE E DE FADIGA

Você está sendo convidado(a) a participar do projeto de pesquisa acima citado. O documento abaixo contém todas as informações importantes sobre a pesquisa que estamos fazendo. Sua colaboração com este estudo será de muita importância para nós, mas se desistir a qualquer momento, isso não causará nenhum prejuízo a você.

Eu,____, profissão ______________________________, residente e domiciliado na ____ portador da Cédula de identidade, RG _____________________ , e inscrito no CPF/MF______________________________ nascido(a) em _____ / _____ /_______ , abaixo assinado(a), concordo de livre e espontânea vontade em participar como voluntário(a) do estudo ***"Os efeitos do Treinamento sobre o Desempenho Motor em Condições de Estresse e Fadiga*** **"**. Declaro que obtive todas as informações necessárias, bem como todos os eventuais esclarecimentos quanto às dúvidas por mim apresentadas.

Estou ciente que:

I) O estudo se faz necessário para que entender a dinâmica da alteração na programação motora de um movimento lateralizado em função de pistas visuais, também lateralizadas, simulando aspectos importantes da cobrança de um pênalti no futebol sob situações de estresse e fadiga.

II) Serão feitas 6 coletas de 2,5 ml. de saliva, no período/intervalo de 2 dias. E após 1 mês serão feitas mais 6 coletas de 2,5 ml. de saliva, também no intervalo de 2 dias

III) Essa(s) coleta(s) serão feitas apenas para este estudo e em nada influenciarão o meu organismo; não vão me curar de qualquer patologia eventualmente presente, nem vão me causar nenhum problema, incomodo e dor no momento da coleta.

IV) A participação neste projeto não tem objetivo de me submeter a um qualquer tratamento, bem como não me acarretará qualquer despesa pecuniária com relação aos procedimentos efetuados com o estudo;

V) Tenho a liberdade de desistir ou de interromper a colaboração neste estudo no momento em que eu desejar, sem necessidade de qualquer explicação;

VI) A desistência não causará nenhum prejuízo à minha saúde ou bem estar físico;

VII) Os resultados individuais obtidos durante este ensaio serão mantidos em sigilo, mas concordo que sejam divulgados no seu conjunto (médias globais) em publicações científicas, desde que meus dados pessoais não sejam mencionados;

VIII) Caso eu desejar, poderei pessoalmente tomar conhecimento dos resultados, ao final desta pesquisa

( ) Desejo conhecer os resultados desta pesquisa.

( ) Não desejo conhecer os resultados desta pesquisa.

IX. Concordo que o material poderá ser utilizado em outros projetos desde que autorizado pela Comissão de Ética deste Instituto e pelo responsável por esta pesquisa.
( ) Sim ou ( ) Não

São Paulo, de de 200

( ) Paciente / ( ) Responsável
....

Testemunha 1 : ______________________________
Nome / RG / Telefone

Testemunha 2 : ______________________________
Nome / RG / Telefone

Responsável pelo Projeto: ______________________________
Martina Navarro, Doutoranda em Fisiologia

Telefone para contato: